# Klamath Basin Integrated Fisheries Restoration and Monitoring Plan (IFRMP) Synthesis Report

FINAL REPORT

*August 14 2017*

Prepared for the Pacific States Marine Fishery Commission

ESSA

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Pacific States Marine Fishery Commission

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Confluence of Salmon and Klamath Rivers, courtesy of USFWS

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Please refer periodically to http://kbifrm.psmfc.org/ to remain apprised of future project events and deliverables.

# List of Abbreviations

| | |
|---|---|
| ACCCNRS | Advisory Committee on Climate Change and Natural Resource Science |
| ACL | Annual Catch Limit |
| AEQ | Adult Equivalent |
| AM | Adaptive Management |
| AMA | Agricultural Management Assistance |
| AMIP | Adaptive Management Implementation Plan |
| BACI | Before-After-Control-Impact |
| BLM | Bureau of Land Management |
| BOR | Bureau of Reclamation |
| CALFED | Collaboration Among State and Federal Agencies to Improve California's Water Supply |
| CCLS | Community Capacity and Land Stewardship |
| CCP | Comprehensive Conservation Plan |
| CDFW | California Department of Fish and Wildlife |
| CDOJ | California Department of Justice |
| CEQA | California Environmental Quality Act |
| CHRPD | California Habitat Restoration Project Database |
| CMP | Coastal Salmonid Monitoring Program |
| COPCO | California Oregon Power Company |
| CPUE | Catch Per Unit Effort |
| CPVI | Conservation Population Viability Index |
| CRITF | Columbia River Inter-Tribal Fish |
| CSP | Conservation Stewardship Program |
| CSS | Commercial Salmon Stamp |
| CWA | Clean Water Act |
| CWT | Coded Wire Tag |
| DIDSON | Dual Frequency Identification Sonar |
| DNR | Department of Natural Resources |
| DPS | Distinct Population Segment |
| DQO | Data Quality Objectives |
| DSS | Decision Support System |
| EIR | Environmental Impact Report |
| EIS | Environmental Impact Statement |
| EPA | Environmental Protection Agency |
| EPIC | Environmental Protection Information Center |
| EQIP | Environmental Quality Incentives Program |
| ERO | Ecosystem Restoration |
| ESA | Endangered Species Act |
| ESU | Evolutionary Significant Unit |

| | |
|---|---|
| FACA | Federal Advisory Committee Act |
| FERC | Federal Energy Regulatory Commission |
| FGDC | Federal Geographic Data Committee |
| FLAR | Forest Land Anadromous Restoration |
| $F_{MSY}$ | Fishing Mortality Rate at Maximum Sustainable Yield |
| FPA | Federal Power Act |
| FRGP | Fisheries Restoration Grant Program |
| FRIMA | Fisheries Restoration and Irrigation Mitigation Act |
| FSC | Fire Safe Council |
| FWS | Fish and Wildlife Service |
| GCMRC | Grand Canyon Monitoring and Research Center |
| GMU | Geographic Management Unit |
| GSI | Genetic Stock Identification |
| HGMP | Hatchery and Genetic Management Plan |
| HVT | Hoopa Valley Tribe |
| IAP | Integrated Assessment Plan |
| ICDT | Integrated Costs Database Tool |
| IFIM | Instream Flow Incremental Methodology |
| IFM | Instream Flow Model |
| IFR | Institute for Fisheries Resources |
| IFRM | Integrated Fisheries Restoration and Monitoring |
| IFRMP | Integrated Fisheries Restoration and Monitoring Plan |
| IGH | Iron Gate Hatchery |
| INSE | Institute for Natural Systems Engineering |
| IRCT | Interior Redband Conservation Team |
| ISAB | Independent Science Advisory Board |
| ISAC | Independent Science Advisory Committee |
| ISRP | Independent Science Review Panel |
| KBAC | Klamath Basin Advisory Council |
| KBCC | Klamath Basin Coordinating Council |
| KBMP | Klamath Basin Monitoring Program |
| KBRA | Klamath Basin Restoration Agreement |
| KBRT | Klamath Basin Rangeland Trust |
| KFHAT | Klamath Fish Health Assessment Team |
| KHSA | Klamath Hydroelectric Settlement Agreement |
| KMP | Klamath Mountain Province |
| KNF | Klamath National Forest |
| KRBFTF | Klamath River Basin Fisheries Task Force |
| KRFC | Klamath River Fall Chinook |
| KRITFWC | Klamath River Inter-Tribal Fish and Water Commission |

| | |
|---|---|
| KRRC | Klamath River Renewal Corporation |
| KRTAT | Klamath River Technical Advisory Team |
| KTAP | Klamath Tracking and Accounting Program |
| KTWQC | Klamath Tribal Water Quality Consortium |
| LCM | Life Cycle Monitoring |
| LRMP | Land and Resource Management Plans |
| LWD | Large Woody Debris |
| MFMT | Maximum fishing mortality threshold |
| MRRIC | Missouri River Recovery Implementation Committee |
| MSST | Minimum Stock Size Threshold |
| MSY | Maximum Sustainable Yield |
| NCCFF | Northern California Council Federation of Fly Fishers |
| NCRWQCB | North Coast Regional Water Quality Control Board |
| NDSI | National Spatial Data Infrastructure |
| NEPA | National Environmental Policy Act |
| NFMS | National Marine Fisheries Service |
| NFP | National Forest Plan |
| NFWF | National Fish and Wildlife Foundation |
| NGO | Non-Governmental Organization |
| NMFS | National Marine Fisheries Service |
| NOAA | National Oceanic and Atmospheric Administration |
| NOAAF | National Oceanic and Atmospheric Administration Fisheries |
| NPCC | Northwest Power and Conservation Council |
| NPPC | Northwest Power Planning Council |
| NRC | National Research Council |
| NRCS | Natural Resource Conservation Service |
| NRDAR | Natural Resource Damage Assessment and Restoration Program |
| NRRSS | National River Restoration Science Synthesis |
| OCSRI | Oregon Coastal Salmon Restoration Initiative |
| ODA | Oregon Department of Agriculture |
| ODEQ | Oregon Department of Environmental Quality |
| ODFW | Oregon Department of Fish and Wildlife |
| OPSW | Oregon's Plan for Salmon and Watersheds |
| ORAFS | Oregon Chapter of the American Fisheries Society |
| OSU | Oregon State University |
| OWEB | Oregon Watershed Enhancement Board |
| OWRD | Oregon Water Resources Department |
| PCFFA | Pacific Coast Federation of Fishermen's Associations |
| PCSRF | Pacific Coastal Salmon Recovery Fund |

| | |
|---|---|
| PERC | Property and Environment Research Center |
| PFMC | Pacific Fisheries Management Council |
| PFW | Partners for Fish and Wildlife |
| PIT | Passive Integrated Transponder |
| PNW | Pacific Northwest |
| PSFMC | Pacific States Fisheries Management Council |
| PSMFC | Pacific States Marine Fisheries Commission |
| RMU | Regional Management Units |
| ROD | Record of Decision |
| RTK | Real Time Kinematic |
| RWQCB | Regional Water Quality Control Board |
| SAB | Scientific Advisory Board |
| SALMOD | Salmon Population Model - a conceptual model that simulates the dynamics of freshwater salmonid populations, both anadromous and resident |
| SALMODII | Salmon Population Model - a conceptual model that simulates the dynamics of freshwater salmonid populations, both anadromous and resident |
| SARP | Sucker Assisted Rearing Program |
| SDM | Structured Decision Making |
| SHIRA | Spawning Habitat Integrated Rehabilitation Approach |
| SHRRC | Steelhead Report and Restoration Card |
| SIAM | System Impact Assessment Model |
| $S_{MSY}$ | Number of adult spawners (S) at maximum sustainable yield |
| SMU | Species Management Unit |
| SOCC | Southern Oregon and Coast |
| SONCC | Southern Oregon/Northern California Coast |
| SQRCD | Siskiyou Resource Conservation District |
| SRCD | Siskiyou Resource Conservation District |
| SRCRMPC | Shasta River Coordinated Resource Management and Planning Committee |
| SRRC | Salmon River Restoration Council |
| SRWC | Scott River Watershed Council |
| STEP | Salmon and Trout Enhancement Program |
| SVRCD | Shasta Valley Resource Conservation District |
| SWCD | Soil and Water Conservation District |
| TAC | Technical Advisory Committee |
| TAMWG | Trinity Adaptive Management Working Group |
| TAT | Technical Advisory Team |
| TL | Total Length |
| TMC | Trinity Management Council |
| TMDL | Total Maximum Daily Load |
| TNC | The Nature Conservancy |

| | |
|---|---|
| TRRP | Trinity River Restoration Program |
| TSS | Total Suspended Sediments |
| UBT | Upper Basin Team |
| UFWS | United States Fish and Wildlife Service |
| UKBCA | Upper Klamath Basin Comprehensive Agreement |
| USBR | United States Bureau of Reclamation |
| USDA | United States Department of Agriculture |
| USDC | United States Department of Commerce |
| USDI | United States Department of the Interior |
| USEPA | United States Environmental Protection Agency |
| USFS | United States Forest Service |
| USFWS | United States Fish and Wildlife Service |
| USGS | United States Geological Survey |
| UWRL | Utah Water Research Laboratory |
| VSP | Viable Salmonid Population |
| VSS | Vane shear strength |
| WCB | Wildlife Conservation Board |
| WELC | Western Environmental Law Center |
| WG | Work Group |
| WIT | Watershed Improvement Tracking |
| WPMP | Water Quality Management Plan |
| WQ | Water Quality |
| WQCP | Water Quality Control Plan |
| WQMP | Water Quality Management Plan |
| WSFR | Wildlife and Sport Fish Restoration |
| WTP | Water Transactions Program |
| WUA | Weighted Useable Area |
| YOY | Young of Year |
| YTEP | Yurok Tribe Environmental Program |
| YTFP | Yurok Tribal Fisheries |

# Unit Conversion Table

Note: Units are presented in the text in the form they are cited in supporting references.

| | | |
|---|---|---|
| acres | 4,046.873 | square meters |
| acre-feet | 1,233.5 | cubic meters |
| cubic feet | 0.02831685 | cubic meters |
| cubic yards | 0.7645549 | cubic meters |
| degrees (angle) | 0.01745329 | radians |
| degrees Fahrenheit | (F-32)/1.8 | degrees Celsius |
| feet | 0.3048 | meters |
| foot-pounds force | 1.355818 | joules |
| gallons (U.S. liquid) | 3.785412 E-03 | cubic meters |
| hectares | 1.0 E+04 | square meters |
| inches | 0.0254 | meters |
| inch-pounds (force) | 0.1129848 | newton meters |
| microns | 1.0 E-06 | meters |
| miles (nautical) | 1,852 | meters |
| miles (U.S. statute) | 1,609.347 | meters |
| miles per hour | 0.44704 | meters per second |
| ounces (mass) | 0.02834952 | kilograms |
| pounds (force) | 4.448222 | newtons |
| pounds (force) per square foot | 47.88026 | pascals |
| pounds (force) per square inch | 6.894757 | kilopascals |
| pounds (mass) | 0.45359237 | kilograms |
| pounds (mass) per cubic foot | 16.01846 | kilograms per cubic meter |
| pounds (mass) per square foot | 4.882428 | kilograms per square meter |
| pounds (mass) per square yard | 0.542492 | kilograms per square meter |
| square feet | 0.09290304 | square meters |
| square inches | 6.4516 E-04 | square meters |
| square miles | 2.589998 E+06 | square meters |
| square yards | 0.8361274 | square meters |
| tons (force) | 8,896.443 | newtons |
| tons (long) per cubic yard | 1,328.939 | kilograms per cubic meter |
| tons (2,000 pounds, mass) | 907.1847 | kilograms |
| yards | 0.9144 | meters |

# Executive Summary

The Pacific States Marine Fisheries Commission is working collaboratively with interested participants to develop an Integrated Fisheries Restoration and Monitoring Plan (IFRMP or Plan) for the Klamath Basin. The Plan will help agencies and Tribes with fisheries management jurisdiction to wisely allocate funds in a coordinated manner to support the most effective restoration and monitoring work in the Klamath Basin. *A key principle underpinning this Plan is that native fish species will be able to return to the upper basin either through removal of the four lower Klamath River dams or by adding extensive new and enhanced fish passage infrastructure that allow native fishes to effectively find and migrate past the dams*. This Synthesis Report lays the groundwork for the Plan by distilling relevant past and current information about stressors on focal fish populations, habitat conditions and the restoration actions that are being pursued to improve natural ecological processes and bring lasting resilience to the ecosystem.

The Klamath River Basin of south central Oregon and northern California has historically been among the largest producers of salmon on the Pacific Coast of the contiguous United States. There were large runs of spring and fall-run Chinook salmon, coho salmon and steelhead, as well as Pacific lamprey, eulachon, green sturgeon and resident native fishes including bull trout, redband trout, and several species of suckers. A variety of human pressures (see Section 3) have since led to long-term and dramatic declines in Klamath Basin fisheries. These declines have been estimated at more than 90% for wild fall-run Chinook salmon, 98% for spring-run Chinook salmon, 67% for steelhead trout, 52%-95% for coho salmon and 98% for Pacific Lamprey, while populations of Lost River and shortnose suckers have declined to a fraction of historic levels. These changes have led to substantial hardships for many communities. There has also been decades of conflict and debate over how to restore fisheries of great cultural and economic importance while also sustaining other natural goods and services (e.g., supplying water for farmers, ranchers, local communities and hydroelectric power generation).

The general organizing framework for restoration and monitoring presented in this report (Figure 3-1) takes an *ecosystem approach*, whereby various watershed inputs (e.g., water, sediment, large woody debris, nutrients) are considered to drive fluvial geomorphic processes (e.g., sediment transport, channel migration, floodplain development) that determine physical geomorphic attributes and the structure and complexity of habitats in the basin. In addition to habitat quantity and structure, *water quality* (e.g., water temperature, dissolved oxygen, un-ionized ammonia, pH, turbidity, microcystin and other fish toxins) *is one of the many important attributes of habitat quality for fish populations*. Combined, habitat quantity and quality will in turn drive biological responses and are important determinants of fish abundance, distribution, and community composition. Stressors on any of the key inputs or processes at different levels of the hierarchy (Figure 3-1) could consequently affect fish populations either directly or indirectly.

The whole of these ecosystem processes and components within the Klamath Basin, including water quality and other attributes, are in scope for evaluation within the Plan but *only insofar as they have important influences on the priority Plan focal fish species* (see Box 1-1). There are numerous other beneficial uses related to human health, aesthetics, cultural, agricultural, commercial, water supply and recreation that are considered to be impaired for the Klamath River. It is recognized that these impairments represent a variety of other parallel concerns that are critically important for agencies, Tribes and stakeholders in the Klamath Basin. However, water quality issues and other elements *that are not directly related to having important effects on fish abundance, distribution, health, and community composition are* <u>*beyond*</u> *the scope of the Integrated Fisheries Restoration and Monitoring Plan*.

The number of entities involved and the legal framework for fisheries management in the Klamath Basin is complex. Many processes and programs have been implemented in an effort to work together to find enduring solutions to the ongoing challenges in fisheries management and competing uses of land and water. These efforts and agreements emerged from recognition that federal, tribal, state, and local governments have individual and sometimes overlapping programs for natural resource management.

This Synthesis Report provides an updated account of current restoration and monitoring activities in the basin for a suite of priority fish species, building on several prior science syntheses that have been completed since 2004. It provides the scientific foundation for beginning the process of prioritizing and sequencing decisions on restoration actions, monitoring plans and evaluation methods. The Synthesis Report provides interested participants with a consolidated repository of useful information, data and tools. This synthesis, together with insights gleaned from other large restoration programs, will assist resource managers and interested participants in their development of the Integrated Fisheries Restoration and Monitoring Plan in 2017-2019.

## Characteristics of the Klamath Basin

The Klamath Basin is unique among Pacific coastal watersheds for many reasons but the most obvious of these is its 'reversed' physiography. Unlike most other North American drainages that empty into the Pacific, the Klamath starts flat and ends steep. Headwaters originate in a low-gradient, arid region spanning the Oregon-California border that is commonly called the 'upper basin'. Farmland, lakes and fringe marshes characterize this region. Flow patterns here are dominated by the annual timing of snowmelt. However, rather than forming surface runoff, much of that melt-water seeps into the ground and resurfaces at downslope springs. This feature makes the area an important source of cool, stable base flows that protect aquatic species during hot summers. Downstream of Upper Klamath Lake, the lower basin's physical and hydrographic features deviate naturally due to geology and because of dams. Much of the lower basin is still wilderness, with steep forested mountains that shed rainfall overland into fast running streams supplying 88% of runoff to the Klamath River. Peak stream flows in the upper basin occur during snowmelt in late spring/early summer, while in the lower basin these flows occur from November to March when rainfall is highest.

While the Klamath Basin was once a major producer of Chinook and coho salmon, other key fishes in the basin include steelhead, sturgeon, eulachon, trout, sucker, and smelt, several of which are listed as threatened under the Endangered Species Act. For fish, the unique physiography of the basin is important because it influences timing, volume, and quality of water flowing to aquatic habitats. Migratory birds are also heavily affected since Klamath wetlands and forests offer a critical layover in spring and fall, with 80% of the Pacific Flyway's migratory waterfowl, shorebirds and other waterbirds using the basin's wetlands.

While land use is now dominated by forestry and agriculture/rangeland, indigenous peoples have hunted and fished in the Klamath Basin since time immemorial. The Basin is home to six federally-recognized tribes: The Klamath Tribes, Hoopa Valley Tribe, Yurok Tribe, Karuk Tribe, Quartz Valley Indian Reservation, and Resighini Rancheria. In addition, the Shasta Nation is not federally recognized. In 2004, the basin was home to approximately 187,000 people. The City of Klamath Falls is the largest population center in the upper basin (pop. ~20,000), while Yreka (pop. ~7,800) and Weaverville (pop. ~3,600) are the largest settlements in the lower basin. Other key economic drivers include fisheries, hydropower production, mining and recreation. Tourism, retail trade, educational services, health care/social assistance and manufacturing are also important sources of employment in the main population centers.

## Historical Context & Stressors

River flows are a key watershed input and an important source of energy. Flows also transplant other key watershed inputs (e.g., sediment, large woody debris) and create and maintain aquatic, floodplain, and riparian habitats.

Hydrologic conditions in the Klamath Basin have changed dramatically over the past century. The water resources there have been the focus of intense human development dating back to the late 1800s and early 1900s, with the basin now extensively modified by levees, dikes, dams, diversions for irrigated agriculture, and the draining of natural water bodies. Major development in the upper Klamath Basin that affected flow patterns began in the 1870's and increased after development of the Klamath Project in 1905, but it was not until Link River Dam was completed in 1921 that the largest water diversions began. There are now six dams on the river mainstem in the upper Klamath Basin, and many smaller irrigation districts and individual operations that affect flow patterns in the upper basin and downstream of Iron Gate Dam. A large portion of the upper basin is used for irrigated agriculture and rangeland, and hundreds of thousands of former wetlands and lakes have been drained and converted to farming and ranching operations. Forest land dominates in the lower basin, with the exception of the Scott and Shasta sub-basins which also have large portions of area in agriculture and rangeland. Human settlement and resource exploitation have created hydrologic alterations that include changes in runoff from timber harvest, other changes in vegetative cover and land use, diversions and storage for agriculture and hydroelectric production, diking of formerly flooded lands, and cut-off of historical flood overflow into Lower Klamath Lake.

Widespread impacts to stream habitats used by fish have occurred in the Klamath Basin. Historical large-scale development of mining, forestry, agriculture and ranching has caused the loss of interconnected floodplains and resulted in increased water temperatures, increased delivery of fine sediments, organic matter and other pollutants, and decreased the supply of large woody debris; impacts that have cumulatively degraded water quality and affected fisheries and other resources in the basin. The Klamath River is listed as a Clean Water Act (CWA) Section 303(d) "impaired" waterway in both California and Oregon, and water quality ratings fail to meet CWA 303(d) listings for a collection of fisheries-related beneficial uses (i.e., Cold Freshwater Habitat, Warm Freshwater Habitat, Rare, Threatened, or Endangered Species, Migration of Aquatic Organisms, Spawning, Reproduction, and/or Early Development, Estuary Habitat, and Marine Habitat).

Climate prediction models for the Pacific Northwest and Northern California suggest a wide variety of changes that could affect the Klamath Basin. These changes include increased average air temperature, increased number of extreme heat days, and changes to annual and seasonal precipitation (e.g., diminished snow pack, more winter rain, lower summer flows, increased frequency of heavy precipitation events) leading to altered stream flow, groundwater, water quality and vegetation.

Disease, fishing, predation by natural or invasive species, hatcheries and low ocean survival can also affect Klamath Basin fish.

Principal fish diseases affecting Klamath fish include ceratomyxosis, columnaris disease, and Ich; these have severely impacted sensitive Klamath fish populations in some years when high disease incidence has caused substantial fish die-offs. Seasonal flow management adjustments as possible at Trinity River and Link River dams are employed in efforts to limit downstream disease outbreaks when they occur. Fish disease outbreaks in both the upper and lower basin are thought to be triggered and exacerbated by adverse water quality conditions that create situations conducive to disease vectors while also stressing fish, predisposing them to infection.

Two fish hatcheries (Iron Gate Hatchery and the Trinity River Hatchery) currently supplement Klamath River salmonid fisheries producing spring and fall-run Chinook, coho salmon, and steelhead. These fish add to overall fishery abundance, but there are concerns that production has diluted natural spawning populations and reduced the genetic diversity of Chinook, coho, and steelhead in the basin.

Overfishing has been identified as a contributing factor in the long-term declines in abundance of harvested anadromous fish species in the Klamath Basin (i.e., Chinook, coho, steelhead, Pacific lamprey), as well as some resident fish species (e.g., lake suckers).

Predation by pinnipeds (i.e., seals and sea lions) on adult salmon can significantly affect escapement numbers within the Klamath Basin. Pinniped populations are likely now at historic highs along the California coast. Invasive predatory fish species are now common and abundant within the Klamath upper basin, with fathead minnow and yellow perch known to affect native sucker populations through predation on young suckers, as well as through competition for food or space. Non-native salmonids such as brook trout and brown trout are known to compete and often displace native redband trout and bull trout from basin streams. The effects of many of the other invasive species in the basin are uncertain, as little quantitative information exists to evaluate their possible impacts.

Ocean conditions dictate growth and survival of anadromous species in the marine phase. While variability in ocean conditions remains a major source of uncertainty in the population dynamics of Klamath salmon, ocean conditions have been identified as a contributing factor in their population declines. Years of poor ocean conditions are thought to affect population growth rates, abundance, diversity, and distribution of Klamath salmon populations as they are reliant on productive ocean environments. At present, there is some uncertainty about where Klamath Basin salmon smolts go after they enter the ocean but it is presumed that most stocks stay in the productive California current upwelling zone, near the shore between San Francisco and the Fraser River in British Columbia.

## Fish Species

The Klamath Basin is home to 30 native fish species. The basin historically produced large runs of steelhead, Chinook salmon, coho salmon, green sturgeon, eulachon, coastal cutthroat trout, and Pacific lamprey that contributed to substantial tribal, commercial and recreational fisheries. Natural populations of harvested native fish species have decreased, in some cases significantly since early 1900s. Fish assemblages of the upper and lower basins are markedly different, reflecting basin differences in topography, water flow patterns, temperatures and other factors.

Only five families of fishes are native to the upper Klamath Basin. The species in these families have become adapted to the shallow lakes, meandering rivers, and climatic extremes of the upper basin. Most, or possibly all, of the native fish species that live in the upper basin are endemic to the watershed. Relatively abundant or common native species include the Klamath tui chub, blue chub, Klamath speckled dace, Upper Klamath marbled sculpin, and Klamath Lake sculpin. Federal ESA-listed fish species found in the upper Klamath Basin include shortnose and Lost River sucker, slender sculpin, Klamath redband trout, and bull trout. The absence of major physical barriers to movement of fish before installation of dams allowed for former use of the upper basin by anadromous species and the apparent occasional entry into the upper basin of Klamath small-scale sucker, which is abundant in the lower basin.

There are 19 species of native fishes in the lower Klamath Basin, 13 of which are anadromous and two are amphidromous (i.e., larval stages in saltwater). Thus 80% of the lower Klamath Basin species require saltwater to complete their life histories. Common native species of the lower Klamath Basin include Klamath River lamprey, Klamath small-scale sucker, Klamath speckled dace, threespine stickleback, and Lower Klamath marbled sculpin. Federal ESA-listed fish species in the lower Klamath Basin include green sturgeon, eulachon, and coho salmon. Green sturgeon, eulachon, Pacific lamprey, coho salmon, chum salmon, Chinook salmon, steelhead, coastal cutthroat trout of the lower basin are Klamath Tribal Trust species.

Conservation or recovery plans are available for each of the major species of concern in the Klamath Basin. These plans all include the overarching goal of recovery of the species to stable, naturally-sustaining populations meeting the criteria for delisting under the Endangered Species Act (ESA). Management of the Klamath system is based heavily on ESA provisions, and regulation actions and funding for restoration typically center on the ESA-listed species. For example, management for ESA-listed suckers and coho drives a substantial proportion of Klamath Irrigation Project operations and Iron Gate Dam operations under the 2013 BiOp. Many of the species recovery plans include adaptive management of recovering populations as an explicit objective, while some recovery plans have a secondary goal of restoring harvesting opportunities.

In the last century the upper Klamath Basin has been invaded by a variety of non-native fish species, most of which were introduced for sport fishing or bait. Most of the non-native species are uncommon in the basin, but some are abundant and widespread. Their effects on native fishes are not fully understood, but non-native fish species dominate numerically in many habitats in the upper basin and potentially threaten native species through competition and predation. Seventeen non-native fishes have been recorded in the Lower Klamath Basin. These are mainly warm- and cool-water species that thrive in slow-current or reservoir environments.

A suite of focal native fish species was chosen for review in this Synthesis Report. These particular species were selected because they each have priority for conservation and management in the Klamath Basin, and because they represent a mix of life histories that cover a broad range of habitats, created and sustained by a variety of physical and ecological processes. Focal species are not intended to act as direct surrogates for the specific needs of other fish in the Klamath Basin. However, evaluating the status of these focal species should provide insights into the condition of ecological processes that support other fish species with *similar* life histories and habitat needs. This Synthesis Report takes a broad ecosystem approach (i.e., looking at watershed processes that create and maintain habitats, and the species that use these habitats). It summarizes population trends, general ecology and life history, habitat requirements, and limiting factors for the focal fish species. It also identifies existing management plans, conceptual models, critical uncertainties and hypotheses, and candidate research assessment priorities.

## Overview of Restoration and Monitoring

There is a long history of fisheries restoration in the Klamath Basin, dating back at least to the earliest attempts at stock supplementation through fish rearing on the upper Klamath River in the early 1900s. Fish monitoring in the Klamath Basin also dates back to the early 1900s with the onset of water quality and flow monitoring, but a concerted effort to understand water quality and other habitat factors did not begin until the late 1900s. Initial monitoring projects were relatively fragmented, focused on specific needs at local sites, and were not explicitly oriented towards fish. Over time, as fish populations declined, conservation and monitoring efforts have become more focused on key stressors and have been better coordinated.

This Synthesis Report relies on public records documenting the numerous restoration projects that have taken place in the basin. Because a large proportion of restoration projects in the Klamath Basin are accomplished with some contribution from public funds through restoration grant programs, most of these projects are well documented in the public domain. Moreover, many of the programs that distribute funds specifically for salmonid restoration have amassed this documentation in publicly available databases covering the entire west coast of the United States. In aggregate, these databases provide a largely representative picture of the scope, scale, and nature of restoration occurring on the West Coast in general, and in the Klamath Basin in particular. The database of restoration projects assembled for this synthesis draws on data acquired either through direct download or provided by participating agencies.

## Restoration

There is a very long history of fish and habitat restoration in the Klamath River Basin that must be documented and understood in order to inform future efforts. While earlier restoration work in the basin was more focused on the immediate benefits provided by instream structure restoration, more recent work has sought to address the root causes of watershed impairment. The vast majority of restoration projects in the Klamath Basin are now carried out with the objective of overall watershed improvement, and although some projects aim to provide benefits to one or more particular target species, most aim to provide a general benefit to all aquatic biota. The many decades of restoration efforts in the Klamath Basin have made gradual progress towards restoring watershed function and fish populations in many waterways (Kier Associates 1999), and have set the stage for the substantial work that still lies ahead.

Many federal, state and tribal government agencies are active in restoration work within the Klamath Basin. Their roles are described in Sections 1 and 6 of this report. Federal agencies involved in restoration work include the National Oceanic and Atmospheric Administration (NOAA), the U.S. Fish and Wildlife Service (USFWS), the U.S. Forest Service, the Natural Resource Conservation Service (part of the U.S. Department of Agriculture), the Bureau of Reclamation, and the U.S. Environmental Protection Agency (USEPA). There are also several State agencies and programs involved in restoration, including the Oregon Department of Fish and Wildlife (ODFW), Oregon Department of Environmental Quality (ODEQ), the California Department of Fish and Wildlife (CDFW), the California State Wildlife Conservation Board (within CDFW, but independent), and the California North Coast Regional Water Quality Control Board (NCRWQCB), among others. Most of these agencies also administer several restoration grant programs that enable local implementing agencies to further their restoration objectives in the basin, and which serve as a useful proxy for the overall level of investment in and focus of restoration activity across the basin. Tribes in both the upper and lower basins have drafted fish, habitat, and water quality restoration plans for their own Tribal lands and are implementing these plans through Tribal Fisheries and Resource Management programs.

The restoration work carried out by these agencies falls into nine broad restoration activity categories: fish passage improvement; fish screening; fish rearing and hatcheries; instream flow restoration; instream habitat restoration; riparian habitat restoration; upland habitat and sediment management; water quality restoration (which encompasses nutrient reduction); and wetland restoration. Trends in restoration activity over time have closely followed important events in Klamath Basin history. The number of grant-driven restoration projects examined here has declined in the last decade, but spending has not followed the same trend, suggesting a shift towards fewer but more intensive restoration actions.

The types of grant-driven restoration actions and their distribution vary widely across the Klamath Basin. This reflects differences in landscapes, human activities, and the distribution of known limiting factors in each sub-basin that restoration is intended to address. Restoration actions such as fish passage improvement and fish rearing are generally concentrated in sub-basins below the dams, where they provide greater benefit to anadromous fish, and are particularly dense in the lower Klamath sub-basin. In contrast, restoration actions such as instream flow, instream habitat, riparian restoration, and sediment reduction that are expected to provide more general benefits to a broader range of species are distributed more evenly across all sub-basins. One notable exception to this pattern is the exceptionally high number of riparian habitat restoration projects in the upper Klamath sub-basin. This sub-basin is arguably one of the most severely impacted by human activities, with the presence of dams and large expanses of rangelands potentially driving greater attention to restoration.

The largest share of restoration actions and spending in the Klamath Basin is divided roughly evenly among projects dedicated to reducing watershed sediment inputs through management of upland habitat and roads, and projects dedicated to riparian restoration. The largest share of restoration projects and spending to date has taken place in the lower Klamath and mid/upper Klamath sub-basins where anadromous fish are still present, and where dam operations have had the greatest impacts.

### Monitoring

As with any monitoring in large river basins, coordinating to avoid duplication and optimizing sampling design is a challenge. Over 32 organizations conduct monitoring in 12 Klamath sub-basins, spanning a wide array of values and stressors. Fish restoration in the Klamath Basin has however been shifting from a fragmented collection of projects toward a more integrated approach that seeks to derive 'benefits of scale' by improving communication and cooperation among all participants who value the river and its network of tributaries. A collaborative foundation was built during development of the Klamath Basin Restoration Agreement and the Klamath Hydroelectric Settlement Agreement. The Klamath Basin Monitoring Program also made significant headway, developing a basin-wide monitoring plan, bringing together water quality monitoring data from all corners of the watershed, and communicating and disseminating these data using interactive web mapping.

Two types of monitoring are essential: status and trend monitoring to track progress towards overall goals and objectives; and project effectiveness monitoring to evaluate and adjust actions aimed at restoration and fish management.

Within the Klamath Basin, there are at least 15 major programs to monitor habitat (including water quality), 14 to monitor fish populations, and nine to monitor the effectiveness of restoration projects. Our review of existing restoration and monitoring plans indicates that most monitoring is focusing on habitat status and trends, followed by population monitoring. Monitoring the effectiveness of restoration projects is less common than the other two forms of monitoring.

A common monitoring framework would help to provide a foundation for monitoring sampling designs and protocols. This general design for the IFRMP monitoring framework should be compatible with most sampling needs for the key assessments that are identified as the full Plan is developed. This includes informing where and when sampling should occur, including how to roll-up and integrate information at different spatial scales. The intention behind creating this common monitoring framework and a recommended sampling design is to provide an accepted base structure around which future assessments and data collection can be coordinated, and through which data can be combined across disciplines to elucidate cause-effect relations at a system scale.

The various monitoring designs for key objectives and their performance indicators must generate sufficiently precise estimates to detect effects of interest against the background level of natural variability. Key metrics, such as estimating the numbers of outmigrating smolts, may require sophisticated statistical approaches to obtain satisfactory levels of precision. The USEPA provides substantial guidance for determining the required level of precision for a study as part of their Data Quality Objectives process.

Monitoring methods will evolve as co-managers move from one restoration phase to the next. However, revisions to established monitoring methods should only be done after a period of evaluation and calibration between the old and new methods, to allow data from the old and new methods to be compared to ensure they are providing the same information.

### Where to From Here

While an important step forward, the Synthesis Report is not intended to present a unified, comprehensive conceptual model for “the way things work” in different parts of the Klamath Basin, or to identify the most effective restoration strategies that have been completed so far. Those tasks are for later in the process of developing the IFRMP. Instead, this Synthesis Report is a first step towards development of the full IFRMP - “a conversation refresher” to invite and expand cooperative engagement of all interested participants through inclusive workshops, interviews and peer review. Its purpose is to invite and expand cooperative engagement of all interested participants through inclusive workshops, interviews and peer review. By providing interested parties with a consolidated repository of useful information on restoration activities with supporting data, case studies and tools, it will be possible to more efficiently and objectively move towards iterative development of the full Plan. The underlying data and information assembled can be further iteratively polished for ‘completeness’ and leveraged in future steps to identify gaps and needs. The future Plan will describe a comprehensive approach based on systematic and iterative methodology that emphasizes learning from the outcomes of carefully designed restoration and monitoring actions.

As advised by the National Research Council (NRC) and others, the most important first step involves embracing an adaptive management mindset and the associated best practices to guide the collaborative design and prioritization of restoration work, and to promote iterative learning and adjustment. NRC has encouraged the broad community of organizations and interested participants pursuing Klamath River restoration to organize assessments around the principles of adaptive management, and to use adaptive management to rigorously assess the river’s response to restoration actions and ultimately the response of fish populations that depend on the river. A solid adaptive management framework is essential for defensible science in support of dam removal or extensive improvements to fish passage facilities and related fisheries goals and objectives.

The multiplicity of entities, plans and programs affecting restoration of Klamath Basin fisheries provides a challenge for undertaking and coordinating adaptive management. However, the process of developing an integrated restoration and monitoring plan provides an opportunity for coordinating restoration and monitoring efforts to support more efficient and effective learning.

Explicitly identifying and then reducing uncertainties that are hampering confident management decisions is a key characteristic of adaptive management. Often conflict can indicate uncertainty, although not all conflict can be resolved by adaptive management. Adaptive management is helpful in situations where there is agreement regarding goals and objectives, but disagreement about how best to achieve them. Using adaptive management to resolve this type of disagreement essentially means applying the scientific method for learning (identifying and testing hypotheses) that is commonly used in research, and applying it to test hypotheses that are relevant to environmental management decisions at an operational scale.

Adaptive management requires sound experimental design, and contrast. In river systems, the opportunities for contrast among actions that affect the whole system are often temporal. Different actions need to be tested and compared across multiple water years. In larger river systems such as the Klamath there will also be some opportunities for creating spatial contrasts among sub-basins or tributaries for actions with a smaller footprint. Some may be sufficiently pristine to serve as 'untreated' controls; others already dramatically altered could serve as a 'worst case' contrast. It is always a challenge to allocate money for monitoring control areas, but it is essential to separate the effects of management actions from other factors, particularly in the era of climate change.

Prior to Plan implementation, setting up adequate governance structures and processes is essential for successful adaptive management. It is important to clearly distinguish technical roles and responsibilities from management roles and responsibilities. Because learning is foundational to adaptive management, entities involved in adaptive management need to have strongly embedded learning processes (looking back at what has been done, and learned) and planning processes (looking ahead to what needs to happen based on what's been learned). It is also critical to share updates to the state of knowledge with all interested participants, in products such as summary reports, fact sheets, and more detailed technical reports. This includes efforts to simplify science and lessons learned for public outreach. Without such updates, there is a risk that valuable insights gained through adaptive management will remain confined to a small technical group intensively involved in the work, while other participants will retain their old paradigms.

Relevant information and lessons are shared from several other large-scale fisheries restoration efforts in the Trinity River, Dry Creek, the Elwha River and the Columbia River Basin.

This Synthesis Report provides an outline of the major steps that should be followed to develop the full IFRMP for the Klamath Basin. These steps are consistent with NRC recommendations and related adaptive management best practices, and include:

1. The vision for restoration in the Klamath River Basin needs to be clearly defined, and a suite of well-bounded conceptual models for each phase of restoration developed.
2. Establishing subregional workgroups and developing an initial outline for the overall Plan that is to be developed, organized by phases of restoration and subregion.

3. Develop a suite of conceptual models for each phase of restoration followed by developing a clear objectives hierarchy and associated key performance indicators for Klamath River restoration.
4. With agreement on problem definition and objectives from the preceding steps, restoration co-managers, practitioners and interested participants should begin to map candidate restoration actions and assessments (management responses) that need to be made annually and periodically to each phase of restoration. In this step, participants will be guided to identify the major substantive phase-specific actions, and the limiting factor(s) / sub-objectives addressed by these actions.
5. For each substantive restoration action, decision criteria and triggers will be iteratively developed. A decision rule is a logical statement of the type "if [criteria], then [decision]." Triggers are defined for each key performance indicator, or for multiple performance indicators in a combined decision rule.
6. For each major restoration action, we will specify one or more monitoring approaches to compare the status and trends of focal fish species and other ecosystem components versus established triggers, as well as to gauge the effectiveness of priority restoration actions. At a future stage, we also recommend developing a common monitoring framework to provide a foundation for monitoring sampling designs and protocols.
7. Because the process of identifying gaps in — and priorities for — restoration actions and monitoring tools tends to be highly influenced by opinion, we recommend concluding the upcoming phase of work (called “Task 1.2”) with the development of an initial prioritization framework that will support the more rigorous and definitive prioritization effort carried out under the next phase (called “Task 1.3”).
8. The next phase of Plan development – Task 1.3 – is intended to identify the priority sequencing of restoration & assessment actions, along with designing a formal monitoring and evaluation framework in support of Plan implementation, and document the assessment and monitoring protocols associated with these priorities.
9. Describe an integrated approach to the collection, storage and retrieval of restoration and monitoring data. This will involve developing a plan for information management, and implementing that plan. Ideally, the data management system should unify existing systems, and coordinate storage of *key* monitoring and assessment data to support rapid feedback from monitored outcomes, data analyses, and modeling.
10. The written outcomes and products from the steps above produce the final IFRMP. An integrated Plan document and associated technical appendices, circulars, tools, brochures and infographics will collectively form a road map guiding integrated fisheries restoration and monitoring in the Klamath Basin. It will be essential to update the full Plan on a 5-yr timeframe to avoid falling out of step with findings and priorities.
11. While the steps above are technical and scientific in nature, prior to Plan implementation we recommend convening a governance forum to review lessons and advice from other large-scale river restoration leaders in other basins. Examples include the Missouri, Platte, Trinity, and Elwha River basins. For example, a small expert panel could provide

summary presentations and impartial advice on lessons learned in planning and conducting large-scale adaptive management efforts and assist the Pacific States Marine Fisheries Commission (PSMFC) and cooperating partners to develop proven strategies for adaptive management governance in large-river basins.

# Roadmap to the Report

- ***Section 1*** introduces the guiding principles and intent behind the development of an Integrated Fisheries Restoration and Monitoring Plan for the Klamath Basin. This includes distinguishing the first step of assembling this Synthesis Report from the broader work required to develop the Plan. It also summarizes findings and advice that have emerged from prior stakeholder and scientific reviews, and the guidance we received from interested participants during development of the Synthesis Report.

- ***Section 2*** provides a brief overview of the physical, biological and human characteristics of the Klamath Basin and supplies separate profiles for each of the major sub-basins. Sub-basin profiles include physical and socio-economic characteristics as well as ecological stressors relevant to fish restoration. Where information is available, unique characteristics of each sub-basin are also listed.

- ***Section 3*** provides an overview of the range of stressors in the environment to which focal fish species of the Klamath Basin are exposed.

- ***Section 4*** provides an overview of the fish communities present within the Klamath Basin, and includes details about the ecology of a subset of focal fish species as well as current monitoring, management and restoration actions that target these focal species.

- ***Section 5*** introduces the historical context for restoration and monitoring in the Klamath Basin, defines the types of restoration and monitoring considered in this report, and describes the approach we have used for synthesizing the major restoration and monitoring actions carried out across the basin to date.

- ***Section 6*** provides an overview of status and trends in restoration actions across the Klamath Basin. It also provides case studies of representative projects for each restoration category, and reviews the state of knowledge on the mechanism and degree of effectiveness of these interventions in achieving their ecological objectives for species and ecosystem recovery.

- ***Section 7*** synthesizes monitoring activities completed and underway in the Klamath Basin as well as potential future activities under a dam-removal scenario. Our assessment takes an integrative approach to explore the large number of monitoring activities basin-wide. We identify two main types of monitoring: (1) status and trend monitoring; and (2) project effectiveness monitoring. We also consider monitoring in the context of both habitat and fish populations.

- ***Section 8*** outlines suggestions for next steps in the development of the Integrated Fisheries Restoration and Monitoring Plan for the Klamath Basin.

# 1 Introduction and Purpose

"[Recovery of endangered] fishes in the Klamath Basin cannot succeed without aggressive pursuit of adaptive management principles, which in turn require continuity, master planning, flexibility, and conscientious evaluation of the outcomes of management"
~ pg. 343, NRC (2004)

This section introduces the guiding principles and intent behind the development of an Integrated Fisheries Restoration and Monitoring Plan for the Klamath Basin. This includes distinguishing the initial step of assembling this Synthesis Report from the broader work that will be required to develop the Plan itself. We summarize the guidance received from interested participants on the present effort to develop the Synthesis Report and the future Plan, the major historical changes in the Basin, the regulatory framework for management of Klamath fisheries, and relevant findings from prior stakeholder and scientific reviews.

## 1.1 Our Task

This report (the "Synthesis Report") is the first step by the Pacific States Marine Fisheries Commission (PSMFC) towards working collaboratively with interested participants[1] in the development of an Integrated Fisheries Restoration and Monitoring Plan ("IFRMP" or "Plan") for the Klamath Basin. An IFRMP was originally envisioned to be developed as *part* of the larger Klamath Basin Restoration Agreement (KBRA) [see Section 1.5.2]. When KBRA expired in 2015, no further work was done on this Plan. Among other uses, the IFRMP is intended to help agencies and tribes, with fisheries management jurisdiction, wisely allocate funds to support restoration and monitoring work in the Klamath Basin. This includes providing decision-making processes and tools that allow agencies to determine how to logically sequence and prioritize the implementation of actions for restoring fisheries and fish habitat, how to design monitoring and evaluation activities to assess the effectiveness of restoration actions, and how to adjust restoration actions based on what is learned. Once completed in 2019, the IFRMP is expected to achieve key recommendations of the National Research Council (NRC 2004, 2008) to:

1. establish clear, integrated basin-scale fisheries restoration goals and objectives;
2. connect *best available science* to actionable decision-making through the development and ongoing application of *a rigorous adaptive management framework*;
3. identify (interim) benchmarks and decision rules for assessing the success of restoration actions;

[1] We use the term "interested participants" to refer to all of the entities that are interested in participating in the development of the Plan. This term is more inclusive than the term 'stakeholder'. We do use 'stakeholder' when citing other documents that have used this term.

4. expand and sustain cooperative engagement of all interested participants;
5. define the methodology for prioritization of future science needs, restoration and effectiveness monitoring to ensure this work is meaningful[2]; and
6. define independent mechanisms for scientific review, and related *sharing of data and analyses*.


Toward this end, the PSMFC is working with ESSA to develop the Plan, starting with the production of this Synthesis Report (Table 1-1).

The **Synthesis Report** is designed to lay the groundwork for the broader Plan by distilling relevant past and current information about stressors on focal fish populations, habitat conditions and the restoration actions that are being pursued to improve fundamental ecosystem processes. This report is not intended to resolve issues, but to summarize the work already completed in the basin and related ongoing efforts. We look objectively at **how restoration and monitoring can be improved** by providing interested parties with a consolidated repository of useful information, data and tools. This repository **highlights apparent gaps and needs** as resource managers move towards formal development of the full IFRMP (2017-2019). In preparing the Synthesis Report, we have also considered the **best practices** in restoration planning and adaptive management from other basins.

This Synthesis Report is the first of several steps towards development of the overall IFRMP. Coordinated by the PSMFC, future steps will *include*:

1. developing draft restoration and monitoring goals, objectives, and interim benchmarks needed to assess progress;
2. developing and embedding an effective adaptive management framework to monitor, evaluate and adjust restoration actions through a systematic collaborative process, as part of Plan implementation; and
3. carrying out peer and public reviews of the Plan prior to finalization.

Funding for these additional steps has been acquired but work on these next steps is not expected to begin until September 2017. The current target for development of the full IFRMP is August 31, 2019.

This work is also informed by outcomes from three prior tasks that supported the development of the Synthesis Report: (1) input received from interested parties at an initial 2-day IFRMP workshop (November 14-15, 2016) to identify critical building blocks) (Appendix A and Appendix

[2] So that agencies, tribes and partners will know how to best direct funding to yield the most effective results.

B); (2) perspectives of the broader community of agencies, tribes, and interested participants obtained from one-on-one interviews (Appendix C and Appendix D); and (3) development of an easily searchable web-based document sharing and calendar tool to facilitate access to information (http://kbifrm.psmfc.org/document-library/) (Appendix F).

Table 1-1: Scope of the Synthesis Report (this report) and the future Plan.

| What the Synthesis Report *Is* and *Does* … | What the Synthesis Report is not and does not do |
|---|---|
| The beginning of a best-science framework for objectively articulating basin-wide **fisheries** restoration and monitoring needs (including water quality, fish habitat, and related ecosystem functions and processes). | It does not provide a comprehensive review of all policy positions, nor does it evaluate how to balance all relevant beneficial uses and socio-economic objectives.<br><br>It does not address water rights and related adjudications, nor does it attempt to resolve the hierarchical authorities of fisheries management agencies in regards to carrying out their mandates. |
| Lay the scientific groundwork for the broader Integrated Fisheries Restoration and Monitoring Plan by distilling relevant past and current information about focal fish population stressors, habitat conditions and the wide array of restoration actions that are being pursued to improve ecosystem processes. This includes, where feasible, identifying available conceptual models, alternative hypotheses, and key scientific uncertainties affecting decisions. | It is not a regulatory tool or an element of a formal negotiated Settlement process (i.e., it is not the next generation of KBRA, etc.).<br><br>It is not a replacement for existing partnerships and/or activities already underway. |
| Summarize the work already completed and underway in the basin and to capture information and context on related ongoing efforts. | This report is not intended to resolve issues. |
| A consolidated synthesis of useful information, data and tools that will highlight preliminary gaps and needs as resource managers move towards formal development of the complete IFRMP. | It does not address the entirety of the National Research Council 2004, 2008 reports. |
| An interim summary of draft fisheries restoration and monitoring goals and objectives throughout the Klamath Basin. | It is not a one-stop-shop for all existing information related to the Klamath Basin. |
| A vehicle to communicate lessons and best practices in adaptive management planning from other basins. | It is not an adaptive management framework. That will however be part of the IFRMP. |
| A conversation starter, and a way to invite and expand cooperative engagement of all interested parties using open workshops, interviews and peer review. | It is not a forum for advocating regulatory and policy preferences regarding decisions on actions such as dam removal. |
| A framework for identifying a logical work plan and budget for completing the overall IFRMP. | The effort coordinated by PSMFC to develop the IFRMP does not include sufficient funding to implement all future restoration and monitoring programs. |

### 1.1.1 Guiding Principles

The principles that guide the development of a future IFRMP are as follows:

1. Take a big picture, *integrative whole-basin approach* to fisheries restoration actions and monitoring needs.

2. Use *best available science*, leveraging (rather than re-inventing) past efforts at synthesis.
3. Native fish species will be able to return to the upper basin either through *removal of the four lower Klamath River dams*[3] *or by adding extensive new and enhanced fish passage infrastructure*[4].
4. Use a *broadly inclusive, transparent* process involving representatives of all interested participants, with peer review.
5. *Connect science & decision-making* on fisheries restoration & monitoring priorities.
6. *Impart an Adaptive Management (AM) mindset and best practices* to guide the collaborative design and prioritization of restoration work, and to promote iterative learning and adjustment.
7. Use the IFRMP development process to *organize and sustain scientific momentum* as policy priorities evolve.

These principles align with and reinforce recommendations of the National Research Council (2004, 2008).

The integrative whole-basin approach (Principle 1) to developing the IFRMP and commitment to leverage existing efforts (Principle 2) throughout the Klamath are foundational. In observing Principles 1 and 2, the Trinity River is of note as it is the largest sub-basin within the Klamath Basin and has a well-established restoration program. The Trinity River Restoration Program (TRRP), created in 2000, is a large-scale, adaptive management program intended to recreate the geomorphic processes required to create and maintain salmonid habitat in the 40 miles below Lewiston Dam (USDI 2000; TRRP and ESSA 2009). An Integrated Assessment Plan (IAP) was developed for the TRRP to guide restoration and monitoring activities in the Trinity River (TRRP and ESSA 2009). While the Klamath faces unique challenges, some elements of the IFRMP will have overlapping objectives with the TRRP's IAP. The strength of connectivity with the Trinity also means that the success of any recovery efforts in the Klamath Basin will be partially dependent on the health of the Trinity sub-basins. Flow issues within the Klamath Basin are complex and in addition to natural variability in hydrologic conditions are often driven by management decisions influenced by the U.S. Bureau of Reclamation (USBR) Klamath Basin Irrigation Project, National Marine Fisheries Service Biological Opinions, PacifiCorp's operational flow releases to the Klamath River from Iron Gate Dam, the TRRP's flow schedule for Trinity River flow releases from Lewiston Dam, and by USBR's Central Valley Operations. Additionally, hatchery and harvest management is intricately connected between the two systems where both hatchery and natural stocks are managed collectively in an integrated harvest management process for ocean and in-river fisheries.

While it is clear that the Klamath faces unique challenges associated with dam removal and water quality that demand a "made in Klamath" approach to restoration and monitoring, there

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[3] Iron Gate, Copco I, Copco II and J.C. Boyle

[4] With trap and haul as needed for species that are unable to efficiently use these passage features.

are also opportunities for the broader Klamath IFRMP to benefit from lessons and experiences in the Trinity. Likewise, the TRRP will benefit from improved downstream conditions (e.g., lower levels of disease) as the Klamath IFRMP progresses (Nichols et al. 2003; True et al. 2010; Bolick et al. 2012). Therefore, consistent with Principles 1 and 2, a coordinated approach to managing and monitoring these interconnected sub-basins will be needed during the collaborative development of the IFRMP.

A brief summary of the technical aspects of the TRRP and a case study describing the adaptive management approach employed by the TRRP is provided in Section 2 and Section 8.3.1 respectively.

### 1.1.2 Project Oversight

The U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) recently contracted with PSMFC to help develop a fisheries restoration and monitoring plan for the Klamath Basin, involving representatives of all interested participants. The approach is intended to be collaborative and transparent while recognizing sovereign and public interests. Following a competitive proposal process, PSMFC contracted ESSA to write the Synthesis Report. An 'Administrative Oversight Group' (Table 1-2) provides administrative guidance, and a 'Technical Working Group' provides input on technical and scientific issues (Table 1-3). ESSA received broad input from interested participants during the initial November 2016 workshop (Appendix B) and related one on one interviews (e.g., Table 1-4) (Appendix D). In the absence of consensus, PSMFC makes decisions on project priorities and scope to meet contractual obligations it has to the USFWS.

Table 1-2: Administrative Oversight Group.

| Name | Affiliation |
|---|---|
| Matt Baun | USFWS |
| Damon Goodman | USFWS - Arcata Fish & Wildlife Office |
| Ryan Fogerty | USFWS |
| Nick Hetrick | USFWS |
| Joe Polos | USFWS - Arcata Fish & Wildlife Office |
| Josh Rasmussen | USFWS |
| Jim Simondet | NMFS |
| Chris Wheaton | PSMFC |
| Tommy Williams | NOAA Fisheries Southwest Fisheries Science Centre |

Table 1-3: Technical Working Group.

| Name | Affiliation |
|---|---|
| Matt Baun | USFWS |
| Caitlin Bean | California Fish and Game |
| Michael Belchik | Yurok Tribe |
| Jared Bottcher | USBR |
| Clayton Creager | North Coast Regional Water Board |
| Mike Edwards | USFWS |
| Robert Franklin | Hoopa Tribe |
| Ryan Fogerty | USFWS |
| Nick Hetrick | USFWS |
| Mike Hiatt | ODEQ |

| Name | Affiliation |
|---|---|
| Eric Janney | USGS |
| Barry McCovey | Yurok Tribe |
| Bob Pagliuco | NMFS |
| Josh Rasmussen | USFWS |
| Jim Simondet | NMFS |
| Wade Sinnen | California Fish and Game |
| Megan Skinner | Klamath Tribes |
| Toz Soto | Karuk Tribe |
| Chris Wheaton | PSMFC |
| Tommy Williams | NOAA Fisheries Southwest Fisheries Science Centre |
| Ted Wise | Oregon Department of Fish and Wildlife |

Table 1-4: Invitations to the initial project workshop and interviews included 57 agencies, tribes, state/federal agencies, NGOs and other interested participants.

| County Agency | Invited | Attending | Interview |
|---|---|---|---|
| Del Norte County Board of Supervisors | X | | |
| Humboldt County | X | | X |
| Klamath County | X | | |
| Shasta Valley Resource Conservation District | X | X | X |
| Siskiyou County Board of Supervisors | X | | |
| Siskiyou County Resource Conservation District | X | X | |
| Trinity County Board of Supervisors | X | | |
| **Tribe** | | | |
| Hoopa Valley Tribe | X | X | X |
| Karuk Tribe | X | X | X |
| Klamath Tribes | X | X | X |
| Quartz Valley Indian Reservation | X | X | |
| Resighini Rancheria | X | X | |
| Yurok Tribe | X | X | X |
| **Federal Agency** | | | |
| Bureau of Land Management | X | X | |
| Bureau of Reclamation | X | | |
| US Fish and Wildlife Service | X | X | X |
| National Marine Fisheries Service | X | X | X |
| National Oceanic and Atmospheric Administration | X | X | X |
| US Department of Agriculture Forest Service | X | X | |
| US Department of Interior | X | | |
| US Bureau of Internal Affairs | X | | |
| US Bureau of Reclamation | X | X | |
| US Department of Agriculture (USFS, USFS-KNF, NRCS) | X | | |
| US Geological Survey | X | X | X |
| **State Agency** | | | |
| California Department of Fish and Wildlife | X | X | X |
| California Natural Resources Agency | X | X | |

| | Invited | Attending | Interview |
|---|---|---|---|
| North Coast Regional Water Quality Control Board | X | X | X |
| Oregon Department of Environmental Quality | X | X | X |
| Oregon Department of Fish and Wildlife | X | X | |
| State of Oregon | X | X | |
| California State Water Board | X | X | |
| **Industry** | | | |
| PacifiCorp | X | X | X |
| **Inter-state Agency** | | | |
| Pacific States Marine Fisheries Commission | X | X | |
| **NGO** | | | |
| American Rivers | X | | |
| California Trout | X | | |
| Klamath Basin Monitoring Program | X | X | X |
| Klamath Water Users Association | X | X | X |
| Mid Klamath Watershed Council | X | | |
| Pacific Coast Federation of Fishermen's Associations | X | | X |
| Institute for Fisheries Resources | X | | X |
| Salmon River Restoration Council | X | | |
| Sustainable Northwest | X | | |
| The Nature Conservancy | X | X | X |
| Trout Unlimited | X | X | X |
| Upper Klamath Water Users Association | X | | |
| National Fish and Wildlife Foundation | X | X | |
| Klamath Bird Observatory | X | | |
| Water and Power Law Group | X | | X |
| Ranch and Range Consulting | X | | |
| **Academia** | | | |
| Oregon State University | X | | |
| University of California - Davis | X | | |

## 1.2 Guidance Received on the Present Effort from Interested Participants

This Synthesis Report provides the scientific foundation for beginning the process of prioritizing and sequencing decisions on restoration actions, monitoring plans and evaluation methods. It is intended to provide interested participants with a consolidated repository of useful information, data and tools that will highlight preliminary gaps and needs as resource managers and interested participants move towards formal development of the full IFRMP in 2017-2019.

A total of 54 participants attended the workshop to kick off the project in Yreka CA on November 14 and 15, 2016 (Appendix A). The workshop introduced the overall project to develop the Plan, and engaged participants in developing the structure and content of the Synthesis Report. The objectives of the workshop were to:

1. provide interested participants with a clear understanding of the intent, guiding principles, phases/schedule, and expected products of the IFRMP for the Klamath Basin;
2. engage with participants who are keen to work with the ESSA team to identify critical building blocks for the Synthesis Report; and
3. review an early draft outline for this project's Synthesis Report, and solicit "likes and dislikes".

During the workshop, participants spent a portion of their time in plenary and two large subgroups – one for the Lower Klamath Basin, the other for the upper Klamath Basin. The first step for the plenary group was to provide interim goals (or fundamental objectives) for habitat restoration and fish recovery in the Klamath Basin (Appendix B). Facilitators then guided the two subgroups through several exercises aimed at eliciting stressors to fish habitats and populations, and identifying the restoration actions underway to reduce these stressors (Appendix B). On day two, the focus shifted to a parallel subgroup exercise to elicit fisheries monitoring underway that would improve understanding of stressors and the effectiveness of the various restoration actions (Appendix B). The ESSA facilitation team then provided an overview of how restoration had been tackled in other basins (including the Russian River/Dry Creek CA, Sacramento River CA, Trinity River CA, Columbia River (WA, OR, ID, MT), Okanagan River BC) to elicit dialogue around what approaches might be most beneficial in the Klamath.

A second means of eliciting guidance from interested participants was a series of **interviews** (November 2016 – January 2017) with agencies and organizations involved in ongoing restoration and monitoring activities in the Klamath Basin (Appendix D). These interviews offered a valuable source of insight into the diverse perspectives of the broader community of agencies, tribes, and interested participants. The interviews provided information to determine alignment on interim goals and objectives, and to identify issues that might affect the success of the Plan. We also asked for insights on whether there were interested participants not present at the kickoff workshop who should be more actively engaged. The interviews complemented our synthesis of literature and information, and helped our team uncover gaps and/or areas of potential misalignment. More generally, first-hand information from interested participants helped our team understand the situation on the ground, and the complex mosaic of roles, responsibilities, needs, priorities, and issues. The interview questions are provided in Appendix C.

A Public Review Draft of the present report was released on June 7 2017 and comments were received through July 14 2017. Nineteen individuals representing eighteen organizations provided formal comments. In addition to directly revising content in the report, Appendix E provides a summary of the comments received and our responses.

### 1.2.1 Klamath Basin Integrated Fisheries Restoration & Monitoring Plan Library

As part of synthesizing information related to Klamath Basin fish restoration and monitoring, the authors of this report gathered key reports and data, and made these accessible via a simple online Document Library[5] (Figure 1-1). We collected information in four stages. First, we conducted an extensive review of available literature from peer-reviewed academic journals, policy documents, formal agreements, science and technical reports, websites and databases. Second, we interviewed local experts who suggested additional materials. Materials from these two stages were uploaded to the Document Library after coding all files by document category and focal topics. Access to these documents is either by direct download or hyperlinks. The Document Library was unveiled during the third stage, a two-day workshop in Yreka where participants were encouraged to bring electronic copies of data and other materials to add to the database. Several workshop participants reviewed the Document Library after the workshop, and submitted additional documents and datasets, all of which were incorporated. The Document Library continues to solicit new material, and is described in Appendix F.


Figure 1-1: Klamath Basin Integrated Fisheries Restoration and Monitoring web-based Document Library accessible at http://kbifrm.psmfc.org/document-library/.

## 1.3 The Big Picture

**The Klamath River Basin of south central Oregon and northern California is the story of an extremely modified watershed, where interested participants are collaboratively seeking a path toward restoration and lasting resilience of degraded watershed processes that will support fisheries and other ecosystem services.**

For millennia, native peoples throughout the Klamath River Basin have had a culture developed around salmon (NRC 2004; USFWS 2013a,c; Oregon Historical Society 2017). The basin's

[5] http://kbifrm.psmfc.org/document-library/

natural resources, including abundant and reliable supplies of fish, clean water, and terrestrial plants and animals, are central to Native American cultural identity (Chaffin et al. 2015). The lower Klamath Basin is home to three federally recognized tribes – the Hoopa Valley, Karuk, and Yurok – and two smaller tribes – the residents of the Resighini Rancheria and the Quartz Valley Indian Reservation. The upper Klamath Basin is home to the federally recognized Klamath Tribes.

The Klamath River Basin, once boasted the third most productive salmon runs on the U.S. Pacific Coast, with large runs of spring and fall-run Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus kisutch*), and steelhead (*Oncorhynchus mykiss*) as well as Pacific lamprey (*Entosphenus tridentata*), eulachon (*Thaleicthys pacificus*), green sturgeon (*Acipenser mediro*stris) and a number of resident native fishes including bull trout (*Salvelinus confluentus*), redband trout (*O. mykiss newberrii*), and several species of suckers (Hamilton et al. 2005; NRC 2008). The Klamath Basin is a geologically dynamic region with historically large runs of anadromous fishes with diverse life histories. These fishes were widely distributed in the basin; some even entered the rivers that fed Upper Klamath Lake. The Salmon, Scott, Shasta, and Trinity rivers, all of which are major tributaries of the Klamath River, were major salmon and steelhead producers. The Shasta River with its cold flows and high productivity, was once especially productive for anadromous fishes. In the Klamath Basin as a whole, Chinook salmon were, and still are, the most abundant salmonid, followed by steelhead. Coho salmon rank third, but are well below Chinook and steelhead in abundance (USDI 2012b).

Long-term declines in Klamath Basin fisheries have been estimated at over 90% for wild fall-run Chinook salmon, 98% for spring-run Chinook salmon, 67% for steelhead trout, 52%-95% for coho salmon, 98% for Pacific Lamprey (USDI 2012b), while Lost River (*Deltistes luxatus*) and shortnose suckers (*Chasmistes brevirostris*) have declined to only a fraction of historical levels (USFWS 2012). These declines and related Endangered Species Act listings are due to multiple stressors, which are described in detail in Sections 0 and 4 of this report. Dams, reduced flows, drainage infrastructure and canals, loss of wetlands and increases in nutrient and sediment inputs are at the root of many of these stresses and have generated the most significant ecological modifications (NRC 2008; Stanford et al. 2011; USDI et al. 2012; USDI, USDC, NMFS 2013).

Since 1988, the Klamath Basin has been a socio-political epicenter of debate over how to sustain and restore fisheries of great cultural and economic importance, while also sustaining other natural goods and services, and concurrently supplying enough good quality water for farmers, ranchers, local communities and hydroelectric power generation. Many communities have experienced hardships. In 2001, the USBR refused to deliver water to farmers and ranchers to comply with the Endangered Species Act and associated Biological Opinion (2001) obligations (Chaffin et al. 2015). This spawned a series of protracted lawsuits over perceived water contract violations, and involved the provision of about $40 million in state and federal disaster aid (Chaffin et al. 2015). In 2010, the Klamath Tribes limited their harvest of suckers to ceremonial use for the 25th consecutive year and experienced their 92nd year without access to salmon (USDI et al. 2012). Weak Klamath River salmon stocks resulted in the closure of commercial salmon fishing in 2006 in the Klamath Management Zone on the California coast, and severely curtailed the commercial fishing season along the Oregon coast (USDI et al.

2012). This is believed to owe in part to a large spawning salmon fish kill in the Klamath River between September 20 and 27, 2002. The federal government declared that year to be a fishery disaster, and released $60 million in relief funds to help compensate the losses to commercial fishermen and fishing related businesses in Oregon and California (Upton 2011). More recently, as of March 2017, *the expected Klamath fall-run Chinook salmon return is forecast to be the lowest on record* (Bacher 2017). Since 2005, growth of toxic algae behind two Klamath River dams (Copco 1 and Iron Gate) has resulted in posted health warnings against water contact (especially health concerns associated with microcystin toxin) in the two reservoirs and the Lower Klamath River (USDI et al. 2012). These challenges have drawn different groups into persistent and divisive conflicts.

Federally funded hydrologic modifications began in the basin in the early twentieth century with the National Reclamation Act (passed in 1902) and the Klamath Irrigation Project, which began construction in 1906. Keno Dam was the final facility built with completion in 1967. The USBR's Klamath Irrigation Project supplies water to approximately 57% of the irrigable land in the upper basin and provides irrigation water to about 240,000 acres of croplands in southern Oregon and northern California (Chaffin et al. 2015). The California Oregon Power Company (COPCO) later oversaw development of power generation and infrastructure projects throughout the region, beginning with the construction of the Copco 1 Dam in 1909 and ending in 1962 with the completion of Iron Gate Dam (Chaffin et al. 2015). COPCO merged into Pacific Power and Light (PacifiCorp) in 1961. PacifiCorp's Klamath Hydroelectric Project (FERC No. 2082) currently consists of seven hydroelectric developments (**Eastside** (3.2MW), **Westside** (0.6MW), **J.C. Boyle** (98MW), **Copco 1** (20MW), **Copco 2** (27MW), **Fall Creek**[6] (2.2MW) and **Iron Gate** (18MW)), and one non-generating dam (**Keno**). The project generates approximately 716 gigawatt-hours of electricity on an annual basis – enough power to supply the energy needs of approximately 70,000 households. The USBR owns **Link River Dam** which PacifiCorp operates in coordination with the company's hydroelectric projects. The Link River Dam, located upstream of PacifiCorp's projects (Figure 1-2) controls storage within and releases from Upper Klamath Lake, the largest freshwater lake in Oregon. **Keno Dam**, located 22 miles downstream of the Link River Dam, does not produce electricity but regulates the water level in Keno Reservoir/Lake Ewauna as required by the operating license for the project issued by the Federal Energy Regulatory Commission.

[6] Originally commissioned and built by Siskiyou Electric Power Company 1903.

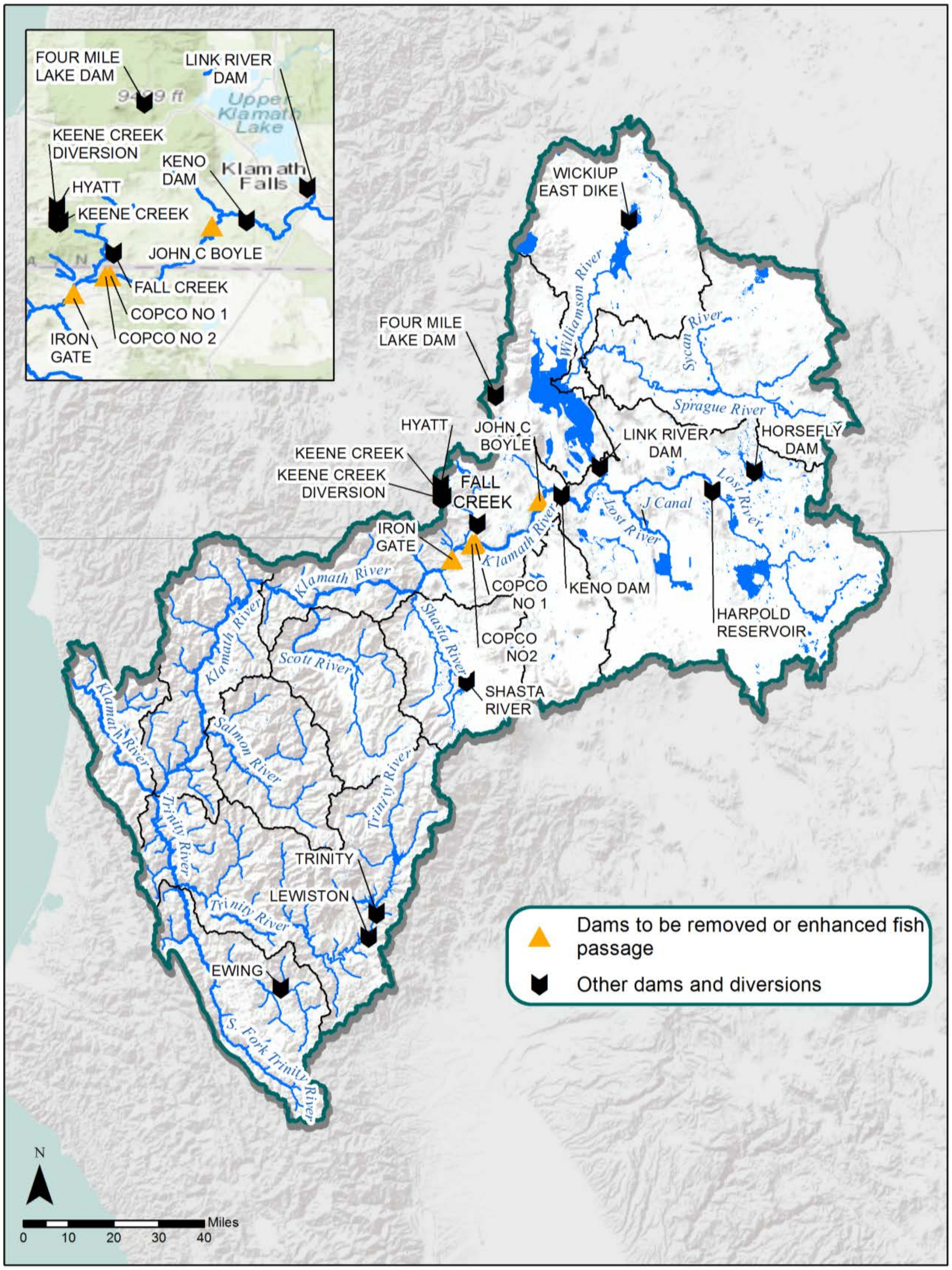


Figure 1-2: Map of the Klamath Basin, Oregon and California, with inset showing location of the four dams that are proposed to be removed, or, enhanced fish passage added.

Between the early 1980s and 2005, there has been a significant shift towards more consideration of fisheries needs and the human groups aligned with those interests (Chaffin et al. 2015). Two pre-conditions were at the heart of this shift: (1) the passage of the Endangered Species Act in 1973, followed by its increasing application over the next decade to many projects and problems; and (2) formal legal recognition of tribal water rights[7]. The Clean Water Act, National Environmental Policy Act (NEPA) (both passed in 1973) and other statutes legitimized a public will to conserve endangered species, protect water quality, and involve citizens in environmental decision-making (Chaffin et al. 2015). Public and scientific attention on the need for additional instream water intensified with the USFWS listing of the Lost River and shortnose suckers as endangered species in 1988 (USFWS 2008a), the NMFS listing of coho salmon as a threatened species in 1997 (NMFS and USFWS 2013), and the associated Biological Opinions (USFWS 2008c, NMFS 2010a; NMFS and USFWS 2013). In 2001, the USBR curtailed irrigation water deliveries from Upper Klamath Lake. Since 2005, there have been widespread closures in commercial salmon fishing harvests off the coast of Oregon, Washington, and parts of California. **These and other events solidified a new reality that all communities of the Klamath Basin would have to work together to find solutions that reach a better balance among multiple objectives** (Chaffin et al. 2015).

There has recently been a movement away from litigation towards a more collaborative approach to finding lasting solutions (Chaffin et al. 2015). Prompted by Federal Energy Regulatory Commission (FERC) relicensing obligations and NRC (2004) reviews, PacifiCorp initiated settlement talks with interested participants in 2006. In February 2010, these interested participants signed the (now defunct) Klamath Basin Restoration Agreement (KBRA), which provided for reduced withdrawals for irrigation and plans for comprehensive ecosystem restoration. The KBRA was paired with the companion Klamath Hydroelectric Settlement Agreement (KHSA) that laid out a process for **decommissioning and removing the four mainstem Klamath River dams (Iron Gate, Copco 1, Copco 2 and J.C. Boyle)** (discussed further in Section 1.5).

Based on the extensive scientific and expert panel evidence and the direction of the U.S. Department of the Interior (USDI), an overarching principle behind the development of the Klamath Basin IFRMP is that either (a) the four lower Klamath River dams will be removed (USDI 2012b, USDI et al. 2012), or failing completing the recommended dam removal action, (b) extensive new and enhanced fish passage infrastructure will be added to allow native fishes to effectively find and migrate past the dams.

In addition to the proposed dam removal (currently planned for 2020) other *proposed* restoration actions include **flow management** (e.g., NMFS 2010a Biological Opinion, Hamilton et al. 2011), a variety of **habitat improvements** (including water quality[8]) (KBRA 2010), and **a conservation hatchery** in support of an active reintroduction program for the tributaries of Upper Klamath

[7] 1983 U.S. Court of Appeals for the Ninth Circuit upholding Klamath Basin tribal water claims with a priority date of "time immemorial" (Benson 2001).

[8] There are currently nine TMDLs established in the Klamath Basin. A TMDL (Total Maximum Daily Load) is a calculation of the maximum amount (load) of a pollutant that a water body can receive and still meet water quality standards. These TMDLs identify the pollutant load reductions that are necessary to meet water quality standards.

Lake. Collectively *with* dam removal, these and other proposed restoration actions are expected to increase the abundance, resilience and genetic diversity of salmonid populations and the related fisheries they support (Secretary of Interior, October 2016 Statement of Support, pg. 18).

Termination of KBRA in 2015 was a setback as it was the *de facto* vehicle through which fish habitat restoration programs were to be funded. This is significant as projected **fish production benefits associated with dam removal are expected to decline substantially without meaningful funding and execution of habitat restoration** (Secretary of Interior, October 2016 Statement of Support, pg. 15). Hendrix (2012) suggested Chinook salmon adult production (natural and hatchery origin age 3 ocean fish) benefits could decrease from gains of 80% to just 10-12%[9] if salmon habitat restoration proceeds slowly because of the expiration of KBRA (Secretary of Interior, October 2016 Statement of Support).

Once developed, **the IFRMP is intended to provide a clear roadmap for integrated basin-wide restoration and monitoring priorities in the Klamath Basin.**

Between 1912 and 2016, 1,384 dams have been removed nationwide (American Rivers[10]). Most of these have been small diversion dams, but several notable large dams including Elwha (Figure 1-3), Condit, Marmot, and Glines Canyon have now been removed. In the dam removals reviewed by O'Connor et al. (2015), the rate of sediment transport and channel evolution has varied from months to a few years, proceeding more quickly if dams were removed rapidly. The sandy sediments impounded behind Condit, Marmot, Glines Canyon, and Elwha dams were removed over periods ranging from hours to three years. O'Connor et al. (2015) cited a small number of cases where migratory fish generally responded quickly to restored river connectivity. Despite these generally positive outcomes, each river basin possesses unique characteristics where local environmental and habitat conditions and the dam's position in the watershed affect physical and ecologic consequences (O'Connor et al. 2015). In the Klamath Basin, the dams are positioned high in the river system and the scale of the proposed dam removal is considerably larger than other examples studied (USBR 2012a,b). In addition to other uncertainties that will need to be addressed, upper basin water quality challenges may persist even after removal of dams on the Klamath River (USBR 2012a,b; KTWQC 2016). The potential trade-offs of dam removal are discussed further in Section 6.5.1.

Reclamation and its contractors have developed a detailed plan for removal of the four mainstem Klamath River dams which can be accomplished in a single year, beginning with a drawdown of the three largest reservoirs between January and March. This timing maximizes the probability that large fractions of suspended sediment eroding from the decommissioned reservoirs will move downstream to the Pacific Ocean more quickly and confine effects on fish to a single year (USBR 2012a,b). In the short-term (1-2 years), higher mortality of some fish from suspended sediment is expected (USDI 2013). The short-term increase in sediment related mortality is anticipated to be outweighed by the larger benefits of improved access to a

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[9] Using baseline represented as the No Action Alternative (Hendrix 2011, 2012), computed as the (Dam Removal Alternative – No Action Alternative)/No Action Alternative x 100%, the median for the 2021-2061 period (dam removal assumed to be 2020) with active reintroduction in the tributaries to upper Klamath Lake. See Hendrix (2012) for details.

[10] https://s3.amazonaws.com/american-rivers-website/wp-content/uploads/2017/02/15104536/DamsRemoved_1999-2016.pdf

superior range of habitats, improved water quality, and reductions in the incidence of disease outbreaks that are presently elevated with the current dams and reservoirs (USDI et al. 2012, Secretary of Interior, October 2016 Statement of Support, pg. 19).


Figure 1-3: Photos of the Elwha and Glines Canyon Dam removal on the Elwha River. The photo[11] in (A) was taken in 2010 and shows adult Chinook salmon blocked in their journey upriver by Elwha Dam with no fish passage. Even after 100 years they persisted, circling at the face of the dam every spawning season, trying to get upstream. The 2012 photo[12] in (B) shows the partially deconstructed Glines Canyon Dam and Lake Mills. The dam is now removed and the Elwha River is free-flowing (C). A newly opened viewpoint perches on part of the dam's former spillway.

[11] Accessed from http://projects.seattletimes.com/2016/elwha/.

[12] Steve Ringman, The Seattle Times, http://www.seattletimes.com/life/travel/glines-canyon-spillway-overlook-opens-in-dam-free-elwha-valley/

Two dams important to the operations of USBR's Klamath Project are the Link River and Keno dams, both of which would remain in place as specified in the KHSA even if the four dams were removed. These two facilities are equipped with fish passage that would allow anadromous and other fish to access the upper basin. However, water quality challenges associated with Link River and Keno dams will not be addressed by the proposed removals.

Sediment transport modeling predicts that 5.4 to 8.6 million cubic yards (1.5 to 2.3 million tons dry weight) would be eroded from the reservoir areas upon dam removal (USDI 2012 and references therein). A large proportion of the sediments (85 percent by weight) are characterized as small particle diameter silts and clays that would remain in suspension and would be transported through the Klamath River to the Pacific Ocean where they would be dispersed by ocean currents. The remaining 15 percent of the sediment is composed of sand, gravel, and cobbles that would be transported through the Klamath River system more slowly, over a period of years or decades, and generally during large flow events (USDI 2012).

Overall, the Klamath River ecosystem is highly complex owing to its great geologic age, "upside down" hydrology (downstream portions of the watershed are steeper gradient and receive more precipitation than the headwaters, highest nutrient loadings in the upper basin), great landscape variation, and over a hundred years of human-induced water diversion and other stressors (Stanford et al. 2011). Even with active restoration and mitigation, there remain pressures that will continue to potentially push the ecosystem towards further decline. Klamath River restoration strategies face several critical uncertainties (Barr et al. 2010; Hamilton et al. 2011; Stanford et al. 2011; USDI 2012; USDI et al. 2012; Quiñones et al. 2014a,b), *some* of which are captured by the following questions:

- What hydrologic conditions will exist at the time of dam removal and during the following 1-5 years? This has important effects on the concentrations of suspended sediment.
- Would increased fall flows increase the rate and proportion of fall-run Chinook salmon, steelhead, and coho salmon spawning in tributaries rather than the mainstem Klamath River? If so, this would reduce their exposure to high concentrations of suspended sediment following dam removal. More generally, are there sufficient refugia from high sediment concentrations of suspended sediment, along the length of the Klamath River?
- With dams removed, what will be the *speed and degree* of recolonization of formerly inaccessible habitats? Recolonization is hypothesized to provide significant future benefits in terms of improved spatial distribution, increased genetic diversity, productivity and resilience to climate change. The rate and extent of recolonization is uncertain.
- What impacts/effect will poor water quality have on the ability of fish to thrive/survive in newly opened habitats?
- What restoration actions will be implemented, and how will they be funded and coordinated?
- To what extent will climate change over the 2020s and beyond offset gains made by restoration actions? Will climate change impacts on water temperatures, water quality, and flows in the Klamath Basin cause further declines in fish populations?

- Will land use and forest management plans ensure the continued presence of and access to cold water refuges produced by springs and forested tributaries?
- Will coho and other salmon be able to successfully pass through the unfavorable summer and fall water quality conditions in the Keno impoundment?
- What is the best way to operate the Iron Gate and Trinity River hatcheries? Operations will need to consider competitive and genetic interactions between reintroduced and native stocks. Despite the operation of these hatcheries, releasing millions of juvenile Chinook, coho, and steelhead into the rivers each year, commercial fisheries for Klamath Basin fishes have largely been curtailed, and sport fisheries have declined (NRC 2004).
- How will year to year variations in marine survival and harvest affect the rate of recovery of fish stocks and fisheries?
- Will the dams actually be removed, and if so when? The prioritization and sequencing of restoration actions and monitoring would be very different with the dams remaining versus a future with the dams removed.
- What will be the magnitude and nature of potential water quality impacts in the river and estuary of increased Klamath River nutrient concentrations following dam removal?
- Will the recent trend towards greater collaboration continue, and help to enable restoration of the basin fisheries? Conflicts over values are inevitable in the Klamath. There are choices, however, in the governance processes used to reduce and resolve these conflicts. Other large basins with conflicts over multiple objectives have developed governance processes that are collaborative and constructive (Fischenich et al. 2016).

These and other uncertainties make it extremely difficult to predict the future long-term trajectory of native fish populations.

**To tackle these challenges there will need to be a transformation to a new paradigm, involving collaborative, adaptive governance, supported by strong science and appropriate processes for conflict resolution.** NRC (2004, 2008) strongly recommended an adaptive management approach – one that takes a basin-wide view of management and restoration and connects best-science to decision-making. As described in Section 8.2, the best practices of adaptive management can contribute towards addressing many of the above-described uncertainties regarding *how* to achieve agreed-upon objectives (e.g., governance that enables Adaptive Management and sustains the engagement of interested participants, clear objectives, interdisciplinary conceptual and simulation models, rigorous design of management actions and monitoring to enable hypothesis testing and ecosystem restoration). Adaptive management does not solve value conflicts. Value conflicts over competing objectives require processes for constructive negotiations in which all interested participants move from defending positions to seeking solutions that at least partially address all participants' concerns (Fisher et al. 1991).

With its well aligned core principles, **the development of the Plan will contribute to the science and decision-making criteria needed to establish restoration and monitoring priorities.**

### Box 1-1: Ecosystem Components Considered by The Integrated Fisheries Restoration and Monitoring Plan and its Relationship to Water Quality

The general organizing framework presented in the Synthesis Report (Figure 3-1) takes an **ecosystem approach**, whereby various *watershed inputs* (e.g., water, sediment, large woody debris, nutrients) are considered to drive *fluvial geomorphic processes* (e.g., sediment transport, channel migration, floodplain development) that determine physical geomorphic attributes and the structure and complexity of *habitats* in the basin. In addition to *habitat quantity and structure*, **water quality** (e.g., water temperature, dissolved oxygen, un-ionized ammonia, pH, turbidity, microcystin and other fish toxins) **is one of the many important attributes of *habitat quality* for fish populations**. Combined, habitat quantity and quality will in turn drive *biological responses* and are important determinants of fish abundance, distribution, and community composition. Stressors on any of the key inputs or processes at different levels of the hierarchy (Figure 3-1) could consequently affect fish populations either directly or indirectly.

The Klamath River is currently listed as a Clean Water Act (CWA) impaired waterway (on the "303(d)" list) in both California and Oregon due to water temperature, sedimentation, pH, organic enrichment/low dissolved oxygen, nutrients, ammonia, chlorophyll-a, and microcystin (an algal toxin). Readers are encouraged to review Section 3.2.3 which provides an excellent overview of the current understanding of pathways in which nutrients and contaminants alter water quality and contribute to stress and mortality of various fish populations. Indeed, the words "water quality" appear over 380 times in the Synthesis Report. This Synthesis also summarizes the role of TMDLs (Total Maximum Daily Loads (see Section 2.4) in setting allowable limits on the amount of phosphorus and other nutrients entering waterways of the Klamath Basin to improve water quality for a variety of purposes, including (but not limited to) fish. While the river does not meet CWA criteria for a number of fisheries-related beneficial uses, there are also numerous other beneficial uses related to human health, aesthetics, cultural, agricultural, commercial, water supply and recreation that are considered to be impaired for the Klamath River (USDI/USDC/NMFS 2013). It is recognized and we respect that these impairments represent a variety of other parallel concerns that are critically important for agencies, Tribes and stakeholders in the Klamath Basin. However, **water quality issues and other elements that are not directly related to having important effects on fish abundance, distribution, health, and community composition are beyond the scope of the Integrated Fisheries Restoration and Monitoring Plan.**

The Plan aims to use best-science and an adaptive management mindset for objectively articulating basin-wide **fisheries restoration needs**, with monitoring and restoration efforts within the Plan directed at key biological and physical factors that heavily influence fish populations. The Plan does not provide a comprehensive review of all policy positions, nor does it evaluate how to balance all relevant beneficial uses and socio-economic objectives. Instead, the Plan will focus on developing a robust and broad set of **ecosystem restoration and monitoring needs** for the Klamath Basin **using a representative set of focal fish species** in a manner that considers stressors acting over all life-history stages, many locations and through *a multitude of physio-chemical and trophic cause-effect impact pathways*. In summary, the whole of ecosystem processes and components within the Klamath Basin, **including water quality** and other attributes, is in scope for evaluation within the Plan but only insofar as they have important influences on the priority Plan focal fish species.

## 1.4 Regulatory Framework for Klamath Fisheries

This section of the report summarizes the overall roles of key federal, state and tribal agencies involved in fisheries management within the Klamath Basin. Section 6.2 provides a more detailed description of the specific roles of organizations involved in habitat and fisheries restoration.

In the Klamath Basin, as elsewhere, there are a number of entities –Federal, State and Tribes – that have distinct roles in day-to-day fisheries management. For example, Lost River and shortnose suckers are federally listed as endangered and are managed and regulated by the U.S. Fish and Wildlife Service (USFWS). Coho salmon are federally listed as a threatened species, and they are managed by the National Marine Fisheries Service (NMFS). Chinook salmon, native trout, lamprey, sturgeon and other fish endemic to the Klamath Basin are regulated by California Department of Fish and Wildlife (CDFW) and the Oregon Department of Fish and Wildlife (ODFW). Additionally, some Klamath Basin tribes' oversee management and regulation of certain fish species that occur on their reservations. The tribes, states and federal agencies also routinely coordinate on fisheries management. For example, the Klamath Tribes' fishery management program consists of cooperative interagency monitoring of Lost River and shortnose sucker populations in Upper Klamath Lake and its tributaries. The Klamath Tribes also provides technical support to population recovery efforts through captive propagation of approximately 1 million larval suckers each year in addition to cooperative planning for the reintroduction of Chinook salmon to the upper Klamath Basin. The Klamath Tribes also monitors fish populations and actively promotes habitat enhancement and restoration on 1 million acres of former reservation land. All fisheries managers are concerned with various regulatory and non-regulatory actions directed toward harvest, habitat restoration, hatchery supplementation and the recovery of imperiled species.

The various Federal and State agencies are responsible for administering an array of laws that affect fisheries management issues in the Klamath Basin (Appendix G). These statutes are wide-ranging and give agencies important mandates to engage in their conservation-oriented missions and fisheries management. Activities range from protecting endangered species, to promoting commercial fishing and the management of invasive species. There are laws and policies that help the agencies fulfill tribal trust responsibilities as well as those that help enhance recreational fishing and other public uses of aquatic species. Some of the more notable legal and regulatory tools used by the federal agencies are briefly summarized in Appendix G.

The history of lawsuits in the Klamath Basin has recently led to a movement towards a more collaborative approach to finding lasting solutions (Chaffin et al. 2015). Leading scholars (NRC 2004, 2008) have emphasized the essential importance of developing the IFRMP in a collaborative and transparent manner that recognizes Sovereign and public interests but is not unduly constrained by a focus on "turf" or "jurisdiction". The challenges to Klamath Basin fisheries managers in meeting restoration and management goals remain vast. To make progress, there will need to be even greater collaboration and more reinforcing integration in tackling the problems (NRC 2004, 2008). Guiding this integration and collaboration is one of the key objectives of the IFRMP. Fortunately, over the last decade, federal and state agencies and

Tribes have been working together in more effective partnerships. There has also been collaboration with various non-governmental parties to negotiate solutions for resolving water-related conflicts in the Klamath Basin (See Section 1.5 describing settlement agreements).

Below we briefly describe the role of each partner agency with responsibilities for fisheries management or functions related to the protection of watershed health in the Klamath Basin.

### 1.4.1 Role of U.S. Fish and Wildlife Service and National Marine Fisheries Service

The Interior Department's **U.S. Fish and Wildlife Service (USFWS)** and the Commerce Department's **National Marine Fisheries Service (NMFS)** together administer the Endangered Species Act (Appendix G). The USFWS has primary responsibility for terrestrial and freshwater organisms, while the responsibilities of NMFS are mainly marine wildlife such as whales and anadromous fish such as salmon. USFWS's mandate is to recover and restore endangered, threatened and imperiled species, fulfill its tribal trust and mitigation responsibilities, and conserve a wider range of fisheries and other aquatic resources. The agency also works to restore habitat across the landscape, prevent and control invasive species, assist Native American tribes and other partners in managing their fish and wildlife resources, advance fisheries and aquatic sciences and technologies, foster outdoor recreational opportunities, educate the public on the economic and ecological benefits of aquatic species and their habitats, and address new and emerging challenges such as climate change.

The mission of NMFS is to recover and conserve marine and anadromous species protected under the Endangered Species Act (ESA) and the Marine Mammal Protection Act and other regulatory authorities. NMFS conducts ESA status reviews and makes ESA listing determinations, designates critical habitat, develops and implements ESA recovery plans, conducts ESA Section 7 consultations and coordinates programs that reduce impacts on protected resources.

### 1.4.2 Role of State of California in the Management of Fisheries Resources in the Klamath Basin

In California, regulatory authority for all **non-tribal in-river fisheries** rests with the **California Fish and Game Commission.** The Commission is composed of five members appointed by the Governor and confirmed by the State Senate. The Commission sets hunting and sport fishing regulations including seasons, bag limits, methods and areas of take. Additionally, the Commission formulates general policies for the California Department of Fish and Wildlife (CDFW) and regulates aspects of commercial fishing (www.fgc.ca.gov/public/information/). The Legislature has delegated to the Fish and Game Commission a variety of powers, some general in nature and some very specific. These powers are delegated within California Statutes that comprise the Fish and Game Code. The current electronic version is found at http://leginfo.legislature.ca.gov/faces/codes.xhtml. Under the Commission, the CDFW serves to implement the State's policies, rules and regulations to manage and protect fisheries resources in waters of the State.

In-river fisheries management in the Klamath Basin is divided into two sets of regulatory management areas. The first management area includes habitats downstream of anadromous barriers, Iron Gate Dam on the Klamath River and Lewiston Dam on the Trinity River. The second management area focuses on habitats above the anadromous barriers.

Recreational fishing within the California portion of the Klamath Basin requires a California sport fishing license and other applicable report cards (steelhead and salmon report cards) (www.wildlife.ca.gov/Fishing/Inland). Fishery regulations above the dams are generally concordant with state-wide trout season bag and possession limit restrictions for stream fishing (reservoirs excluded). The Klamath River, above Iron Gate Dam, is traditionally open to angling between the last Saturday in April through November 15 (www.wildlife.ca.gov/Fishing/Inland).

Fishery regulations below Iron Gate Dam affect all recreational fishers (non-tribal members) in all areas including the Hoopa and Yurok Reservation lands. Most tributaries in the Lower Klamath River are closed to fishing year round, with the exception of Bogus Creek and the Salmon, Scott, and Shasta rivers (www.wildlife.ca.gov/Fishing/Inland). These areas are restricted by time and area closures and "catch and release" regulations, with the exception that two hatchery-marked steelhead may be retained.

State regulatory changes are generally considered on a two-year cycle; however, because of the dynamic management within the Klamath Basin this regulatory cycle is performed annually. The annual cycle is required to incorporate prospective levels of adult fall Chinook salmon allocations into daily bag and possession limits or other restrictions for the recreational fishery which are commensurate with the expected level of harvestable adult fall Chinook. Regulations for other species (sturgeon, spring Chinook, steelhead, coho, etc.) are also updated annually in the Klamath Basin.

### 1.4.3 Role of the State of Oregon in the Management of Fisheries Resources in the Klamath Basin

Oregon also operates under a **Commission** system, with responsibility for fish and wildlife conservation planning and regulatory programs shared by many agencies, organizations and institutions (www.dfw.state.or.us/conservationstrategy/). Fish management in Oregon is directed under policy and statute (ORS 496.012 and OAR 635-007-0502). The Wildlife Policy states:

- Prevent serious depletion of any indigenous species.
- Provide the optimum recreational and aesthetic benefits for present and future generations of the citizens of this state.

Specific fish management in the Oregon section of the Klamath Basin is driven by the Klamath Basin Fish Management Plan (1997, OAR 635-500-3600, 635-500-3885, 635-500-3890). ODFW also prioritizes conservation and recovery of State Sensitive Native Fish species identified in the *Oregon Conservation Strategy* (ODFW 2006).

### 1.4.4 Role of Tribes in Fisheries Management in the Klamath Basin

There are six federally recognized Tribes in the Klamath Basin: Yurok Tribe, Resighini Rancheria, Hoopa Valley Tribe, Karuk Tribe, Quartz Valley Indian Community of the Quartz Valley Reservation, and The Klamath Tribes. Tribal culture is tied to the Klamath River. Traditions, ceremonies, and spiritual practices are deeply rooted in the Klamath Basin ecosystem – the river, lakes and tributaries, fish, plants and wildlife. Klamath Basin tribes work to co-manage their fisheries resources with their federal trustee under federal law and provisions established through key consultation policies, including the U.S. Department of Interior's Policy on Consultation with Indian Tribes[13] and the USFWS's Native American Policy[14].

As a result of record-low forecasts for returning Chinook salmon on the Klamath River in 2017, the Lower Klamath Basin Tribes have been faced with their lowest allocation of harvestable fish under contemporary management through PFMC, forcing closures of entire tribal fisheries and catastrophically curtailing ceremonial and subsistence fishing throughout the basin (Houston 2017; Sims 2017). The Klamath Tribes, whose ancestral territory is upstream of the Klamath River dams, was confronted with complete loss of their ceremonial fishing when dam construction beginning in 1918 resulted in extirpation.

Since the late 1990s, the **Yurok Tribe's** Lower Klamath Division of Fisheries (YTFP-LKD) has been conducting comprehensive watershed and physical habitat assessments to guide watershed restoration and species recovery efforts in the Lower Klamath River sub-basin. Initial restoration planning efforts included development of the *Lower Klamath Sub-Basin Watershed Restoration Plan* that prioritized upslope restoration and identified tributary-specific restoration objectives for each lower Klamath tributary (Gale and Randolph 2000). Sub-basin restoration objectives include: (1) reducing sediment inputs from upslope sources by decommissioning priority road segments and stream crossings; (2) restoring native, conifer-dominated riparian forests; and (3) enhancing aquatic habitats and associated floodplains. YTFP-LKD works closely with the CDFW and the NMFS to identify and implement priority Southern Oregon/Northern California Coast (SONCC) coho salmon recovery actions for the sub-basin (CDFW 2004a; NMFS 2014). YTFP-LKD also conducts performance monitoring to assess effectiveness of implemented restoration actions to guide their adaptive management approach and to ensure knowledge transfer to basin partners. YTFP-LKD continues implementing priorities outlined in the Lower Klamath Plan as well as using real-time restoration performance, watershed, and biological assessments to guide restoration actions in an adaptive, collaborative, and long-term stewardship approach.

The **Klamath Tribes** are based in the upper Klamath Basin and serve a membership of Klamath, Modoc, and Yahooskin Peoples. They actively monitor and manage water quality and quantity within the upper basin. The 2013 adjudication of their water right resulted in significant instream flow protections for the upper basin (UKBCA 2014). The Klamath Tribes' Fisheries Department is currently working with ODFW to develop a salmon reintroduction plan. They are also developing comprehensive planning to guide restoration throughout the entire upper basin.

[13] https://www.doi.gov/sites/doi.gov/files/migrated/cobell/upload/FINAL-Departmental-tribal-consultation-policy.pdf
[14] https://www.fws.gov/nativeamerican/pdf/Policy-revised-2016.pdf

Restoration planning will include reach by reach prescriptions and be consistent with applicable TMDLs.

The Klamath Tribes suffered the loss of their historic salmon fishery after the construction of the dams began in 1918. Despite this loss, they continue to coordinate with USBR, USFWS, and other state and federal agencies to promote the management and restoration of other non-anadromous upper basin species. Their water quality monitoring program is extensive and includes key upper basin tributaries such as the Williamson and Sprague rivers.

The **Hoopa Valley Tribe's** (HVT) Fisheries Department co-manages tribal trust fisheries resources for the benefit of tribal members on the mainstem Klamath and Trinity Rivers as well as key tributaries. HVT is a signatory to the Trinity River Record of Decision (ROD) (USDI 2000) that broadly speaking aims to restore Trinity River fish populations to pre-dam levels. The HVT is a participating member of Trinity Management Council (TMC) where the Tribe holds a unique co-management role in relationship to the Trinity River Restoration Program (TRRP). HVT coordinates with USBR and other state, federal, and tribal agencies within the basin to manage flow releases on the Trinity River, plan and implement landscape level restoration efforts to restore fish habitat, augment coarse sediment, monitor and manage fish populations and their recovery, and engage in watershed restoration to promote fish passage and reduce fine sediment inputs. HVT also works to regulate and monitor water quality to reduce the prevalence of fish disease, nuisance algae, and other detrimental factors impacting the health of the fishery.

Subsistence fishing continues to be a vital element of the Hoopa culture and economy. Tribal fishing is actively monitored and managed by the HVT Fisheries Department, which participates in annual Pacific States Fisheries Management Council (PSFMC) technical collaborative fisheries management for the broader Klamath Basin, along with CDFW, NMFS, USFWS, and other tribes. HVT also actively co-manages the hatchery on the Trinity River.

The **Resighini Rancheria** is located at the top of the Klamath River estuary. Resighini members are of Yurok ancestry and retain an unbroken tradition of fishing for salmon on the Klamath River since time immemorial. They do not have a formal fisheries department but actively participate in policy forums to promote fisheries restoration throughout the basin. The Resighini Rancheria advocates for improved water management and water quality in the upper Klamath Basin because of the linkages to downstream fisheries health. They also favor dam removal through the FERC process independent of KHSA.

The mission of the **Karuk Tribe's** Department of Natural Resources is to protect, enhance, and restore cultural and natural resources, as well as ecological processes, upon which Karuk people depend. Subsistence fishing by Karuk Tribal members continues to this day at Ishi Pishi Falls and has strong ceremonial significance. The Karuk Tribe's Fisheries Department works to protect the health and abundance of tribal trust fisheries resources throughout the Klamath Basin, including harvest management. Overarching goals include better understanding ecological processes that support the fishery as well as enhancing the fisheries through restoration (Karuk Department of Natural Resources 2015).

The Karuk Tribe actively monitors water quality and fisheries resources on the Klamath River as well as key tributaries, including the Scott, Shasta, Salmon Rivers and numerous creeks. They have worked with state and federal agencies, as well as tribal partners to remove the Klamath River dams and comprehensively restore the basin, including its hydrology, for the benefit of the fishery. The Karuk Tribe also works to restore fish passage throughout the basin (e.g., Dwinnel Dam on the Shasta River), protect instream flows, assess and better manage impacts from groundwater utilization (Hathaway 2012; Papadopulous & Associates 2012), and implement numerous restoration projects to improve fish habitat. The Karuk Tribe also actively manages forest resources and fire-related issues throughout the mid-Klamath Basin.

The **Quartz Valley Indian Community** is a federally recognized tribe of the Klamath, Karuk, and Shasta Peoples in Siskiyou County, California, with tribal offices headquartered in Fort Jones, CA, near the Scott River. Quartz Valley's Environmental Department works to protect and restore the natural environment for current and future generations. They have an active water quality monitoring program and have participated in basin-wide fisheries management and restoration-related forums.

When considering the role of tribes in fisheries management in the Klamath River, it is important to understand the nature of "Indian rights." Pierce (1998) states that, "*The fact is that these rights, such as Tribal fishing rights and the right to self-governance, are rights that the Indian People as sovereign nations had prior to conquest, and they retained these "Reserved Rights" when they gave up their land by Treaty or Agreement."* The Federal government has the responsibility to uphold tribal trust responsibilities and to safeguard the fishery to ensure that tribes with fishing rights are able to practice those rights (USDI 2012).

### 1.4.5 Other Agencies

Other agencies with important responsibilities for watershed health and fisheries management in the Klamath Basin are described in Section 6 of this report, and include:

- California State Water Resource Control Board;
- Oregon Department of Environmental Quality;
- North Coast Regional Water Quality Control Board;
- USDA Natural Resources Conservation Service;
- U.S. Forest Service;
- The Bureau of Land Management and
- Regional Conservation Districts.

Numerous U.S. laws govern and affect fisheries management issues in the Klamath Basin. These statutes are wide-ranging and give the agencies and tribal governments of the basin important mandates to engage in their conservation-oriented missions and fisheries management. Some of the more notable legal and regulatory tools used by the federal agencies are briefly summarized in Appendix G.

# 1.5 Prior Settlement Processes

Many significant processes and programs have been playing out in the Klamath Basin for several years. These efforts and agreements are born out of recognition that a multitude of federal, tribal, state, and local governments have individual and sometimes overlapping programs for natural resource management. There appears to be general acceptance of the need to work together to find enduring solutions to the ongoing challenges in fisheries, water quality, and competing uses of land and water. As important background, we summarize three relevant negotiated settlements with broad relevance to fisheries restoration.

## 1.5.1 The Klamath Hydroelectric Settlement Agreement (KHSA)

The **Klamath Hydroelectric Settlement Agreement** (KHSA) grew directly out of the Alternative Dispute Resolution Procedures of the Federal Energy Regulatory Commission (FERC) (18 C.F.R. 385.601, et seq.). The parties, including PacifiCorp, elected to negotiate a settlement that contemplates the potential removal of PacifiCorp's hydroelectric facilities on the Klamath River as an alternative to relicensing those facilities. KHSA was originally linked to the KBRA and signed on the same day (February 18, 2010). This Agreement (KHSA 2016) was signed by PacifiCorp, the owner and operator of the four Klamath River dams subject to removal. The KHSA called on the Interior Secretary to decide[15] whether or not to remove Klamath River dams based on whether dam removal and the KBRA would together advance the restoration of salmonids in the Klamath River, and be in the public interest. The Interior Secretary was required to make this decision after the completion of numerous scientific, economic, and engineering studies, and a public Environmental Impact Statement/Report (EIS/R) process under the National Environmental Policy Act (NEPA) (USDI et al. 2012). When signed in 2010, the KBRA and KHSA were linked together as companion agreements, considered to be non-severable from each other. When KBRA expired in December 2015, however, the future of the KHSA was uncertain.

In January 2016, PacifiCorp and the collective of signatories decided it still wanted to pursue dam removal even without ratification of KBRA and amended the KHSA along with the US, OR and CA. This amended KHSA was signed on April 6, 2016. The amendment to the KHSA (KHSA 2016) paved the way for dam removal to go forward without the larger package of KBRA restoration actions (flow management, hatchery, fish reintroduction and monitoring). The amended KHSA essentially privatized dam removal, eliminating the need for the Interior Secretary and Congress to play the decisive role in deciding whether the dams stay or go. Instead, **the amended KHSA calls on the Federal Energy Regulatory Commission (FERC) to decide whether or not to decommission the dams**. The amended KHSA further established a private corporation, **the Klamath River Renewal Corporation (KRRC)**, to be the dam removal entity. The KRRC is led by a board of directors consisting of former Oregon Governor Ted Kulongoski, and representatives of tribal governments, Oregon and California. Further the amended KHSA also directed **$450M collected for dam removal to be transferred to the KRRC** to use in removing the dams, provided that FERC approves the request for dam

[15] Known as the "Secretarial Determination" (see USDI 2012 and Secretary of Interior, October 2016 Statement of Support).

license surrender, transfer and dam decommissioning. The dam removal target date per the amended KHSA is **January 2020**.

## 1.5.2 The Klamath Basin Restoration Agreement (KBRA)

In February 2010, interested participants from the Klamath Basin signed the Klamath Basin Restoration Agreement (KBRA), which provided for reduced withdrawals for irrigation and plans for comprehensive restoration of the ecosystem (Chaffin et al. 2015). The KBRA was negotiated concurrently with the KHSA by more than 45 organizations (KBRA 2010). The signatory parties to the KHSA recognized that dam removal alone would not address many of the issues within the basin. The stated goals of the KBRA were: (1) restore and maintain ecological function and connectivity of historical fish habitats; (2) re-establish and maintain naturally sustainable and viable populations of fish to the full capacity of restored habitats; and (3) provide for full participation in harvest opportunities of fish species (USDI 2012). The original KBRA entailed various proposed restoration actions that were to be undertaken by Federal, State, local, tribal, and private interests. It called for upwards of **$96M per year** (2017 dollars) of funding for **habitat restoration projects** (including environmental water management, water quality), a **reintroduction program** (including an associated conservation hatchery), development and delivery of a **monitoring** plan, and development of other water resource management plans and tools (Appendix C-2, KBRA 2010). The restoration activities and monitoring projects prescribed by the KBRA often lacked specificity, and were often only generally defined in scope and location (USDI 2012).

The *restoration component* of the KBRA package recommended using best available science and **adaptive management** to establish **restoration priorities** in the first 10 years of implementation. At the time (2010-2012), the focus areas were coarse sediment management between Keno Dam and the Shasta River, reduction of organic nutrients above and below Keno Reservoir, and projects that prepare habitats for use by anadromous fish (USDI 2012b). For example, poor water quality in the Keno impoundment (due to high temperatures and high cyanobacteria biomass decomposition and reducing dissolved oxygen) could act to temporarily block juvenile migration of fall-run adult Chinook salmon. Among other possible solutions to this potential problem, a seasonal trap and haul program for migrating fall-run adult Chinook has been contemplated, moving them around Keno Reach for several years following dam removal, until water quality improves in the Keno impoundment.

The *reintroduction component* of KBRA included investigations, monitoring, and actions to reintroduce anadromous fish above the four dams prior to and after dam removal (USDI 2012b). The KBRA recommended that the *monitoring component* be coordinated with the restoration and reintroduction plans to inform **adaptive management processes** and include methods for stock identification, status and trends, and monitoring of the effectiveness of restoration actions (USDI 2012b). The “adaptive management process” described in the KBRA was aimed at: (1) identifying uncertainties associated with implementing restoration projects; (2) ensuring that monitoring would be used to generate new information to reduce these uncertainties; (3) providing added learning; and (4) ensuring accountability that restoration programs were maximally focused on achieving the short- and long-term goals and objectives of the KBRA (USDI 2012b). The adaptive management process described in the KBRA included definition of specific objectives, metrics to track achievement of those objectives, monitoring and evaluation, and procedures to use the evaluation results to inform and improve future management and identify the most effective actions (KBRA 2010).

The KBRA also outlined a governance and coordination framework for providing recommendations to Federal Agency Parties. It envisioned a Klamath Basin Advisory Council (KBAC) and a Technical Advisory Team (TAT) for providing recommendations to Federal Agency Parties. The KBAC would oversee the implementation of the KBRA, while the TAT would govern decisions related to Environmental Water. Under the suggested governance arrangement, an Upper Basin Team (UBT) would also provide oversight on water use retirements to the Federal Lead Party, through the structure of the KBAC. The KBRA proposed that a Klamath Basin Coordinating Council (KBCC) would provide coordination and oversight of various elements of the Agreement not requiring recommendations for Federal Agency Parties. It was understood that these various bodies would individually or collectively require Charter(s) pursuant to the Federal Advisory Committee Act (FACA).

While not all restoration actions hinged on dam removal, a variety of KBRA actions did. Congress objected to the linkage of KBRA to the removal of four dams on the Klamath River. In the end, Congress did not fund the agreement, and after five years without approval the KBRA expired on December 31 2015.

### 1.5.3 The Upper Klamath Basin Comprehensive Agreement

The Upper Klamath Basin Comprehensive Agreement (UKBCA) (UKBCA 2014) was originally envisioned as a major part of the KBRA but was negotiated separately. The Agreement details water management and restoration actions planned for watersheds above Upper Klamath Lake including Wood, Williamson, and Sprague rivers and their tributaries. A driving force behind this Agreement was the 2013 Final Order of Adjudication by the State of Oregon for the Klamath Basin. This adjudication concluded that the Klamath Tribes have the most senior water rights in the system (including over the U.S. Bureau of Reclamation and the Klamath Project), with the Tribes' water rights dating to "time immemorial". As is the case with any senior water right, this allows the Klamath Tribes of Oregon to make "calls" for regulating junior water rights holders. As a result, many junior rights landowners were motivated to sign on to the UKBCA. The Tribes agreed to not make full water rights calls on junior water rights holders (mostly irrigators) in exchange for water rights provisions and restoration work in watersheds important to the Klamath Tribes. The agreement is intended to limit the continued litigation over water rights in the Adjudication and is meant to help implement the water rights provisions of the (defunct) Klamath Basin Restoration Agreement. Because Congress failed to fund the KBRA and this agreement is linked to the KBRA, and because some irrigators in these areas did not all agree on water retirements, the Klamath Tribes invoked a "meet and confer" process to try to work on differences. If these differences cannot be worked out, this agreement will expire in 2018.

## 1.6 Previous Efforts at Science Synthesis

There is an enormous amount of information about the Klamath Basin's water related resource management challenges (Section 1.2.1; http://kbifrm.psmfc.org/document-library/). This

Synthesis Report intentionally focuses on providing an updated account of current restoration and monitoring activities in the basin for a suite of priority fish species. Our effort builds on several prior science syntheses that have been completed since 2004. Below we briefly summarize some of the key insights.

### 1.6.1 National Research Council (2004 and 2008)

In 2001 the U.S. Department of Interior and the U.S. Department of Commerce requested that the National Research Council (NRC) form a committee to complete two reports. This work was inspired by the 2001 decision of the U.S. Bureau of Reclamation to curtail water deliveries from the Klamath Project[16] to uphold biological opinions to protect endangered species. The first of two efforts by the National Research Council focused on the recovery of endangered Lost River suckers, shortnose suckers and threatened coho salmon (NRC 2004). The NRC's 2004 report summarized current understanding and information needs, as well as recommending candidate research, restoration and monitoring actions. NRC (2004) suggested that for three species (coho salmon, Lost River and shortnose suckers), the annual cost of research, monitoring, and restoration projects (unrelated to dam removal) would be on the order of **$9.5M per year** (2017 dollars). The authors also recommended using an **adaptive management** framework to guide restoration efforts in the Klamath Basin (Chapter 10, NRC 2004). They pointed out that an **overall integrated strategy** to ecosystem management and restoration was missing, and instead the Klamath Basin is characterized by a disjointed, dysfunctional and adversarial approach too often led by crisis management and deferral of action (NRC 2004). They instead recommended the use of adaptive management to prioritize, implement and monitor restoration activities, so that public and private investments would enjoy higher rates of success (NRC 2004). Chapter 10 of the NRC (2004) report included a summary of some of the key components of adaptive management (further discussed in Section 8.2 of this report) as follows:

- establishing clear goals and objectives;
- improving dialogue amongst managers, scientists and interested parties;
- developing conceptual models of cause-effect linkages among stressors and habitats, focal species and management decisions;
- working out alternative hypotheses for restoration actions that can be experimentally tested and monitored for effectiveness;
- identifying key uncertainties;
- determining criteria and procedures to set priorities for and sequence restoration actions;
- implementing thoughtful designs for restoration actions[17], coupled with rigorous monitoring that will reveal responses to management actions;

[16] Rendering roughly 1,400 farms and 210,000 acres110 of cropland without water and triggering about $40 million in state and federal disaster aid to the affected irrigators who suffered impacts from the 2001 drought (Chaffin et al. 2015).

[17] For example, NRC (2004) authors felt that the Klamath and Trinity basins provide an unusual opportunity for large-scale tests of hypotheses relating the effect of hatchery operations to the welfare of wild salmon and steelhead populations. This involves treating the Trinity River and Klamath River as paired basins and manipulating operations of Iron Gate Hatchery (substantially reducing or eliminating for a period of years) while Trinity Hatchery production continues.

- comparing forecasted responses to management actions (expected outcomes) with observed outcomes; and
- conducting systematic, regular re-assessment of findings and necessary revisions to conceptual models, hypotheses, models, monitoring programs and priority restoration actions.

The authors concluded "[the adaptive management] approach is both ecologically and socially responsible, given that ultimately all agencies and other stakeholders have limited resources with which to operate" (pgs. 336-337, NRC 2004) and "**[Recovery of endangered] fishes in the Klamath Basin cannot succeed without aggressive pursuit of adaptive management principles**, which in turn require continuity, master planning, flexibility, and conscientious evaluation of the outcomes of management" (pg. 343, NRC 2004). The NRC completed a second report in 2008 (NRC 2008). Despite the considerable amount of science that had been done in the Klamath Basin, NRC (2008) observed that lack of **an overall framework for "identifying science needs"** has prevented the science from being effectively used in management decisions that would help to resolve or at least reduce the continuing controversies.

NRC's 2008 report focused on two large efforts to model the hydrology of the Klamath Basin: (1) the Natural Flow Study by the U.S. Bureau of Reclamation; and (2) a study of instream flow needs of endangered and threatened fishes, by Utah State University. The 2008 NRC review praised the attempt to apply two-dimensional hydrodynamic modeling using the Instream Flow Incremental Methodology (IFIM) to characterize fish habitat. The Hardy Phase II collaborative efforts requested the development of **daily flow series**, however, only monthly flow time series for naturalized flows were provided by the U.S. Bureau of Reclamation model used in the study. The lack of daily resolution in the hydrologic modeling provided to the Hardy Phase II efforts was considered a short-coming: "in short, planners operate on a monthly basis, but fish live on a daily basis" (pg. 10 NRC 2008). These restrictions also precluded other study elements such as dissolved oxygen levels, water temperatures, nutrient loadings, contaminants and sediment concentrations (NRC 2008). The NRC committee also noted the **lack of a broader functional eco-hydrologic analysis** of flow-data time series, and the impacts of flows on the habitat utilization, survival rates and production of coho and Chinook salmon. Despite these restrictions, the Hardy Phase II study included an assessment of how the proposed changes in the flow regime and associated water temperatures would improve the number and increase the size of Chinook reaching the estuary under the proposed instream flows compared to historical operations. The NRC (2008) committee concluded that the flows recommended by the instream flow study would be an improvement over the flow regime existing at that time.

Re-affirming the NRC (2004) findings regarding the need for adaptive management principles, NRC (2008) found that the integration of individual studies into a coherent whole had not taken place and was unlikely to take place under the present scientific and political arrangements. NRC (2008) was critical in suggesting that science in the basin was being done by "bits and pieces" with inadequate linkage to the many studies underway in the Klamath Basin. The authors also emphasized the **need for a truly impartial body to define the vision for science and restoration needs**, made up by neutral scientists who do not represent the values of a particular management agency or tribal government (NRC 2008). The 2008 NRC report concluded that **connecting effective science with successful decision making** will require following the best practice elements of adaptive management.

The NRC 2008 report includes a useful diagram on adaptive management (Figure 1-4), drawn from the CALFED Bay-Delta restoration program.

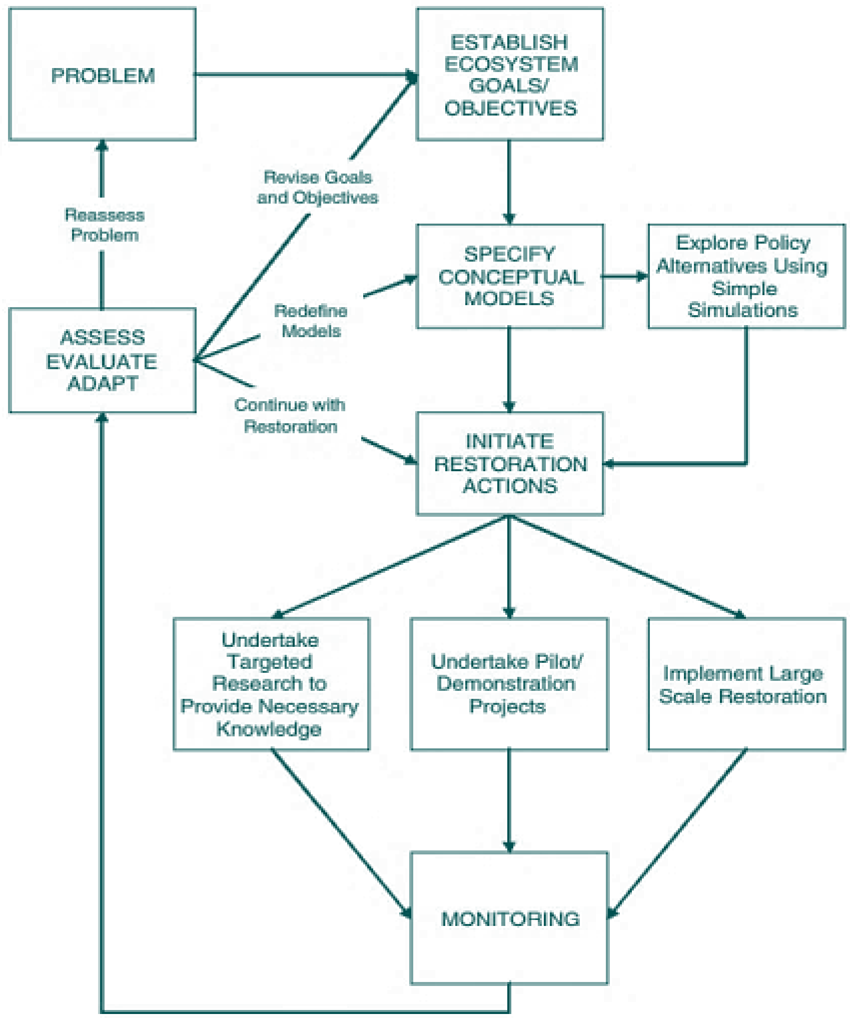



Figure 1-4: Flow diagram for adaptive management of scientific activities. Source: NRC (2008), originally CALFED Bay-Delta restoration program, and originated by Dr. Michael Healey.

NRC (2008) lamented that **the essential features that enable adaptive management remain essentially undeveloped on the Klamath Basin**. Instead, science efforts in the Klamath River Basin have been reactionary, initiated in response to immediate management crises rather than developing coherent understanding. Furthermore, data collection and modeling have been disconnected. The committee noted: "*Adaptive management in the greater Klamath River basin would benefit substantially by adopting organizational and process approaches that are being used to support restoration planning in the Trinity River sub-basin and could enjoy enhanced effectiveness and efficiencies by collaborating with existing Trinity River efforts in a basin-wide science program*" (pg. 205, NRC 2008).

### Box 1-2: The Role of Models in Ecosystem Management

The 2008 NRC committee also devoted considerable attention to the numerous ways that models (including hydrologic, hydraulic, water-quality, habitat, biological, and management models) can assist in ecosystem management. One of the founding fathers of adaptive management, Holling (1978), described "shared vision modeling" and gaming approaches to represent knowledge, uncertainties and illustrate trade-offs among objectives. Here, computer models form the central venue and technical arbiter for negotiations, constituting an agreed-on technical basis for discussions and comparison of performance for proposed alternatives. The development of suites of interacting models can help to address many technical concerns, including issues of scale, and should follow a systematic process of development and application, including testing (NRC 2008).

### 1.6.2 Klamath Facilities Removal Final EIS/R

The U.S. Department of Interior completed the Klamath Facilities Removal Environmental Impact Statement/Environmental Impact Report (USDI et al. 2012). This EIS/R, developed in accordance with the requirements of the National Environmental Policy Act (NEPA) and the California Environmental Quality Act (CEQA), analyzed the potential impacts to the environment from the Proposed Action – the removal of four PacifiCorp dams (J.C. Boyle, Copco 1, Copco 2, and Iron Gate, collectively referred to as the Four Facilities; Table 1-5) under the Klamath Hydroelectric Settlement Agreement (KHSA) including implementation of features of the Klamath Basin Restoration Agreement (KBRA). The No Action (status quo) Alternative was the least environmentally preferable alternative when compared to the Proposed Action (USDI et al. 2012).

Table 1-5: General information on the four mainstem Klamath River dams that have been the focus of dam removal evaluations. *Source*: Table ES-2, Klamath Dam Removal Overview Report (USDI 2012b).

| | J.C. Boyle | Copco 1 | Copco 2 | Iron Gate |
|---|---|---|---|---|
| Year Operational | 1958 | 1922 | 1925 | 1962 |
| Location (River Mile) | 224.7 | 198.6 | 198.3 | 190.1 |
| Dam Type | Concrete & Earthfill Embankment | Concrete | Concrete | Earthfill Embankment |
| Dam Maximum Height | 68 feet | 135 feet | 33 feet | 189 feet |
| Dam Crest Length | 692 feet | 410 feet | 335 feet | 740 feet |
| Reservoir Surface Area | 420 acres | 1,000 acres | N/A | 944 acres |
| Reservoir Storage Volume | 2,629 acre-feet | 40,000 acre-feet | 73 acre-feet | 53,800 acre-feet |
| Spillway Type | Overflow Spillway with Control Gates & Diversion Culvert | Overflow Spillway with Control Gates & Diversion Tunnel | Overflow Spillway with Control Gates | Uncontrolled Overflow Spillway and Diversion Tunnel |
| Maximum Power Capacity (Megawatts) | 98 | 20 | 27 | 18 |

According to the Lead Agencies, Alternative 2, "Full Facilities Removal of Four Dams (Proposed Action)", would **provide access to at least 420 miles of historical habitat**[18] **above Iron Gate Dam** for anadromous fish (USDI et al. 2012). The EIS/R concluded that under Alternative 2, the entire river from Keno Dam to the Pacific Ocean would **become a well-connected, free-flowing river**, providing new fish habitat in the hydroelectric reach[19], and improving fish migration to and from the upper basin. Evidence assembled for the Proposed Action indicated it would also provide anadromous fish with **access to low gradient, historical habitat of importance to spawning and rearing** within Copco 1 and Iron Gate Reservoirs. Consequently, the size and diversity of these populations was expected to increase under this action[20] (USDI et al. 2012). Additionally, the EIS/R noted that fish would **gain access to cold water springs** in the hydroelectric reach and the upper basin, offering **added protection against future climate change** (warming) and improved winter growth opportunities for rearing (USDI et al. 2012).

The suspended sediment pulse caused by dam removal was expected to produce short-term mortality but would over the long-term have more than compensatory fishery benefits (e.g., improving spawning and rearing owing to the added recruitment of gravel within and below the hydroelectric reach) (USDI et al. 2012). The EIS/R observed that removal of the four dams would also create **a more natural flow pattern,** provide **more bedload transport**, and **eliminate the stranding effects of peaking flows and entrainment** into hydroelectric facilities. The preferred alternative in the EIS/R was found to **substantially reduce problems with dissolved oxygen, pH and algal toxins** produced in reservoirs in the hydroelectric reach and transported downstream. The EIS/R suggested that while there is some uncertainty associated with the cycle of disease in juvenile salmon (e.g., the magnitude of disease loading of myxospores associated with different densities of fish carcasses), the **occurrence of juvenile salmon fish disease may be partially reduced** because of increasing overall dispersal of adult salmon carcasses (which would reduce concentration of myxospores), increases in bedload and sediment transport, and reductions in food resources for the intermediate fish disease host. The USDI (2012b) concluded that there would be lower disease risks to resident fish, and that there would be a lower likelihood of a disease hot spot for *C. shasta* above the current location of Iron Gate Dam. However, newer research has cast some doubt on the strength of this conclusion (Foott et al. 2016a).

While producing substantial benefits for fish, the removal of the four dams would eliminate all associated hydropower production beginning in 2020 along with associated PacifiCorp tax revenues (USDI et al. 2012). There would be losses of benefits of the associated project reservoirs such as flat water fishing and some white-water recreation opportunities associated with the artificial peaking flows in the hydroelectric reach[21]. With the elimination of reservoirs and changes to recreational amenities, dam removal would decrease the value of some properties with access to or views of the reservoirs (USDI et al. 2012). The EIS/R also identified

[18] Note: the actual suitability of all of the stream reaches of habitat for anadromous fish has not been rigorously evaluated.
[19] The portion of the Klamath River that includes the four most downstream dams (J.C. Boyle, Copco 1, Copco 2, and Iron Gate Dams).
[20] Note: These benefits in theory would also be realized by adding extensive new and enhanced fish passage infrastructure that allows native fishes to effectively find and migrate past the dams as effectively as if the dams were removed.
[21] There would however be some new recreational benefits along the hydroelectric reach including additional river access and rafting opportunities in the bypassed reaches.

a variety of other input received regarding controversial project issues during the public scoping process (mixture of values based concerns and disputed facts) (Table ES-8, USDI et al. 2012).

The Klamath Facilities Removal EIS/R also identified supportive and reinforcing means through which the (subsequently expired) implementation of KBRA (KBRA 2010) restoration projects and programs would accelerate basin-wide habitat recovery for fish and accelerate improvement of basin-wide water quality (USDI et al. 2012). For example, in the Upper Basin, the KBRA would have supported water quality improvements in Upper Klamath Lake and Keno Reach, with benefits to migrating salmon and steelhead populations, as well as resident sucker populations in Upper Klamath Lake. The EIS/R remarked that the Fisheries Reintroduction and Management Plans in the (now defunct) KBRA also afforded accelerated fish reintroduction to the upper basin and provided for multiple benefits under adaptive management (USDI et al. 2012).

### 1.6.3 Secretarial Determination, Expert Panels and Overview Report

The Department of the Interior (in conjunction with the Bureau of Reclamation, U.S. Geological Survey, and partners at the Federal, State, tribal and local levels) completed a 4-year study, **the most comprehensive engineering, scientific, and environmental study of dam removal ever undertaken** (Secretary of Interior, October 2016 Statement of Support, pg. 19). This process produced 50 new scientific reports, convened four independent science panels, finalized an environmental impact statement under the national Environmental Policy Act, generated a biological opinion (NOAA Fisheries and the U.S. Fish and Wildlife Service) and produced the Klamath Dam Removal Overview Report (USDI 2012b). Sharing scientific components with the Klamath Facilities Removal EIS/R (USDI et al. 2012), the core findings from this determination were:

4. Removing the four mainstem dams (Iron Gate, Copco 1, Copco 2 and J.C. Boyle) would under no harvest conditions increase production of adult Chinook salmon upwards of 80% relative to no action alternative modeling (Hendrix 2011, 2012).
5. Dam removal is the economically superior choice[22] with the probable cost **roughly $170M less expensive than dam relicensing and associated structural modernization requirements**[23] (including updated, effective fish ladders) and changes to future operations that reduce power generation efficiency.
6. Removing dams would immediately improve water quality by eliminating serious temperature, dissolved oxygen and toxic algal bloom conditions in the reservoirs and the downstream river.

[22] The high costs of relicensing the Klamath Hydroelectric Project are related to Federal Power Act (FPA) regulations, which would ultimately require construction and operation of fish passage facilities at the dams. Additionally, Water Quality Certification under Section 401 of the Clean Water Act would require changes to the four facilities to improve degraded water quality created by the reservoirs. The technical complexities of fish passage, and the severity of the water quality problems at the four facilities, generated substantial uncertainty for PacifiCorp regarding the cost of successfully addressing both factors. Also, relicensing would result in reduced power generation and reduced power peaking opportunities. **Taken together, these factors reduce the economic viability of the Klamath Hydroelectric Project for PacifiCorp and its customers** (USDI 2012a,b).

[23] Note: While dam removal under the KHSA is less expensive than relicensing and constructing extensive new and enhanced fish passage infrastructure that allow native fishes to effectively find and migrate past the dams, dam removal also provides no future benefits in terms of power generation (which relicensing would).

7. Reservoir bottom sediments did not contain chemicals in concentrations exceeding human or biological health screening levels (USDI 2012b, Secretary of Interior, October 2016 Statement of Support).

Considering these peer reviewed findings, **the Secretary of the Interior *at that time* determined in April 2013 that removal of the four mainstem dams was in the broad public interest** including being the most appropriate means of advancing fisheries restoration objectives. The Secretarial Statement of Support also reminded its audience that under the amended KHSA (April 6 2016), **the final authority for approving or denying dam removal now resides solely with the Federal Energy Regulatory Commission (FERC)**. Both PacifiCorp and the newly formed Klamath River Renewal Corporation (KRRC) filed their joint application for dam license surrender, transfer and dam removal with FERC on September 23 2016.

# 2 The Klamath Basin

The purpose of this section is to provide:

- a general overview of defining physical, biological and human characteristics of the Klamath Basin; and
- sub-basin profiles including physical and socio-economic characteristics as well as sub-basin specific ecological stressors relevant to fish restoration.

This section provides a brief overview of the physical, biological and human characteristics of the Klamath Basin and supplies separate profiles for each of the major sub-basins. Sub-basin profiles include physical and socio-economic characteristics as well as ecological stressors relevant to fish restoration. Where information is available, unique characteristics of each sub-basin are also listed. Many overview syntheses already exist in the peer reviewed and grey literature; the reader is referred to these sources for more detail (provided in the bibliography for this section). The purpose of this section is not to re-iterate work that has already been done but to briefly summarize key characteristics of the basin that are broadly relevant to fish restoration and monitoring.

Figure 2-1 illustrates the sub-basin boundaries that are used throughout this report. These boundaries primarily follow USGS HUC8 delineations with the exception of the Lower Klamath HUC8. This boundary has been divided into the Lower Klamath River and Mid Klamath River sub-basins to better reflect the physiography of these sections of the Klamath watershed. These boundaries are used in this report primarily to facilitate synthesis and should not be misinterpreted as indicating separated or self-contained ecosystems. The subbasins in the Klamath comprise a single unified ecosystem. Many species have evolved to utilize some or all of these subbasins. For example, a region and its tributaries may provide refugia for fish while another (e.g. the mainstem sections) has sub-optimal conditions.

## 2.1 Physical Characteristics

Klamath Basin ecosystems and fish are affected by contrasting precipitation patterns, climates and diverse landscapes across river basin, which spans over 12,000 square miles (>31,000 $km^2$) in southern Oregon and northern California (USDI, USDC, NMFS 2013) (see Figure 2-1). The basin is unique among Pacific Northwest coastal watersheds. Unlike the typical steep mountain origins of other basins, the Klamath River's headwaters begin in gently sloped desert, marshlands and open valleys. Downstream of Upper Klamath Lake these waters coalesce into the river's mainstem and proceed toward the Pacific Ocean at a much steeper gradient (Stanford et al. 2011; Thorsteinson et al. 2011).

This defining "reversed" feature of the Klamath Basin has implications for seasonal flow patterns and variability in different portions of the watershed. Temporal differences and variability in climate and precipitation influence migration patterns, ranges and life stages of aquatic and riparian species. Much of the mainstem's source water is supplied by upper basin springs emerging from aquifers recharged by snowmelt from the Crater Lake area and the Cascade Mountains (Stanford et al. 2011). Sycan, Williamson, Wood and Sprague Rivers are the four main tributaries draining the basin upstream of Upper Klamath Lake (Thorsteinson et al. 2011; Walker et al. 2012). Surface runoff contributions in this part of the basin are relatively low, with annual precipitation ranging from just 15-40 inches (38-100 cm) (KTWQC 2016).


Figure 2-1: Sub-basins of the Klamath River Basin. Sources: USGS 2005; USGS 2010; USGS 2014.

In decreasing order of annual discharge, the major tributaries in the lower basin are the Trinity, Scott, Salmon and Shasta Rivers (Thorsteinson et al. 2011). The lower basin contrasts with much drier upland sections, receiving 40-150 inches (100-380 cm) per year (KTWQC 2016). Whereas the headwaters are more snowmelt driven, with about half of annual precipitation falling as snow, the downstream sections are dominated by rainfall (with spring snowmelt contributions from the Trinity Alps) (Thorsteinson et al. 2011).

As a result of these contrasting precipitation patterns, flow regimes in the lower basin are more variable than in the upper basin. In the upper basin, peak flows occur during snowmelt in late spring/early summer (NMFS 2015). In the lower basin, peaks occur from November to March when rainfall is highest (NMFS 2015). Some creeks in the lower basin have dry alluvial reaches during summer low-flow conditions (Voight and Gale 1998), and flash flood events frequently occur in winter (Thorsteinson et al. 2011; NMFS 2015). Shasta and Scott River sub-basins are drier exceptions due to orographic effects similar to those in the upper basin (e.g., rain shadow of Salmon and Marble Mountains versus the Cascades). Shasta is primarily spring fed, while Scott has alluvial aquifers similar to the headwater regions (Thorsteinson et al. 2011). Groundwater from the upper basin supplies critical source water for lower basin ecosystems and fishes during dry months (NMFS 2015). These cooler waters also act as a buffer for fish and other aquatic/riparian species against higher summer temperatures (Thorsteinson et al. 2011). Shasta and Scott contribute very little, if at all, to these baseflows.

The steeper gradients of the Klamath downstream of Upper Klamath Lake play a defining role in shaping lower mainstem habitat. The river extends through a narrow canyon from Klamath Falls to the Shasta River confluence (Thorsteinson et al. 2011), then bisects the Klamath Mountains past Scott and Salmon River confluences to the Trinity River confluence (Thorsteinson et al. 2011). Landslides and soil slips are common in these sections (Voight and Gale 1998), which are also host to fast moving water with several rapids. These characteristics can contribute to natural fragmentation and degradation of fish habitat (Voight and Gale 1998), but under natural conditions they also encourage large movements of sediment that produce key downstream features for aquatic species such as pools, runs and tailouts.

## 2.2 Biological Characteristics

Mirroring its physical characteristics, biological characteristics of the basin are also diverse. High elevations in the upland sections consist of the dry alpine coniferous forests of the Cascade Range, giving way to semi-arid desert lands, open valleys and marshlands. An important habitat feature of Upper Klamath Lake is its fringing marshes such as those present in the Williamson River Delta, which hosts many bird, plant and fish species including Lost River (*Deltistes luxatus*) and shortnose suckers (*Chasmistes brevirostris*) (KTWQC 2016; TNC 2017). Vegetation in the lower basin includes some conifers also found in the upper basin (ponderosa pine, Douglas, grand, and white fir) as well as hardwoods such as madrone and oaks, with redwoods and other temperature rainforest conifers near the coast (Thorsteinson et al. 2011).

The Klamath Basin hosts about 3,500 plant species (including 281 endemics), 200 vertebrate species, and 30 native fish species (USDI et al. 2013; NMFS 2015). The most common mammals include deer, elk, bears, bats and squirrels, but at least 78 different mammals are reported (USDI et al. 2013). The basin is internationally known for its abundance and diversity of birdlife (USDI et al. 2013). Klamath forests and wetlands are part of the Pacific Flyway, with 80% of the Flyway's migratory shorebirds, waterfowl and other waterbirds using them as key layover refuges in spring and fall (NMFS 2015). Twenty species of amphibians and reptiles are also known in the basin including salamanders, frogs, toads, turtles, lizards, skinks, and snakes (USDI et al. 2013).

The basin historically produced large runs of steelhead (*Oncorhynchus mykiss irideus*) , Chinook salmon (*Oncorhynchus tshawytscha),* coho salmon (*Oncorhynchus kisutch*), green sturgeon (*Acipenser medirostus*), eulachon (*Thaleichthys pacificus*), coastal cutthroat trout (*Oncorhynchus clarkii clarkia*) and Pacific lamprey (*Lampetra tridentata*) and was once the third largest producer of salmon in the lower United States, but today only a fraction of the river's historic runs still remain (NMFS 2015). Five salmon species once thrived in the basin along with many endemic fishes including several species of sculpin, chub and lamprey (six lamprey species – more than any other watershed in the world) (Thorsteinson et al. 2011). Several fish populations are now listed as threatened under the federal Endangered Species Act including coho salmon, bull trout, Lost River sucker, shortnose sucker and longfin smelt. Oregon and California also list both sucker species under their respective endangered species regulations (USDI et al. 2013).

## 2.3 Human Characteristics

Indigenous peoples have inhabited the Klamath Basin since time immemorial (>11,000 years) (USDI et al. 2013). The Basin is home to six federally-recognized tribes: The Klamath Tribes, Hoopa Valley Tribe, Yurok Tribe, Karuk Tribe, Quartz Valley Indian Reservation, and Resighini Rancheria. In addition, the Shasta Nation is not federally recognized. The Klamath Tribes in the upper basin have been particularly affected by habitat fragmentation and other development. These Tribes have witnessed the complete loss of their culturally significant salmon fishery and the near loss of their sucker fishery (NMFS 2015).

The Klamath Basin is home to approximately 187,000 people (NRC 2004). The City of Klamath Falls and the adjacent unincorporated area of Altamont form the largest population center in the upper basin (pop. ~40,000) (U.S. Census Bureau 2012). Yreka (pop. ~7,800) and Weaverville (pop. ~3,600) are the largest settlements in the lower basin (see Figure 2-2). Although not located within the basin, Arcata (pop. ~17,200) and Eureka (pop. ~27,200) south of the Klamath River estuary, and Medford, OR (pop. ~75,000) are important centers for the Klamath, housing several offices for the basin's active conservation and resource management agencies and organizations.

In terms of areal extent, lands designated for public and private forest use are dominant throughout the basin (KTWQC 2016) (see Figure 2-3). Agriculture and rangeland area is small in comparison but located in sensitive valley bottoms and along the shores of Upper Klamath Lake with significant impacts to riparian ecosystems from development for irrigation, particularly via the Klamath Irrigation Project (KTWQC 2016). Most of the intensive agriculture is located downstream of Upper Klamath Lake in Lost, Butte, Shasta, Upper Klamath River, and Scott sub-basins. Activities include cattle grazing and crop production (cereals, forage, potatoes, sugar beets, onions, peppermint, horseradish and pea seed) (Smith and Rykbost 2001). Much of the remaining land is dedicated to low-density residential area and Tribal reservations. Protected areas include Crater Lake National Park, Lava Beds National Monument, three National Wildlife Refuges in the upper basin that are primarily oriented toward conservation of wetlands (KTWQC 2016). Other key protected areas include Butte National Grasslands, Klamath National Forest, and parts of several other national forests.

Economic output from the Klamath Basin was estimated at about $14.85 billion in 1998 (adjusted to 2017 USD on May 17, 2017; http://www.usinflationcalculator.com) (Committee on Endangered and Threatened Fishes in the Klamath River Basin 2008). At that time, the region supported about 144,000 jobs. Economic opportunities are primarily in fisheries, farming, ranching, hydropower production, timber harvest, mining, and recreation (USDI et al. 2012). Consistent with land use patterns, the upper basin economy is dependent upon agriculture and forestry but also supports a tourism and public employment sector. In Klamath Falls, the retail sector dominates ($540 million in 2012), followed by health care/social assistance, and manufacturing (U.S. Census Bureau 2012). The lower basin economy is focused on retail trade, educational services and health care/social assistance (Committee on Endangered and Threatened Fishes in the Klamath River Basin 2008).

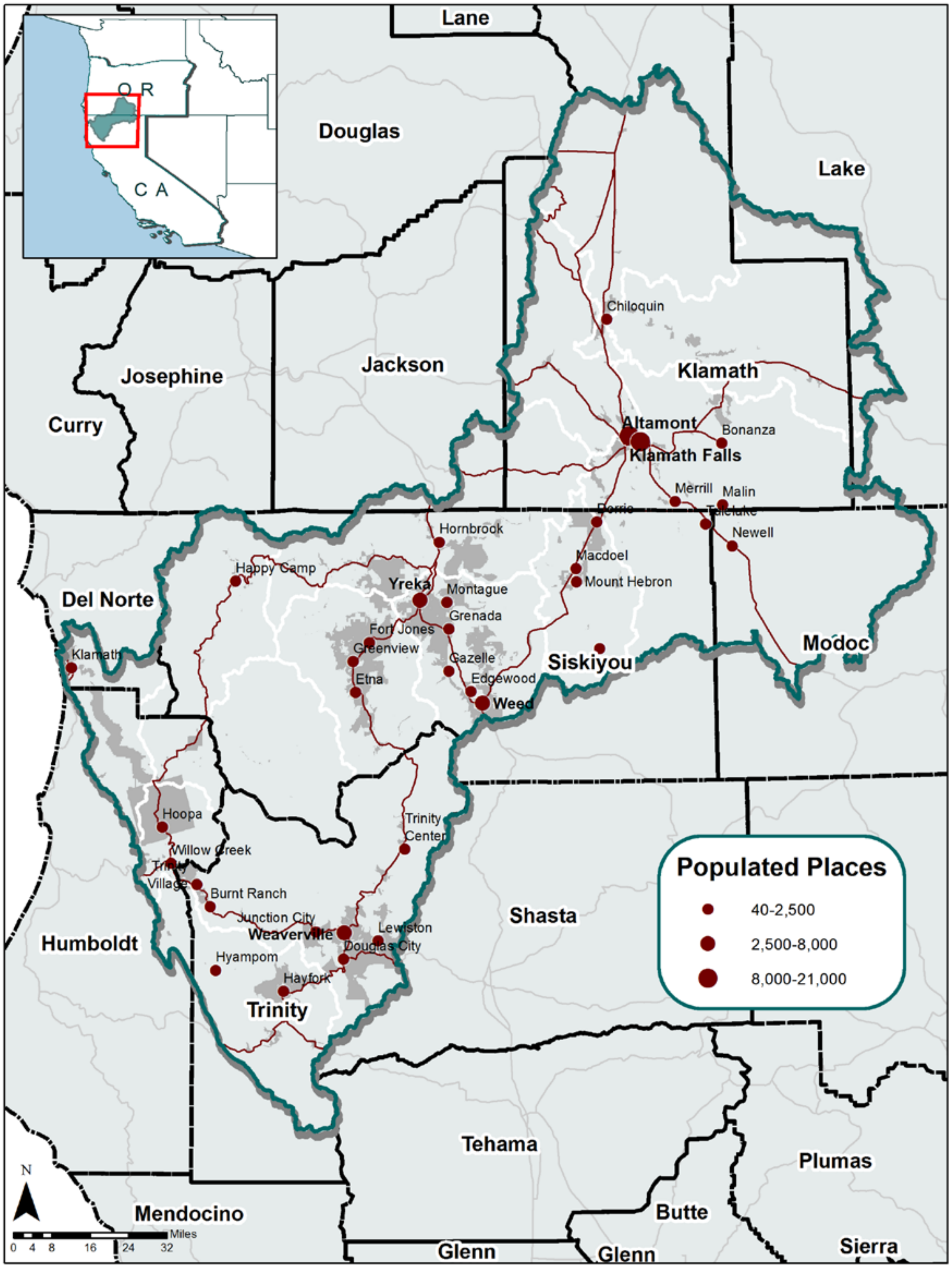



Figure 2-2: Klamath Basin counties, towns and cities. Sources: USGS 1999; California Resources Agency 2004; USGS 2010; USGS 2014; USFS 2014.

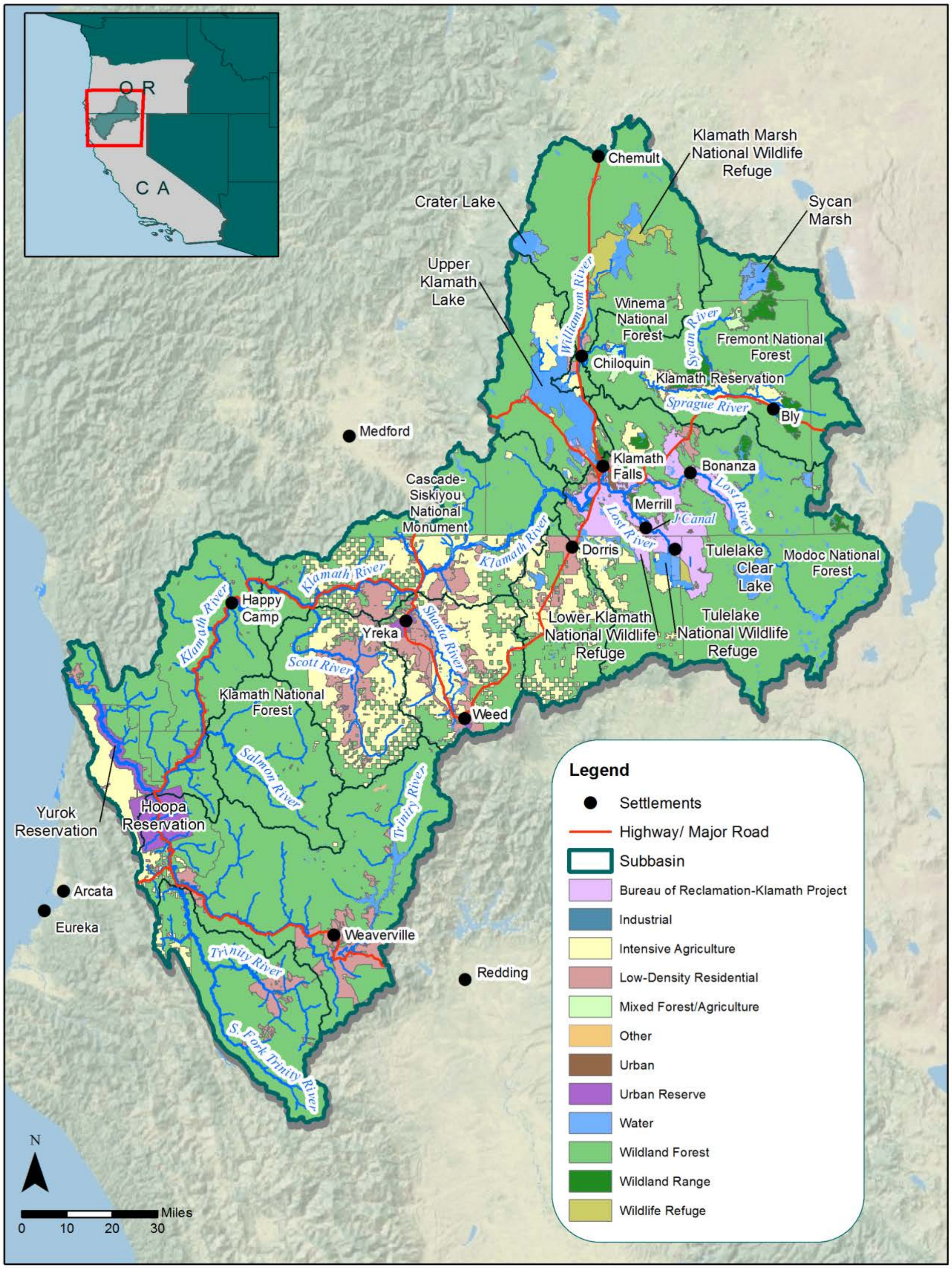



Figure 2-3: Klamath Basin major land uses. Sources: USGS 1999; USGS 2005; California Resources Agency 2004; USGS 2010; USFS 2014.

## 2.4 Sub-basin Profiles

This section provides separate profiles for each sub-basin identified in Figure 2-1. These profiles are intended as a quick reference guide for major features unique to each sub-basin and include the following information:

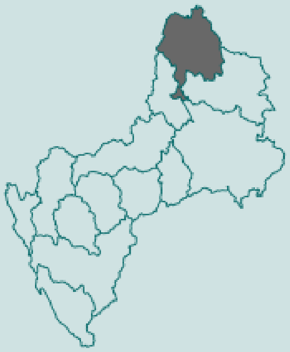
- Area
- Counties
- Settlements
- Land Use
- Land Cover
- Threatened Fish
- TMDLs Established (TMDL = Total Maximum Daily Loads – see box below)
- Other Stressors
- Unique Characteristics
- Environmental Plans

Data for the sub-basin profiles are synthesized from a variety of sources including: Shasta River CRMPC 1997; Voight and Gale 1998; ODEQ 2002; Committee on Endangered and Threatened Fishes in the Klamath River Basin 2008; Thorsteinson et al. 2011; USBR 2012a,b; PacifiCorp 2013; USFWS 2014; NMFS 2015; KTWQC 2016; Royer & Stubblefield 2016; ODEQ 2017; Trinity River Restoration Program n.d.; TNC n.d.; EPA n.d.; USGS n.d.; USGS n.d.; USDA-NRCS n.d.; OWEB n.d.

### Box 2-1: Note on "303(d) list" and Total Maximum Daily Loads (TMDLs)

The US federal Clean Water Act of 1972 is the primary law governing water pollution nationwide. Section 303(d) of the Act requires states to identify waters where current pollution control technologies alone cannot meet the water quality standards for that water body. These water bodies are placed on the list of impaired surface waters, also known as the 303(d) List. States submit their list for approval by the U.S. Environmental Protection Agency (USEPA) every two years (in some cases, the USEPA can also list waters independently). Placement on the 303(d) List generally triggers development of a pollution control plan called a Total Maximum Daily Load (TMDL). TMDL is the maximum amount of a pollutant a water body can contain while still achieving water quality standards. TMDL targets are set for each listed pollutant and can include dissolved oxygen, pH, turbidity, stream temperature, invasive species, microcystin, ammonia toxicity, chlorophyll-a, nutrient load, algae and bacteria. Once data and information reflect that a water body is meeting water quality standards it can be considered for removal from the 303(d) List.

In the Klamath Basin, the California North Coast Regional Water Quality Control Board (NCRWQCB) and the Oregon Department of Environmental Quality (ODEQ) are the lead agencies responsible for adopting TMDLs and establishing targets. Major plans governing the implementation of TMDL objectives in California include the NCRWQCB's Action Plan for the Klamath River TMDLs Addressing Temperature, Dissolved Oxygen, Nutrient, and Microcystin Impairments in the Klamath River in California and Lost River Implementation Plan (2010), Action Plan for the Scott River Sediment and Temperature TMDLs (2006), and the Action Plan for the Shasta River Watershed Temperature and Dissolved Oxygen TMDLs (2006). Plans governing TMDL implementation in Oregon include ODEQ's *Upper Klamath and Lost River Subbasins TMDL and Water Quality Management Plan (2017)*, and *Upper Klamath Lake Drainage Total Maximum Daily Load and Water Quality Management Plan (2002)*. The California plans address TMDLs for sediment and stream temperature in the Scott River sub-basin, stream temperature and dissolved oxygen in the Shasta River sub-basin, temperature, dissolved oxygen, nutrient, organic matter, and microcystin in Lower Klamath River, Mid Klamath River and Upper Klamath River sub-basins, and nutrient and biochemical oxygen demand in the Lost River sub-basin. The Oregon plans address TMDLs for dissolved oxygen and pH in the Sprague sub-basin, nutrient load, stream temperature, pH, and chlorophyll-a in the Williamson, and Upper Klamath Lake sub-basins, and stream temperature, pH, ammonia, chlorophyll-a, and dissolved oxygen in Upper Klamath River and Lost River sub-basins.



# WILLIAMSON

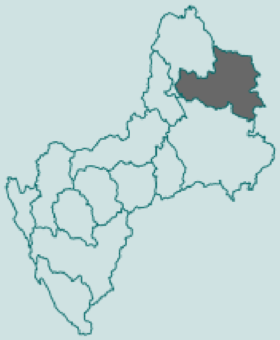
| | |
|---|---|
| **Area** | 1,420 sq mi / 3,678 $km^2$ |
| **Counties** | Douglas; Klamath; Lake |
| **Settlements** | Chiloquin; Chemult |
| **Land Use** | public & private forestry; protected areas; agriculture & livestock grazing |
| **Land Cover** | forest; shrubland/grassland; hay/pastureland; water/wetlands; rangeland; relatively flat terrain |
| **Threatened Fish** | Lost river sucker; shortnose sucker; bull trout; redband trout |
| **TMDLs Established** | high stream temperature |
| **Other Stressors** | degraded habitat due to land use; increased phosphorous loading; invasive species (e.g., brook trout); streambank erosion; noxious weeds; poor grazing practices |

## Unique Characteristics:

- Williamson River tends to have relatively low stream temperatures, high dissolved $O_2$, and optimal pH upstream of its confluence with Sprague River
- Largest tributary to Upper Klamath Lake (50% of inflow, the majority from the Sprague River)
- Crater Lake National Park (CLNP)
- Williamson River Delta on northeast shores of Upper Klamath Lake
- Large restoration project in Williamson River Delta by The Nature Conservancy to aid in sucker recovery and re-introduce connectivity between the Delta, Upper Klamath Lake and Agency Lake
- Klamath Marsh National Wildlife Refuge
- Winema & Deschuttes National Forest
- Wood River and Wood River Wetland restoration projects (Bureau of Land Management)

## Environmental Plans:

- Klamath Tribes Wetland and Aquatic Resources Program Plan
- Klamath Tribal Water Quality Consortium Upper Klamath Basin Nonpoint Source Pollution Assessment and Management Program Plan
- Winema and Deschuttes National Forest Land and Resource Management Plans
- USDA & BLM Water Quality Restoration Plan for the Upper Klamath Basin
- ODEQ Upper Klamath Lake Drainage Total Maximum Daily Load (TMDL) and Water Quality Management Plan



# SPRAGUE

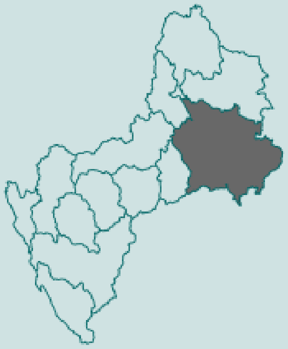
| | |
|---|---|
| **Area** | 1,580 sq mi / 4,092 $km^2$ |
| **Counties** | Klamath; Lake |
| **Settlements** | Beatty; Bly; Klamath Reservation |
| **Land Use** | public & private forestry; agriculture & livestock grazing |
| **Land Cover** | forest; grass/pasture/hayland; rangeland; wetlands |
| **Threatened Fish** | shortnose sucker; Lost River sucker; bull trout; other vulnerable species (not listed): lamprey, redband trout |
| **TMDLs Established** | low dissolved $O_2$, high pH; increased phosphorous loading to the lakes (external loading); high stream temperatures |
| **Other Stressors** | heavy irrigation; cattle ranching; invasive species (e.g., brook trout); streambank erosion; noxious weeds |

## Unique Characteristics:

- Fremont & Winema National Forest
- Broad alluvial valleys along mainstem Sprague & Sycan Rivers
- Largest tributary of Williamson River
- 1914 Chiloquin dam was removed in 2008

## Environmental Plans:

- Klamath Tribes Wetland and Aquatic Resources Program Plan
- Klamath Tribal Water Quality Consortium Upper Klamath Basin Nonpoint Source Pollution Assessment and Management Program Plan
- Fremont and Winema and National Forest Land and Resource Management Plans
- USDA & BLM Water Quality Restoration Plan for the Upper Klamath Basin
- ODEQ Upper Klamath Lake Drainage Total Maximum Daily Load (TMDL) and Water Quality Management Plan



# LOST

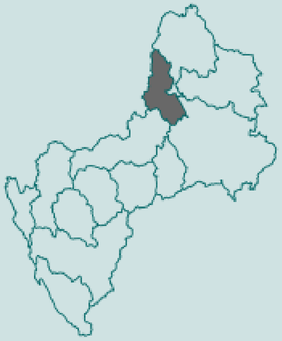
| | |
|---|---|
| **Area** | 3,010 sq mi / 7,795 $km^2$ |
| **Counties** | Modoc; Klamath Lake; Siskiyou |
| **Settlements** | Altamont; Bonanza; Merrill; Malin; Tulelake; Newell |
| **Land Use** | private (almost entirely private land in Lake Ewauna/Keno section); agriculture & livestock grazing; Tule Lake and Lower Klamath National Wildlife Refuges |
| **Land Cover** | canyon and forest (upper Lost); Klamath Project & wildlife refuges (lower Lost); interior lakes and marshes; grain crops; hay/pastureland; rangeland |
| **Threatened Fish** | shortnose sucker; Lost River sucker; bull trout; redband trout; Klamath largescale sucker; blue chub |
| **TMDLs Established** | low dissolved $O_2$, high pH, ammonia toxicity, high stream temperatures; nutrient loading, chlorophyll-a, microcystin; biochemical oxygen demand |
| **Other Stressors** | High nitrogen and biochemical $O_2$ demand; bacteria, algae; channelization & water diversions; dams; wetland drainage; urban development; noxious weeds; soil erosion |

## Unique Characteristics:

- Contains much of the Bureau of Reclamation's Klamath Project (irrigation)
- Three protected wildlife refuges: Clear Lake, Tule Lake, and Lower Klamath
- Klamath River is diverted into the Lost system via A-Canal, Lost River Diversion Channel and smaller canals (e.g., Ady Canal)
- Water may also be returned to Klamath River depending on daily seasonal water needs (e.g., from Klamath to Lost in summer; Lost to Klamath in winter)
- Freemont, Klamath, Modoc and Winema National Forests
- Flow is controlled by Clear Lake and Gerber reservoirs
- Lower Klamath Lake is nearly drained from its original extent

## Environmental Plans:

- Klamath Tribal Water Quality Consortium Upper Klamath Basin Nonpoint Source Pollution Assessment and Management Program Plan
- Fremont, Klamath, Modoc and Winema National Forest Land and Resource Management Plans
- USDA & BLM Water Quality Restoration Plan for the Upper Klamath Basin
- ODEQ Upper Klamath and Lost River Subbasins Total Maximum Daily Load (TMDL) and Water Quality Management Plan



# UPPER KLAMATH LAKE

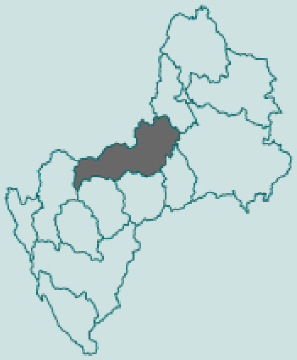
| | |
|---|---|
| **Area** | 724 sq mi / 1,874 km$^2$ |
| **Counties** | Jackson; Klamath |
| **Settlements** | Klamath Falls |
| **Land Use** | public & private forestry; agriculture & livestock grazing |
| **Land Cover** | forest; water/wetlands; grass/pasture/haylands; rangelands |
| **Threatened Fish** | shortnose sucker; Lost River sucker; interior redband trout; bull trout |
| **TMDL Established** | low dissolved $O_2$, high pH from high algal productivity, ammonia toxicity, chlorophyll-a, high stream temperatures, high nutrient loads (~39% of the external load on an annual basis is from anthropogenic sources such as agriculture, livestock, and related erosion; sediment recycling of previously loaded external phosphorus during summer months accounts for 61% of the load entering the lake on an annual basis) |
| **Other Stressors** | conversion of riparian habitat to irrigation for agriculture and livestock; invasive species (e.g., brook trout); soil erosion; overstocking of forestlands |

## Unique Characteristics:

- Contains Klamath Hatchery
- Contains Upper Klamath Lake and Agency Lake
- Annie and Sun Creeks originate in Crater Lake National Park and are major tributaries of Wood River
- Both lakes are listed under CWA 303(d) as hypereutrophic with low dissolved $O_2$ and high pH
- Annual summer bloom of blue-green algae, likely responsible for occasional die-offs of Lost River and shortnose sucker
- Size of Upper Klamath Lake is reduced from historic extent by agricultural draining of surrounding wetlands
- Klamath Irrigation Project diverts water into the Lost River
- Rogue River & Winema National Forests
- Upper Klamath National Wildlife Refuge (marsh and open water on west shores)
- USFWS office in Klamath Falls

## Environmental Plans:

- Klamath Tribes Wetland and Aquatic Resources Program Plan
- Klamath Tribal Water Quality Consortium Upper Klamath Basin Nonpoint Source Pollution Assessment and Management Program Plan
- Fremont, Klamath, Modoc and Winema National Forest Land and Resource Management Plans
- USDA & BLM Water Quality Restoration Plan for the Upper Klamath Basin
- ODEQ Upper Klamath Lake Drainage Total Maximum Daily Load (TMDL) and Water Quality Management Plan (WQMP)
- Klamath Falls Resource Area Management Plan
- Revised Recovery Plan for the Lost River sucker and shortnose sucker



# UPPER KLAMATH RIVER

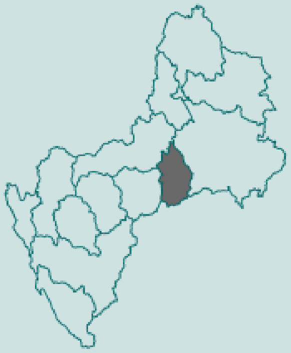
| | |
|---|---|
| **Area** | 1,916 sq mi / 3,670 $km^2$ |
| **Counties** | Jackson; Klamath; Siskiyou |
| **Settlements** | Hornbrook |
| **Land Use** | public & private forestry; BLM (federal); livestock grazing |
| **Land Cover** | forest, grass/hay/pastureland; shrub/rangeland |
| **Threatened Fish** | coho salmon; shortnose sucker; Lost River sucker; Bull Trout; redband trout |
| **TMDLs Established** | high microcystin events (from cyanobacteria); chlorophyll-a; mercury, low dissolved $O_2$, high pH; high stream temperatures, organic matter |
| **Other Stressors** | Hydroelectric Project dams/reservoirs have altered flow regime from riverine to more lake-like conditions; summertime hypolimnetic anoxia (in reservoirs) from thermal stratification and microbial decomposition of algae; thermal lag created by dams (cooler in spring, warmer in fall); high nutrient loads increase algal growth/decay; *M. aeruginosa* (Copco/Iron Gate reservoirs); increased sediment load from land use (e.g., forestry, roads); algae; periphyton; adverse hatchery effects; degraded riparian forest; increased disease/predation/competition; barriers (e.g., dry areas); impaired estuary/mainstem function; increased turbidity levels |

## Unique Characteristics:

- Contains Iron Gate Hatchery
- Upper Klamath section contains the majority of dams/reservoirs in the Klamath Basin (J.C. Boyle, Iron Gate, Copco 1)
- Iron Gate Dam blocks salmonid migration from historic range
- High-volume springs downstream of JC Boyle Dam supply cold water to mainstem
- Lack of long-term baseline data on water quality
- Klamath, Rogue River, Winema National Forests
- Cascade-Siskyou National Monument

## Environmental Plans:

- Klamath, Rogue River, Winema National Forest Land and Resource Management Plans
- North Coast Region Water Quality Control Plan
- Upper Klamath and Lost River Subbasins TMDL and Water Quality Management Plan
- Final Recovery Plan for the SONCC ESU of Coho Salmon



# BUTTE

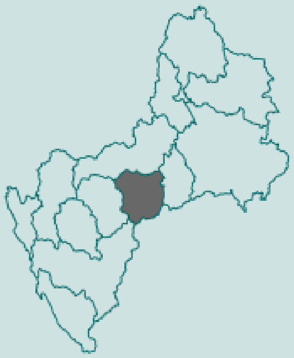
| | |
|---|---|
| **Area** | 600 sq mi / 1,560 km$^2$ |
| **Counties** | Klamath; Siskiyou |
| **Settlements** | Dorris; Macdoel; Mount Hebron |
| **Land Use** | public & private forestry; agriculture & livestock grazing |
| **Land Cover** | forest; agricultural & rangeland; water/wetlands |
| **Threatened Fish** | shortnose sucker; Lost River sucker; Warner sucker; interior redband trout; bull trout; Hutton Springs tui chub; Foskett speckled dace |
| **TMDLs Established** | N/A |
| **Other Stressors** | grazing practices; noxious weeds; groundwater depletion |

## Unique Characteristics:

- Primarily a closed sub-basin, there is no natural surface water connection to the Klamath River
- A drain in Meiss Lake can be used to pump water to the Klamath River to avoid flooding
- Klamath National Forest
- Butte Valley National Grassland
- Butte Valley Wildlife Area
- Large waterfowl populations

## Environmental Plans:

- N/A



# SHASTA

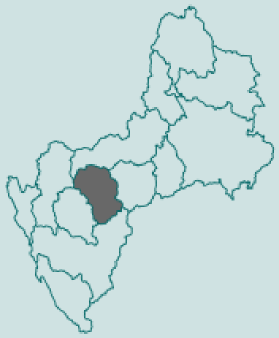
| | |
|---|---|
| **Area** | 795 sq mi / 2,059 $km^2$ |
| **Counties** | Siskiyou |
| **Settlements** | Yreka; Weed; Montague; Grenada; Gazelle; Edgewood |
| **Land Use** | public forestry; tourism; agriculture & livestock |
| **Land Cover** | forest; agriculture & rangeland |
| **Threatened Fish** | coho salmon |
| **TMDLs Established** | high water temperatures; low dissolved $O_2$ |
| **Other Stressors** | agricultural land use; irrigation; reduced stream shade from agriculture and livestock; tailwater return flows; flow modification and diversion; diversion of spring inflow; channel impoundments and alterations; microclimate changes from near-stream vegetation removal; organic enrichment; adverse hatchery effects; degraded riparian forest; increased disease/predation/competition; altered sediment supply; lack of floodplain and channel structure; altered hydrologic function; barriers (e.g., dry areas); impaired estuary/mainstem function |

## Unique Characteristics:

- Shasta Resource Conservation District supports projects to reduce ponding and warm water returns
- Highly managed agricultural region
- Insufficient data to establish baseline water quality trends
- Dwinnell Dam blocks anadromous passage
- Klamath and Shasta-Trinity National Forests
- Wide alluvial valleys in the central portions
- Fractured volcanics drive groundwater hydrology
- Uppermost of the major tributaries in the lower Klamath Basin
- Big Springs Ranch restoration project led by The Nature Conservancy
- Historically supported large populations of Chinook, coho and steelhead
- Cold spring inflows provide critical habitat for anadromous species
- Yreka U.S. Fish and Wildlife Service offices

## Environmental Plans:

- Shasta Watershed Restoration Plan
- Action Plan for the Shasta River Watershed Temperature and Dissolved Oxygen TMDLs
- Final Recovery Plan for the SONCC ESU of Coho Salmon



# SCOTT

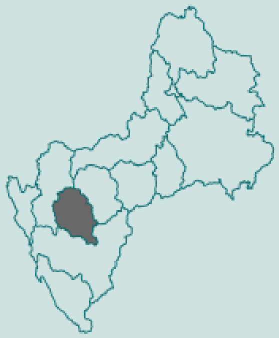
| | |
|---|---|
| **Area** | 813 sq mi / 2,107 $km^2$ |
| **Counties** | Siskiyou |
| **Settlements** | Fort Jones; Greenview; Etna |
| **Land Use** | public forestry; agriculture & livestock |
| **Land Cover** | forest; agriculture & rangeland |
| **Threatened Fish** | coho salmon |
| **TMDLs Established** | high water temperatures; increased sediment loads |
| **Other Stressors** | reduced habitat, filled/buried spawning gravels, reduced macroinvertebrates (food for rearing salmon), decreased channel depth; loss of large woody debris; increased nutrient and bacteria levels from agriculture and livestock grazing; low dissolved $O_2$; high pH; decreased flows, increased algal growth, macroinvertebrate changes, and lowered water table are predicted with climate change; aluminum; degraded riparian forest; increased disease/predation/competition; lack of floodplain and channel structure; altered hydrologic function; impaired estuary/mainstem |

## Unique Characteristics:

- Highly managed agricultural region
- Significant decline of historic salmonid populations
- Significant alteration of the watershed by surface mining
- Klamath & Shasta-Trinity National Forest
- Alluvial aquifer provides groundwater supplies similar to those in the upper Basin
- Second largest tributary of the Klamath River (5% of annual runoff)
- Portions of the river dry up in summer and fall. In some years there is not enough water for fish passage into the canyon
- Scott Valley Community Groundwater Monitoring Program
- East Fork Scott River Off-Channel Habitat Restoration Project
- Wide/flat floodplain that historically featured large areas of wetland (now drained) and beaver ponds
- Low proportion of hatchery origin coho

## Environmental Plans:

- Scott River Restoration Plan
- Quartz Valley Tribal Water Quality Plan
- Action Plan for the Scott River Sediment and Temperature TMDLs
- Final Recovery Plan for the SONCC ESU of Coho Salmon



# SALMON

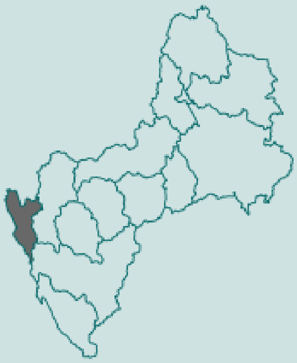
| | |
|---|---|
| **Area** | 750 sq mi / 1,943 $km^2$ |
| **Counties** | Siskiyou |
| **Settlements** | Cecilville; Forks of the Salmon; Sawyers Bar; Somes Bar |
| **Land Use** | USFS (federal) (98.7%); forestry; road construction |
| **Land Cover** | forest; steep, rugged terrain |
| **Threatened Fish** | coho salmon; green sturgeon; Pacific lamprey; spring Chinook; fresh water mussel |
| **TMDLs Established** | high water temperatures |
| **Other Stressors** | high summer stream temperatures (periodic) due to reduced shading from degraded riparian forest; historic disturbance from gold mining in 1850s (diversions, dams, sediment, major changes to channel structure); excessive sediment from forestry and road construction; catastrophic fires (increased erosion/sediment load); algae; bacteria; adverse hatchery effects; increased disease/predation/competition; lack of floodplain and channel structure; impaired estuary/mainstem function |

## Unique Characteristics:

- The most pristine tributary in the Lower Klamath watershed
- Natural unregulated flow with no significant diversions
- Supplies cold water to Klamath River
- 60% of watershed is ancestral Karuk territory
- Hosts the only viable and completely wild spring Chinook run remaining in the Klamath Basin
- Klamath & Six Rivers National Forests
- Supports spawning populations of fall Chinook, spring Chinook, coho, steelhead trout, green sturgeon and Pacific lamprey

## Environmental Plans:

- Salmon River Restoration Plan
- Salmon River Restoration Strategy
- Salmon River Spring Chinook Recovery Plan
- North Coast Region Water Quality Control Plan
- Final Recovery Plan for the SONCC ESU of Coho Salmon



# LOWER KLAMATH RIVER

| | |
|---|---|
| **Area** | 492 sq mi / 1,274 km$^2$ |
| **Counties** | Del Norte; Humboldt |
| **Settlements** | Klamath; Hoopa Reservation; Yurok Reservation |
| **Land Use** | public forestry; agriculture; forestry |
| **Land Cover** | forest; shallow soils; steep slopes; grass/pasture/hayland |
| **Threatened Fish** | coho salmon; green sturgeon, white sturgeon, Pacific lamprey, eulachon |
| **TMDLs Established** | high nutrient load from agriculture and upstream algal blooms; low dissolved $O_2$; microcystin; high stream temperatures, organic matter |
| **Other Stressors** | high pH; ammonia toxicity; high chlorophyll-a (planktonic and periphytic algae); reduced fish habitat (e.g., lack of floodplain and channel structure); altered sediment supply; adverse hatchery effects; degraded riparian forest; increased disease/predation/competition (e.g., *C. shasta* due to ideal host habitat below Iron Gate dam); altered hydrologic function; barriers (e.g., dry areas); impaired estuary/mainstem function |

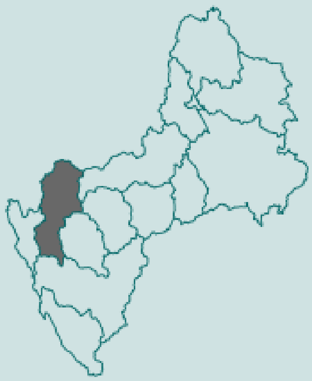
## Unique Characteristics:

- High salmon mortality can occur in this section (see stressors)
- Hoopa Tribal waters overlap with Klamath River mainstem at Satins Rest Bar
- Heavy annual precipitation; rainfall dominant
- Many tributaries are seasonally intermittent
- Highly variable flows, frequent winter floods
- 19 native fish species in Klamath Basin below Iron Gate: 13 are anadromous and 2 are amphidromous (larval stages in saltwater), 4 are resident
- 17 non-native species are present in the lower basin
- Klamath and Six Rivers National Forests

## Environmental Plans:

- Yurok Tribe Lower Klamath Restoration Plan
- Yurok Tribal Water Quality Plan
- Karuk Department of Natural Resources Strategic Plan for Organizational Development
- Resighini Rancheria Tribal Water Quality Plan
- North Coast Region Water Quality Control Plan
- Final Recovery Plan for the SONCC ESU of Coho Salmon

# MID KLAMATH RIVER



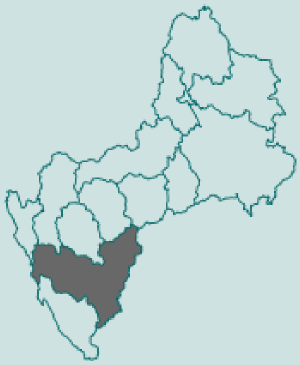
| | |
|---|---|
| **Area** | 1,038 sq mi / 2,688 $km^2$ |
| **Counties** | Siskiyou; Humboldt; Del Norte; Josephine |
| **Settlements** | Happy Camp |
| **Land Use** | agriculture; forestry |
| **Land Cover** | forest; shallow soils; steep slopes |
| **Threatened Fish** | coho salmon; green sturgeon, white sturgeon, Pacific lamprey, eulachon |
| **TMDLs Established** | high nutrient load from agriculture and upstream algal blooms; low dissolved $O_2$; microcystin; high stream temperatures, organic matter |
| **Other Stressors** | high pH; ammonia toxicity; high chlorophyll-a (planktonic and periphytic algae); reduced fish habitat (e.g., lack of floodplain and channel structure); altered sediment supply; adverse hatchery effects degraded riparian forest; increased disease/predation/competition (e.g., *C. shasta* due to ideal host habitat below Iron Gate dam); altered hydrologic function; barriers (e.g., dry areas); impaired estuary/mainstem function |

## Unique Characteristics:

- High salmon mortality can occur in this section (see stressors)
- Heavy annual precipitation; rainfall dominant
- Many tributaries are seasonally intermittent
- Highly variable flows, frequent winter floods
- 19 native fish species in Klamath Basin below Iron Gate: 13 are anadromous and 2 are amphidromous (larval stages in saltwater), 4 are resident
- 17 non-native species are present in the lower basin
- Klamath, Rogue River and Six Rivers National Forests

## Environmental Plans:

- Mid Klamath Sub-basin Resource Recovery Plan
- Karuk Department of Natural Resources Strategic Plan for Organizational Development
- Karuk Tribal Water Quality Plan
- North Coast Region Water Quality Control Plan
- Final Recovery Plan for the SONCC ESU of Coho Salmon



# TRINITY

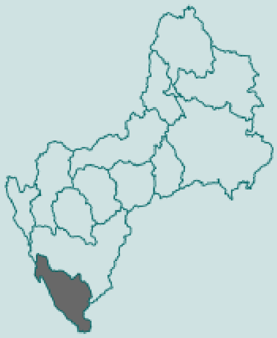
| | |
|---|---|
| **Area** | 2,036 sq mi / 5,274 $km^2$ |
| **Counties** | Shasta; Trinity; Humboldt; Siskiyou |
| **Settlements** | Weaverville; Lewiston; Douglas City; Junction City; Trinity Center; Burnt Ranch; Trinity Village; Willow Creek |
| **Land Use** | Tribal land (Hoopa); public land (wilderness areas, national forests); private land; forestry; mining; road construction; recreation; residential development |
| **Land Cover** | forest; varied terrain; steep/rugged terrain as well as alluvial valleys |
| **Threatened Fish** | coho salmon |
| **TMDLs Established** | N/A |
| **Other Stressors** | impoundment/barriers and diversion; fine sediment loads from historic mining and forestry; adverse hatchery effects; impaired water quality (sediment, mercury); degraded riparian forest; increased disease/predation/competition; lack of floodplain and channel structure; altered hydrologic function; impaired estuary/mainstem function |

## Unique Characteristics:

- Contains Trinity River Hatchery
- Largest tributary of the Klamath River
- Major flow diversion from Trinity River to Sacramento River led to declines in steelhead and salmon
- Wide elevation range from 30ft - 9,000ft
- Contains Trinity Alps Wilderness areas, Shasta-Trinity National Forest, Six Rivers National Forest, Bureau of Land Management and Bureau of Reclamation lands
- Trinity and Lewiston dams
- Diversions to Sacramento Basin
- Habitat degradation has resulted in a severe decline of coho, Chinook and steelhead populations
- Historically highly productive habitat for anadromous fishes
- Trinity River Restoration Program office in Weaverville

## Environmental Plans:

- Trinity River Restoration Program
- Yurok Tribal Water Quality Plan
- Hoopa Valley Tribal Water Quality Plan
- North Coast Region Water Quality Control Plan
- Final Recovery Plan for the SONCC ESU of Coho Salmon



# SOUTH FORK TRINITY

| | |
|---|---|
| **Area** | 930 sq mi / 2,407 km$^2$ |
| **Counties** | Trinity; Humboldt |
| **Settlements** | Hayfork; Hyampom |
| **Land Use** | public land (wilderness areas, national forests) |
| **Land Cover** | forest; steep/rugged terrain |
| **Threatened Fish** | coho salmon |
| **TMDLs Established** | N/A |
| **Other Stressors** | adverse hatchery effects; impaired water quality (sediment); degraded riparian forest; lack of floodplain and channel structure; altered hydrologic function; barriers (e.g., dry areas); impaired estuary/mainstem function |

## Unique Characteristics:

- Largest tributary of Trinity River
- Undammed; Largest unregulated watershed in California
- Punctuated by alluvial reaches
- Hosts a wild spring Chinook salmon population (possibly not as viable as Salmon sub-basin population)

## Environmental Plans:

- North Coast Region Water Quality Control Plan
- Final Recovery Plan for the SONCC ESU of Coho Salmon

### Box 2-2: Spotlight on the Trinity Subbasins

The goal of the Trinity River Restoration Plan (TRRP) is "to restore and sustain natural production of anadromous fish populations downstream of Lewiston Dam to pre-dam levels, to facilitate dependent tribal, commercial, and sport fisheries' full participation in the benefits of restoration via enhanced harvest opportunities" (TRRP and ESSA 2009). The means of achieving this goal is to restore the processes that produce a healthy alluvial river ecosystem, implementing management actions (described below) in a science-based adaptive management program. A case study of the TRRP is provided in Section 8.2 describing the Adaptive Management approach employed to guide monitoring and restoration in the Trinity. In this section we provide a bit more technical detail about the: stressors, management actions, objectives and monitoring approaches employed by the TRRP and potential linkages with the Klamath IFRMP.

TRRP management actions fall into three broad categories:

- increased annual flow regimes and variable reservoir releases;
- fine and coarse sediment management; and
- mainstem channel reconstruction (channel rehabilitation sites).

*(continued on next page)*

## Box 2-2: Spotlight on the Trinity Subbasins (continued)

The Integrated Assessment Plan (IAP)(TRRP & ESSA 2009) identifies 6 major objectives:

- create and maintain spatially complex channel morphology;
- increase/improve habitats for freshwater life stages of 5 anadromous fish;
- restore and maintain natural production of anadromous fish populations;
- restore adult anadromous fish numbers to pre-TRD levels in order to facilitate dependent tribal, commercial, and sport fisheries full participation in the benefits of restoration via enhanced harvest opportunities;
- establish and maintain riparian plant communities that support fish and wildlife; and
- rehabilitate and protect wildlife habitats and maintain or enhance wildlife populations following implementation.

These major objectives provide the organizing framework for the IAP. Within each, there are more specific sub-objectives which lead to specific management actions and monitoring assessments. Over 75 unique assessments were identified in the IAP, which were then prioritized. Some assessments are contingent on the findings from others, some inform multiple objectives, some are important for informing short-term implementation of management activities while others are important for informing long-term progress towards program goals, and others are of higher or lower priority depending on available funding and current understanding of limiting factors. The process for prioritization within and across program objectives is described in the IAP and requires both technical as well as policy input. Detailed summaries of monitoring activities completed on the Trinity River can be found through the online data portal (ODP). Each monitoring activity is linked to one or more of the major objectives identified in the IAP.

Linkages between the TRRP and IFRMP

The Trinity River in its entirety is a large and important component of the Klamath system and therefore the success of any recovery efforts in the Klamath Basin recovery program are dependent on the health of the Trinity sub-basins. Additionally, there are a number of specific linkages between the two Programs. Flow issues within the Klamath Basin are complex and are often driven by management decisions that are influenced by USBR's Klamath Basin Irrigation Project, PacifiCorp's operational flow releases to the Klamath River from Iron Gate Dam, the TRRP's flow schedule for Trinity River flow releases from Lewiston Dam, and USBR's Central Valley Operations. Hatchery and harvest management is intricately related between the two systems. Hatchery and natural stocks are managed through an integrated harvest management process for ocean and in-river fisheries (PFMC). While the Klamath faces some unique challenges associated with dam removal, there are also many areas where the broader Klamath program can benefit from experiences in the Trinity (e.g., adaptive management, overlapping objectives, common monitoring metrics and methods, etc.). Likewise the TRRP will benefit from improved downstream conditions (e.g., lower levels of disease) as the Klamath program progresses (Nichols et al. 2003; True et al. 2010; Bolick et al. 2012).

Synthesis of Science on the Trinity River

Extensive research and monitoring has occurred on the Trinity River over the past several decades. The TRRP website provides frequent updates about current restoration or monitoring activities. Annual reports summarize recent activities and progress towards goals. Additionally, the ODP is a repository for all types of information about the Trinity River including: policy, research, restoration, and monitoring reports as well as data. A few key reports are highlighted here:

- Trinity River Flow Evaluation Final Report (USFWS and HVT 1999);
- Trinity River Draft and Final Environmental Impact Statement/Environmental Impact Report (USFWS et al. 2000);
- Secretarial Record of Decision (ROD) (USDI 2000);
- Conceptual models and hypotheses for the Trinity River Restoration Program (TRRP 2009a);
- Integrated Assessment Plan (TRRP and ESSA 2009); and
- Review of the Trinity River Restoration Program following Phase 1, with emphasis on the Program's rehabilitation strategy (Buffington et al. 2014).

# 3 Historical Context & Stressors Affecting Focal Fish Species

This section provides a concise overview of the range of stressors in the environment to which focal fish species of the Klamath Basin are exposed.

## 3.1 Simple Organizing Framework

We use a simple organizing structure (Figure 3-1) in this Synthesis Report to review the effects of historical stressors on key processes in the Klamath Basin. The organizing framework mirrors one developed for evaluating watershed inputs and processes in the Sacramento River (Stillwater Sciences 2007) and is intended as a coarse integration of all the elements of the basin aquatic ecosystem (i.e., watershed, mainstem, tributaries) within a descending hierarchy of linked system processes. More detailed, sub-basin specific submodels may be added to this organizing framework in the future as part of the development of the IFRMP. Within the general framework presented here, various watershed inputs (e.g., water, sediment, large woody debris, nutrients) are considered to drive fluvial geomorphic processes (e.g., sediment transport/deposition/scour, channel migration, bank erosion, floodplain development, surface and groundwater interaction) that will determine physical geomorphic attributes and the structure and complexity of habitats in the basin. Habitat structure, quantity and quality (e.g., instream aquatic habitats, riparian habitat, wetlands, water quality, contaminants, migration barriers, etc.) will in turn drive biological responses and are important determinants of fish abundance, distribution, and community composition. Stressors on any of the key inputs or processes at different levels of the hierarchy could consequently affect fish populations either directly or indirectly. For example, stressors could act directly on fish populations (e.g., a disease that kills fish, etc.) or impacts from particular stressors could be indirect, with effects on biological responses cascading down from higher levels in the hierarchy. Even where stresses can act directly on fish populations (i.e., at the biological response level), it is likely that the degree of response will be affected by the condition of processes/attributes at the higher levels. Different stressors could also potentially act at multiple levels in the hierarchy. In addition to monitoring of biological responses, associated monitoring should be developed to assess the status of various stressors and system processes at each level of the hierarchy. Similarly (as illustrated in Figure 3-1), restoration actions should be targeted to address key stressors identified at different levels of the hierarchy.

The conceptual organizing framework for the synthesis step of Plan development is holistic in considering stressors and interactions amongst watershed inputs, water quality, fluvial geomorphic processes, physical habitat and biological responses. In our experience, every decision support exercise must include assumptions about what will be included and excluded to keep the effort tractable. This involves seeking a balance of indicators and representative species for evaluation given the state of scientific knowledge, the types of decisions the effort is meant to support, and budgetary resources.

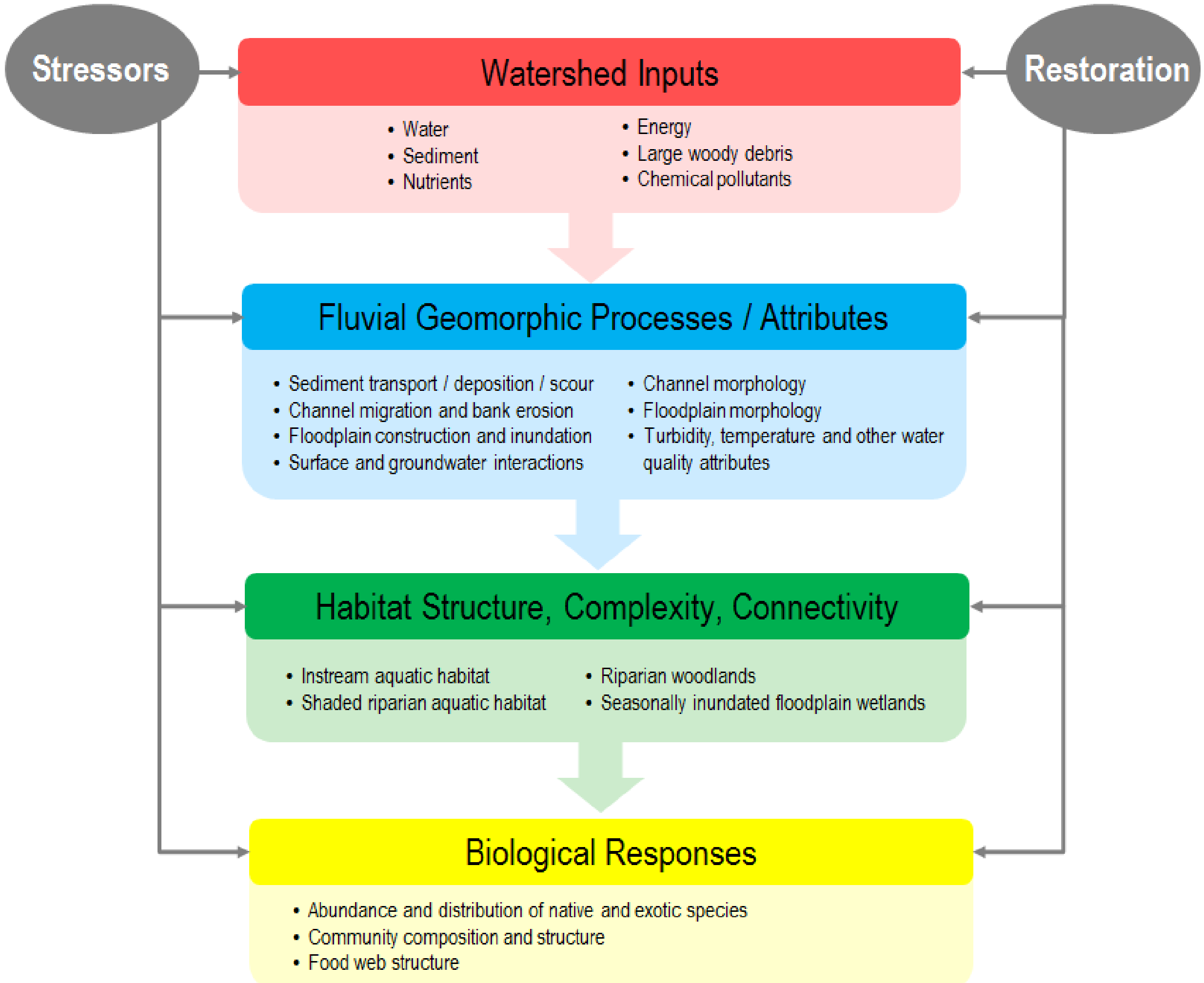



Figure 3-1: Simple organizing framework used within this Synthesis Report. The figure illustrates the linkages between watershed inputs, fluvial geomorphic processes and attributes, habitat conditions, and the responses of aquatic biota within the Klamath Basin. Cause-effect linkages cascade from the top of the figure to the bottom, with stressors acting either indirectly or directly on the yellow box at the bottom representing aquatic biota. Identification of key stressors that may be acting at different levels in the hierarchy also provides the foundation for designing restoration actions to remove, mitigate or compensate for these effects.

## 3.2 Changes in Flow Regime & Watershed Inputs

This section provides a general description of the effects of past human disturbances in the Klamath Basin on key watershed inputs and natural flow regimes as depicted at the top of Figure 3-1. We summarize historic and contemporary water management throughout the basin, riparian and floodplain function and changes over time, the role of nutrients and contaminants, sediment supply and transport, and the anticipated effects of climate change on the Klamath Basin. We provide a more detailed discussion of changes to watershed inputs affecting fish species in Section 4, which describes each of the focal fish species.

### 3.2.1 Water Management

River flows are both a key watershed input and a key source of energy. Flows also transplant other key watershed inputs (e.g., sediment, large woody debris) and create and maintain aquatic, floodplain, and riparian habitats. The water resources of the Klamath Basin have been the focus of intense human development dating back to the late 1800s and early 1900s (USDI, USDC, NMFS 2013), with the basin now extensively modified by levees, dikes, dams, and the draining of natural water bodies. Major development in the upper Klamath Basin that affected flow patterns began after Congress authorized USBR's Klamath Project in 1905. Diversion of irrigation water through A Canal began as early as 1907, but it was not until Link River Dam was completed in 1921 that larger water diversions began (USDI, USDC, NMFS 2013). In addition to USBR's Klamath Project, there are many other smaller irrigation districts and individual operations in the upper Klamath Basin (often referred to as "off project users") that have combined acreage of farmland similar to the 235,000 acres served by the Klamath Project. These smaller irrigation operations also affect flow patterns in the upper basin and downstream of Iron Gate Dam (USDI, USDC, NMFS 2013). Irrigated agriculture and ranching in the upper basin includes hundreds of thousands of former wetlands and lakes that were drained and converted to farming and ranching operations. Water diversions in the Klamath Basin have drained 75 percent of the original wetlands and reduced the total annual flow of the river and its major tributaries (NRC 2004).

These modifications have allowed for distinct differences in land uses within the Klamath's upper and lower basins. A large portion of the upper basin is used for agriculture and rangeland, whereas forest land dominates in the lower basin, except for the Scott and Shasta sub-basins (which also have large portions of area in agriculture and rangeland) (NRC 2008). Human settlement and resource exploitation have created hydrologic alterations that include changes in runoff from timber harvest, other changes in vegetative cover and land use, diversions and storage for agriculture and hydroelectric production, diking of formerly flooded lands, and cut-off of historical flood overflow into Lower Klamath Lake (NRC 2008). Alterations of the original hydrologic system began in the late 1800s, accelerated in the early 1900s, and continue today (USFWS 2013a,c). These alterations include water-control works by private land and water owners, by the large and intricate USBR Klamath Irrigation Project (initiated in 1905 to improve the region's ability to support agriculture), and by the PacifiCorp dams (NRC 2008). As described in Section 1, there are six dams on the river mainstem in the upper Klamath Basin, listed below in order downstream from Klamath Lake together with the date that they became operational in brackets (NRC 2008; USFWS 2013a,c; USDI, USDC, NMFS 2013):

- Link River (1921)
- Keno (1965)
- J.C. Boyle (1958)
- Copco 1 (1918)

- Copco 2 (1925)
- Iron Gate (1962)

Link River Dam regulates the lake levels of Upper Klamath Lake., while Keno Dam regulates water in the Keno Reservoir. Both Link River and Keno dams are relatively small and have fish passage facilities. The four larger dams generate hydroelectric power (NRC 2008), with the stretch of river from the beginning of the J.C. Boyle Reservoir to Iron Gate Dam known as the Hydroelectric Reach (USDI, USDC, NMFS 2013).

Other than slightly increasing evapotranspiration (Asarian et al. 2009), the four hydroelectric dams do not affect annual volumetric water supply or availability to the Klamath River and Upper Klamath Lake (USBR 2011), although management of water released through the dams does affect flow timing and magnitudes of peak releases. Reclamation operations in this regard are directed by provisions in the 2013 BiOp to prevent jeopardy of ESA listed species. The volume of water available to fish species throughout the basin is affected primarily by USBR's Klamath Project water deliveries to upper basin water users. Even with potential future dam removal, these water deliveries are expected to continue. Potential impairments to fish species of concern resulting from insufficient elevations in Upper Klamath Lake, insufficient flow in the mainstem Klamath River, and impaired water quality will persist unless actions are taken to reduce the impacts of water deliveries.

In 2005, USBR conducted an assessment to determine the natural flow of the Upper Klamath River, which included the entire upper Klamath Basin south to Keno, Oregon and the area south of Lower Klamath Lake. The study used a water budget approach to estimate the effects of agricultural withdrawals on natural flows within the study area and estimated what monthly natural inflows would be without agricultural development (USBR 2005). Results indicated simulated monthly flows at Keno would be substantially higher than the contemporary minimum flow thresholds allowable much further downstream at Iron Gate Dam without agricultural withdrawals, even during periods of drought (90% exceedance) (USBR 2005). For example, during the month of August, when the minimum flows at Iron Gate Dam are presently required to be a minimum of 900 cfs (NMFS and USFWS 2013), a natural flow condition would have resulted in an estimated flow of 1,684 cfs at a 90% exceedance condition (USBR 2005), a difference of 53%.

Traditionally, the natural hydrograph of the Klamath River and its tributaries displayed a spring pulse followed by recession to a base flow condition by late summer (NRC 2004). Operation of dams has resulted in significant changes in these natural flow patterns while at the same time blocking upstream access to salmon and other migratory species, and trapping cobbles and gravels essential to maintaining downstream channel geomorphology and spawning habitats (USFWS 2013a,c). Reaches of the Klamath River below J.C. Boyle Dam experience substantial daily fluctuations in response to operating rules for generating electrical power to meet peak demand periods. Flows above J.C. Boyle change more gradually (NRC 2008).

The Klamath Dam Removal Overview for the Secretary of the Interior (USDI, USDC, NMFS 2013) defined three distinct periods (described below) of contrasting hydrologic conditions in the Klamath Basin over the past century: (1) pre-1913; (2) 1961-2000; and (3) 2008-2010. Klamath

Basin hydrology within each of these defined time periods, as well as subsequent to 2013, is summarized below.

- **Pre-1913 hydrology.** This time period defines the pre-dam era, beginning with the availability of historical U.S. Geological Survey (USGS) discharge data from the Klamath River at Keno (June 1, 1904). Data from 1905 to 1913 provide the best representation of flow conditions in the upper basin under which fish evolved and prior to the construction of major dams or the full development of irrigated agriculture. Hydrographs across water years at Keno in this period indicated flow variability at several scales (annual, seasonal, and daily) with a general pattern of steadily increasing flows during the fall and winter, peaking around April when snowmelt at higher elevations was at a maximum (Figure 3-2). Recession from peak flow was very slow during the spring and summer, not reaching a yearly minimum flow of about 1,000 cfs until September. A large component of flow during the spring and summer months was from groundwater and large wetland complexes, accounting for this slow recession. Daily flow variability was remarkably small in the upper basin, reflecting a hydrologic system dominated by discharge from large groundwater aquifers and wetland complexes.

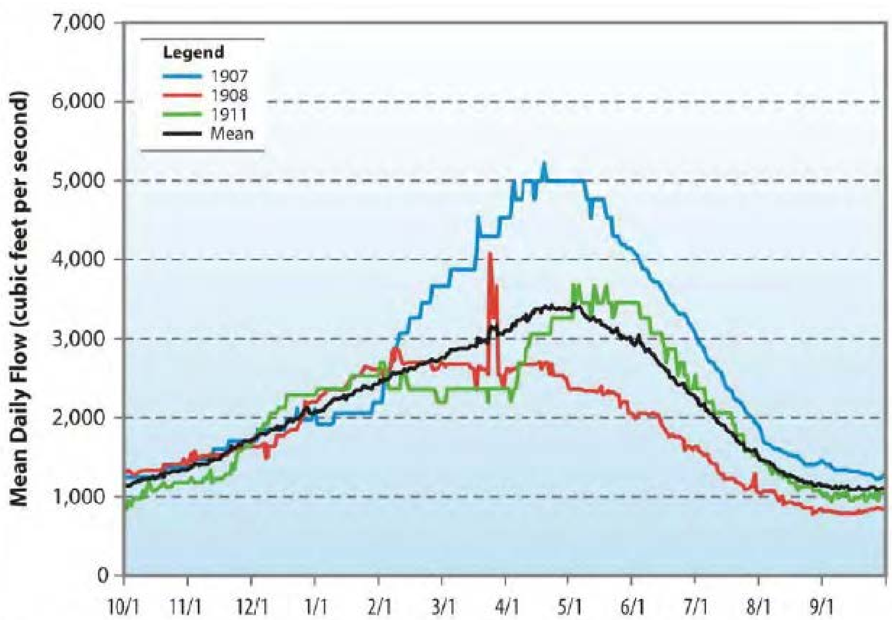



Figure 3-2: Mean daily flow at Klamath River at Keno (USGS gage 11509500) for the period 1905 to 1913 and for three separate water years generally representing drier (1908), average (1911) and wetter (1907) conditions. Figure from USDI, USDC, NMFS 2013.

- **1961 to 2000 hydrology.** This time period characterizes Klamath River hydrology following the completion of Iron Gate Dam in 1962, when proscribed minimum flows below the dam were stipulated by the FERC as part of a long-term license agreement. These minimum flows had a large influence on water use and dam operations in the upper basin, and provided for more stable flow conditions than in earlier decades. However, they also altered the timing of when the lowest flows occurred in the year (typically June and July) and they did not restore other features of a more natural flow regime coming from the upper basin.

Under the FERC requirements, minimum fall flows were slightly increased over what was observed naturally (i.e., prior to 1913) while minimum spring and summer flows were substantially reduced compared to more natural flows.

The development of USBR's Klamath Project and other smaller irrigation districts and individual operators subsequent to 1913 and the associated changes in land and water used in the upper basin also affected hydrologic responses. The changes from natural (pre-1913) conditions included: (1) mean annual flows decreased due to agricultural diversions; (2) annual peak discharges decreased and shifted from late April to mid-March (about a 6-week shift); (3) the recession from the seasonal peak became steeper, reaching yearly minimum flows in July rather than September; and (4) spring and summer flows decreased, owing to agricultural diversions and water storage in Upper Klamath Lake.

The operations of PacifiCorp's four hydroelectric facilities on the Klamath River also affected daily stream flows during this period. None of these dams are operated for flood control or to store irrigation water; all are operated near full pool to maximize hydroelectric production and power peaking. Operations of PacifiCorp's four hydroelectric facilities dampened natural flow variability downstream of Iron Gate Dam, through two different mechanisms. First, tributary inputs into the Hydroelectric Reach were dampened by the presence of the large reservoirs. Second, the flow regime was perturbed by upward and downward adjustments in releases from Link River and Keno dams to create stable flows for hydroelectric power generation and to meet minimum flow requirements at Iron Gate Dam.

- **2008 to 2010 hydrology.** During this time period, minimum flow requirements were established for Klamath River and minimum lake level requirements were established in Upper Klamath Lake. In 2010, NOAA Fisheries published a biological opinion on Reclamation's Klamath Project (NMFS 2010a). This biological opinion established new monthly minimum flow requirements below Iron Gate Dam to protect ESA threatened coho salmon (*Oncorhynchus kisutch*). Additionally, a biological opinion published by the USFWS (2008) on ESA listed suckers (Lost River (*Deltistes luxatus)* and shortnose (*Chasmistes brevirostris*)) established monthly minimum Upper Klamath Lake water elevations. These biological opinions formed the basis of required environmental flows in the Klamath River and Upper Klamath Lake elevations, and attempted to strike a balance between protecting ESA listed fish while maintaining other beneficial uses of water. The NMFS's 2010 biological opinion attempted to restore some critical natural flow patterns important to fish in the Klamath River, such as increasing minimum flows from October through November, and from May through July, and increasing fall and winter flow variability. The NMFS's 2010 biological opinion also included increased spring discharges in certain years (typically average and wetter than average years) to improve habitat quantity and quality for coho salmon in multiple critical mainstem reaches.
- **2013 to present hydrology.** NMFS and USFWS published a joint biological opinion that updates the 2010 biological opinion to account for Upper Klamath Lake elevations that were lower than previously analyzed, in combination with the 2010 NMFS's jeopardy biological opinion (NMFS and USFWS 2013). The 2013 biological opinion used a Water Resource Integrated Modeling System (WRIMS) model to develop a volumetric-based Environmental Water Account (EWA) to be available for release into the Klamath River

between March 1 and September 30 of a given year as well as an Upper Klamath Lake Reserve to establish September 30 storage thresholds in Upper Klamath Lake. The 2013 biological opinion proposed minimum spring/summer Iron Gate Dam target flows (Table 3-1) as well as Upper Klamath Lake September 30 elevation targets (Table 3-2). The minimum elevation target for Upper Klamath Lake at the end of September is 4,138.10 ft. (1,261.29 m) (NMFS and USFWS 2013). The minimum flows targeted for Iron Gate Dam are similar to but not identical with the minimum flows established in the 2010 NMFS biological opinion. For example, spring flows during the month of March and November were reduced by 275 cfs and 300 cfs respectively, while summer flows in July increased by almost 100 cfs. During most other months, minimum flows remained nearly unchanged. Target minimum flows for fall/winter operations are also established (Table 3-1). The 2013 biological opinion did result in an increase of minimum flow targets at Iron Gate Dam for any month managed under the EWA.

Table 3-1: Target monthly Iron Gate Dam minimum releases. Table adapted from NMFS and USFWS 2013.

| Month | Iron Gate Dam Average Daily Minimum Target Flows cfs ($m^3$/sec) |
|---|---|
| March | 1,000 (28.3) |
| April | 1,325 (37.5) |
| May | 1,175 (33.3) |
| June | 1,025 (29.0) |
| July | 900 (25.5) |
| August | 900 (25.5) |
| September | 1,000 (28.3) |
| October | 1,000 cfs (28.3) |
| November | 1,000 cfs (28.3) |
| December | 950 (26.9) |
| January | 950 (26.9) |
| February | 950 (26.9) |

Table 3-2: Target end of September Upper Klamath Lake elevation targets. Table from NMFS and USFWS 2013.

| March50 Volume (acre-feet) | End of September Elevation Modeling Objectives ft. (m) |
|---|---|
| 210,000 | 4,138.10 (1,261.29) |
| 310,000 | 4,138.10(1,261.29) |
| 620,000 | 4,138.20 (1,261.32) |
| 830,000 | 4,138.35 (1,261.37) |
| 1,030,000 | 4,138.54 (1,261.43) |
| **≥ 1,240,000** | 4,138.75 (1,261.49) |

The EWA is managed by an Environmental Water Account Manager, to be an employee of USBR. The 2013 biological opinion describes the establishment of a multi-agency Flow Account Scheduling Technical Advisory team, which was to meet and establish flow management methodology and guidelines subsequent to the release of the biological opinion (NMFS and USFWS 2013). In February of 2017, a Court Order (Case 3:16-cv-04294-WHO) was issued, requiring BOR to reconsult with NFMS and USFWS for the Klamath Project. Until consultation is completed, BOR is required to adjust Project water and operations to allow for: 1) winter-spring flushing flows designed to flush out polychaete worms that host *C. Shasta,* and 2) emergency dilution flows released downstream of Iron Gate Dam to reduce *C. shasta* infection of Klamath River salmonids. All other parameters of the 2013 Biological Opinion remain in effect.

**Phase II Evaluation of Instream Flow Needs for the Lower Klamath River.** This phase of flow management recommendations involved an independent recommendation of regulatory minimum flows developed by Hardy et al. (2006) (Phase II) that evaluated instream flow needs in the lower Klamath River downstream of Iron Gate Dam. The assessment resulted in the development of minimum monthly flows for specific reaches of the Klamath River downstream of Iron Gate Dam. These minimum monthly flows consider all anadromous species and life stages and are not driven solely by coho salmon, as is the case with the biological opinions issued by NMFS. The instream flow assessment builds upon the output of monthly flows generated by USBR's Natural Flow Study (USBR 2005). Physical habitat in specific reaches of the Klamath River was modeled to estimate salmonid growth and production resulting from the amount and quality of habitat available at specific flow thresholds. Water temperatures, ramping rates, and fish disease were also considered (Hardy et al. 2006).

The resulting instream flow recommendations for a 95% exceedance condition for Upper Klamath Lake inflow (extreme drought condition) are approximately the same as the minimum flows required under the 2013 biological opinion for spring and late summer months, lower than those required in June and July, and notably higher than the minimum flows established for fall and winter months (October through January) (Hardy et al. 2006; NMFS and USFWS 2013) (Table 3-3).

Table 3-3: Comparison of monthly Iron Gate Dam minimum releases established in the 2013 biological opinion (NMFS and USFWS 2013) to the instream flow recommendations for a 95% exceedance condition developed by Hardy et al. (2006) for all salmonid species and life stages.

| Month | 2013 Biological Opinion Iron Gate Dam Average Daily Minimum Target Flows cfs ($m^3$/sec) | 95% Exceedance Instream Flow Recommendations from Hardy et al. 2006 cfs ($m^3$/sec) |
|---|---|---|
| March | 1,000 (28.3) | 1,275 (36.1) |
| April | 1,325 (37.5) | 1,325 (37.5) |
| May | 1,175 (37.5) | 1,175 (37.5) |
| June | 1,025 (29.0) | 1,025(29.0) |
| July | 900 (25.5) | 805 (22.8) |
| August | 900 (25.5) | 880 (24.9) |
| September | 1,000 (28.3) | 970 (27.5) |
| October | 1,000 cfs (28.3) | 1,395 (39.5) |
| November | 1,000 cfs (28.3) | 1,500 (42.5) |
| December | 950 (26.9) | 1,260 (35.7) |
| January | 950 (26.9) | 1,130 (32.0) |
| February | 950 (26.9) | 1,415 (40.1) |

**Water management in tributaries downstream of Iron Gate Dam.** Historic and contemporary changes in flow management in the Scott, Shasta, and Trinity Rivers are important factors in the broader recovery of salmonids throughout the Klamath Basin.

- **Trinity River.** Releases from Lewiston Dam into the Trinity River, which is the largest tributary to the Klamath River downstream of Iron Gate Dam, are governed by the 2000 Record of Decision (ROD) (USDI 2000). ROD flows began in 2005, with increasing flows in the Trinity River also providing benefit to Klamath River salmonids, which are managed as a single stock. Under the ROD, a volumetric allocation of water is managed each year based on water year type by way of a formal flow scheduling process to help restore the Trinity River fishery through an adaptive management process. In part, the flow scheduling process considers ecological objectives in the Klamath River, specifically water temperature criteria in the Klamath River at Weitchpec during specific parts of the year. Flow releases in the Trinity River are also managed to encourage outmigration of salmonids from the Trinity, through the Klamath, and into the ocean. Additionally, since 2010 and in coordination with the TRRP Fall Flow Workgroup, USBR has allocated and released pulse flows in late August followed by sustained base flows through most of September to cool the lower Klamath River and reduce fish disease impacts and avoid a mass fish kill (e.g., USDI 2013). In the spring of 2017 approaches to augmented flows to reduce the likelihood and severity of any fish disease outbreak were formalized in a new Record of Decision (ROD) for the Long –Term Plan to Protect Adult Salmon in the Lower Klamath River signed by USBR to fulfill its commitment to avoiding fish die-off in the lower Klamath River. Under this ROD augmenting flows in the lower Klamath River with water from Trinity Reservoir (via Trinity River) are to be considered under an adaptive management approach when flow of the lower Klamath River is projected to be less than 2,800 cubic feet per second in late summer. The ROD will establish management direction in this regard through 2030 (USBR 2017, webpage).
- **Scott River.** The Scott is an undammed tributary that enters the mid-Klamath River. The flow regime in the Scott River is altered, in particular during late summer and early fall when agricultural diversions are most significant. Decreased flows during this period, in part due to heavy reliance on groundwater (Hathaway 2012; Papadoplos & Associates 2012), decrease habitat availability, raise water temperatures, isolate stream reaches, increase stranding potential and delay spawning access (SRWC 2006). While salmonids in the Scott River are believed to have been historically abundant, current monitoring indicates low population levels for multiple species (e.g., Knechtle et al. 2016, NMFS 2015).
- **Shasta River.** The Shasta is a large tributary that enters the mid-Klamath River; it has significant potential for fishery production. The natural flow regime of the Shasta River is altered, largely as a result of surface and groundwater development associated with agricultural uses (Willis et al. 2013). Reductions in instream flows have reduced habitat availability and quality, elevated water temperatures, and isolated floodplain habitats (Willis et al. 2013). Dwinnel Dam is a channel spanning irrigation dam constructed in 1928 on the mainstem Shasta River. The dam blocks fish access to an estimated 22% of the watershed (Cannon 2011). Due to the 1932 adjudication, the only water that the

Montague Water Conservation District (MWCD) is required to release from the Dwinnel Reservoir at baseflow is for priority water rights downstream (C. Bean, pers. comm.).

The long-term legacy effects of past water and land management activities in the Klamath Basin are considered to have caused significant impacts to flow amount, timing, magnitude, and frequency (both in tributaries and the mainstem) (NRC 2008). While there are some gaps in our understanding of the overall influence of water diversion and damming on flow quantity and pattern (Stanford et al. 2011), the suite of hydrologic alterations throughout the Klamath Basin is considered to have reduced channel-shaping flows, reduced maintenance flows, reduced flows for instream habitats, altered annual seasonal patterns, and reduced base flows (NRC 2008). Additionally, basin water supplies are over-allocated and do not meet all user needs; these challenges have been particularly acute in dry years (USDI/CDFW 2012). Water shortages, combined with the need to provide water to address the needs of ESA-listed species, national wildlife refuges, and farming communities have led to the reduction of irrigation water deliveries to farmers in dry years (USDI/CDFW 2012).

### 3.2.2 Riparian Corridors

Riparian vegetation represents important habitat to terrestrial and aquatic species. Riparian vegetation also stabilizes stream banks and reduces soil erosion, while affecting geomorphic channel processes by increasing hydraulic roughness of streams, by inducing deposition on bars and along channel margins, and by changing the direction of flow (NRC 2008). Degradation or loss of riparian corridors can reduce or eliminate stream shading resulting in increased water temperatures (especially in small tributaries), and can increase delivery of sediment, nutrients or chemicals to stream channels. Associated floodplains (the strip of land that sometimes borders a stream channel and that is normally inundated during seasonal floods, Bridge 2003) can also detain or alter nutrients throughout the system (NRC 2008). Loss of floodplains (see Section 3.3.1) reduces the connectivity between aquatic and floodplain systems, thereby limiting biotic exchanges between the stream channel and the floodplains that can provide additional food and space for aquatic organisms, and reducing or eliminating access to refuge areas from high in-channel velocities (NRC 2008). Floodplain habitats and their connectivity to the aquatic environment have been lost or degraded within areas of the Klamath Basin as a result of ditching and diking to promote drainage and prevent overbank flows (NMFS and USFWS 2013). Water diversions have likely lowered the water table in different areas throughout the basin, also limiting general growth of riparian vegetation (NMFS and USFWS 2013). Timber harvest and associated activities have occurred over large portions of the Klamath Basin, resulting in significant loss of old-growth and late seral second-growth riparian vegetation along streams in forested areas of the basin (NMFS and USFWS 2013). Many stream reaches within the upper Klamath are either lacking riparian forest altogether or lack complex, late seral forest (NMFS and USFWS 2013).

Large woody debris (LWD) from riparian areas that is deposited in river channels is important for storing sediment, halting debris flows, and decreasing downstream peak flows (Stillwater Sciences 2007). LWD alters the longitudinal profile and reduces the local gradient of a stream channel, especially when log dams create slack pools above or plunge pools below them, or when there are sites of sediment accumulation (Swanston 1991). In fish-bearing streams LWD contributes to aquatic habitat complexity, can provide shelter, and in some systems may have local effects on flow thereby creating velocity refugia for migrating or resident fish in the absence of complex bank habitat (Stillwater Sciences 2007). Impacts from reduced LWD supply include poorer spawning habitat quality, loss of pool volume and complexity for adult holding and juvenile rearing, reduced shading, and loss of velocity refugia (NMFS and USFWS 2013). The large mainstem dams present in the Klamath upper basin also stop downstream recruitment of LWD, compounding local losses of LWD in downstream spawning areas and contributing to downstream channel simplification (NMFS and USFWS 2013). Due to downstream channel simplification from channel straightening, levees, and armoring, the LWD that is available along mainstem corridors is highly mobile during high flow events, further decreasing retention of the LWD that does get recruited (NMFS and USFWS 2013). Cumulatively, a legacy of degraded riparian corridors, with resultant increased water temperatures, increased fine sediment delivery, and decreased LWD recruitment, along with the associated loss of interconnected flooplains have led to widespread impacts to stream habitats used by fish in the Klamath Basin.

### 3.2.3 Nutrients and Contaminants

**See Also Box 1-1 – Ecosystem Components Considered by The Integrated Fisheries Restoration and Monitoring Plan and its Relationship to Water Quality**

A legacy of large-scale development of mining, forestry, agriculture and ranching operations in the Klamath Basin has degraded water quality with impacts on fisheries and other resources (NMFS and USFWS 2013). Excessive loading of phosphorus linked to watershed development has been a key factor driving the massive blooms of the nitrogen-fixing cyanobacteria *Aphanizomenon flos-aquae* that dominate Upper Klamath Lake (Walker et al. 2012). Phosphorus enters surface waters in the upper basin both naturally (e.g., from groundwater discharge) and through land-disturbing activities such as farming, grazing, timber harvest, and road building (KTWQC 2016). The historical draining and conversion to farm and pasture land of tens of thousands of acres of former wetlands near Upper Klamath Lake greatly increased the natural loading of phosphorus and nitrogen. Annual cycles of flooding, draining, and agricultural activities associated with grazing and irrigated cropland have oxidized the peaty soils, caused land subsidence, increased erosion and exported large nutrient loads to Upper Klamath Lake and the downstream river for nearly a century (Carpenter et al. 2009; Snyder and Morace 1997, as cited in USDI, USDC, NMFS 2013; Walker et al. 2012). These human activities are considered the main causes for the increased erosion and loading of nutrients (particularly phosphorus) from the watershed that are generally contemporaneous with a change in Upper Klamath Lake's trophic state and shift to dominance by large blooms of blue-green algae (ODEQ 2002, as cited in Walker et al. 2012). Inputs of nutrients from these sources cause seasonal cyanobacteria blooms that have been linked to degradation of water quality (e.g., low dissolved oxygen, high pH, and toxic levels of un-ionized ammonia) in Upper Klamath Lake and the Klamath River (Walker et al. 2012, USDI, USDC, NMFS 2013). Degraded water quality been linked to general impacts to fish health in Upper Klamath Lake (Kann and Smith 1999) and specifically to large die-offs and redistribution of endangered sucker species (Perkins et al. 2000a,b, Kann and Welch 2005, and Banish et al. 2009, as cited in Walker et al. 2012).

Upper Klamath Lake was considered eutrophic prior to settlement by Anglo-Americans, but is now classified as being hypereutrophic (highly enriched) due in large part to human manipulations (KTWQC 2016). Paleolimnological evidence indicates that *Aphanizomenon flos-aquae* blooms (as indicated by *Aphanizomenon flos-aquae* akinetes preserved in lake sediments) did not appear in Upper Klamath Lake until the latter part of the 19$^{th}$ century and increased substantially after that time (Bradbury et al. 2004 and Eilers et al. 2004, as cited in Walker et al. 2012). Figure 3-3 illustrates nutrient loading processes in Upper Klamath Lake. Ciotti et al. (2010) and Walker et al. (2015) clearly document the relationship of land use to high nutrient loading in the Sprague and Wood River valleys, with downstream effects on Upper Klamath Lake water quality. Agriculture discharges contribute directly to adverse water quality in Upper Klamath Lake and basin reservoirs, with basin TMDLs (Total Maximum Daily Loads, see section 2.4) identifying waste load allocations attributed to agriculture for dissolved oxygen, pH, ammonia toxicity, and chlorophyll-a (ODEQ 2017). Inputs of fertilizer, herbicides, and insecticides within agriculture runoff have also contributed to impaired water quality (USFWS 2013a-c). Based upon analysis of extensive water quality monitoring datasets and mathematical modeling of the lake phosphorus, algal bloom, and pH dynamics, the Oregon Department of Environmental Quality (ODEQ) determined that reduction of phosphorus loads from anthropogenic sources would be the most effective means of improving water quality conditions in Upper Klamath Lake (ODEQ 2002, as cited in Walker et al. 2012). This management strategy of reducing excessive phosphorus loads to achieve water quality standards in the upper Klamath Basin is consistent with several reviews of nutrient control concluding that reduction of phosphorus inputs (rather than nitrogen) is the most effective means to reduce eutrophication (Schindler et al. 2008, Carpenter 2008, and Smith and Schindler 2009, as cited in Walker et al. 2012).

Ecosystem improvement efforts such as wetland restoration and other watershed management activities in the upper Klamath Basin are implemented regularly to reduce nutrient loading to the lake due to development and land management (Walker et al. 2012). In 2002, the ODEQ established a TMDL that set allowable limits on the amount of phosphorus entering the Upper Klamath Lake drainage from external sources as a means to reduce the frequency, magnitude, and extent of algal blooms and thereby improve water quality (ODEQ 2002, as cited in Wherry et al. 2015). The model developed by ODEQ (2002) predicts that adherence to TMDL limits should generate a long-term reduction in total phosphorus and chlorophyll-a in the lake. Recent supporting analyses and modeling by USGS (Wood et al. 2013; Wherry et al. 2015) have refined the understanding of nutrient dynamics in Upper Klamath Lake (particularly in regard to the rate of internal loading/cycling of phosphorus from sediments). This new modeling indicates additional promise for returning Upper Klamath Lake to a healthy state as external phosphorus loading is further reduced; implementing the suggested TMDL model refinements should help to generate further improvements in water quality in Upper Klamath Lake and downstream in the basin (Wherry et al. 2015).

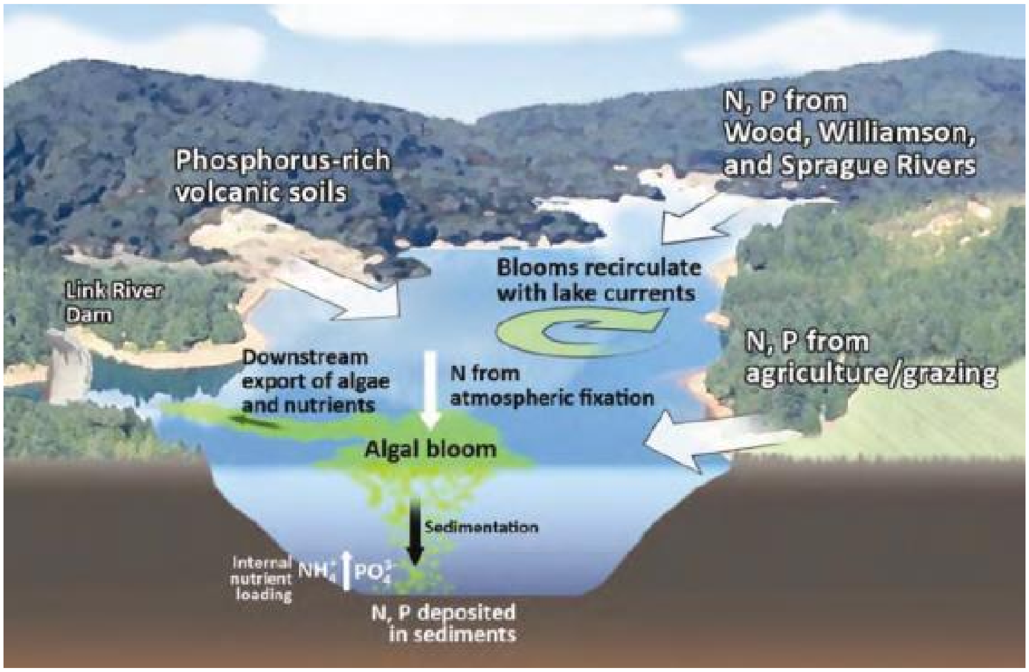



Figure 3-3: Schematic of general nutrient inputs, internal loading, and algal growth in Upper Klamath Lake. Figure from USDI, USDC, NMFS 2013.

PacifiCorp's large reservoirs in the upper basin act as net nutrient sinks (Asarian et al. 2009) and also negatively affect Klamath Basin water quality (USDI, USDC, NMFS 2013). For example, large blooms of *Microcystis aeruginosa* cyanobacteria regularly occur during summer months in the downstream reservoirs Copco 1 and Iron Gate (Asarian and Kann 2011). These blooms of cyanobacteria have been documented as the cause of harmful concentrations of the algae toxin microcystin, both in the reservoirs and in the Klamath River downstream of Iron Gate Dam (USDI, USDC, NMFS 2013; Otten et al. 2015; Gillett et al. 2016). Although dense *Microcystis* blooms and associated toxins originate in the lacustrine waters of the Copco and Iron Gate impoundments, cyanobacterial cells and toxin are transported downstream as far as the Klamath River estuary (Otten et. 2015), leading to public health concerns for the entire middle and lower Klamath River (Genzoli et. al. 2016). Bioaccumulation of microcystin can occur in a variety of Klamath River fish species and other aquatic biota (e.g., freshwater mussels) (multiple studies cited in Genzoli et al. 2015). Temperature modeling (Perry et al. 2011; PacifiCorp 2005 and NCRWQCB 2010a-c, as cited in USDI, USDC, NMFS 2013) indicates that the Copco 1 and Iron Gate reservoirs significantly influence downstream water temperatures in the Klamath River, delaying the natural warming and cooling of riverine water temperatures on a seasonal basis. Spring water temperatures immediately downstream of Iron Gate Dam are generally 1.8-4.5$^{o}$F cooler than would be expected under natural conditions, while late summer/early fall water temperatures are generally 3.6-18$^{o}$F warmer (USDI, USDC, NMFS 2013). This intense reservoir temperature effect diminishes with distance downstream as water temperatures become progressively more influenced by the natural heating and cooling regimes of the surrounding air temperatures and tributary inputs (USDI, USDC, NMFS 2013). By the time water reaches the Salmon River (RM 66) the effects of the reservoirs on water temperature are not discernable (PacifiCorp 2005; NCRWQCB 2010a-c as cited in USDI, USDC, NMFS 2013). Nonetheless, the current temperature regimes in the Klamath River and its tributaries often approach or exceed physiological optima that have been determined for salmon (Thorsteinson et al. 2011).

Water quality dynamics in the middle section of the Klamath River midsection are heavily impacted by the Upper Klamath Lake and downstream reservoirs, resulting in generally low total nitrogen:total phosphorus (TN:TP) ratios (Oliver et al. 2014, as cited in Gillett et al. 2016). These low nitrogen conditions favour the development of nitrogen fixing cyanobacteria (e.g. *Calothrix sp*., *Rivularia sp*.) and benthic diatoms (e.g. *Eipithemia sp*., *Rhopolodia sp*.) in this part of the river (Gillett et al. 2016). Although estimated nutrient concentrations are predicted to increase in the mainstem Klamath River downstream of the dams in the event of dam removal, the resulting effects on downstream algal and macrophyte growth are complex and may vary by reach (Asarian et al. 2010). Increased nitrogen concentrations after dam removal would likely shift N-fixing algae farther downstream (from their current upstream limit of approximately Seiad Valley), and upstream flora could be replaced by non N-fixers (Asarian et al. 2010). The lower Klamath River above the confluence with the Trinity River displays high rates of gross primary production (GPP). Maximum rates of GPP recorded in the Klamath River at Seiad (~22 g O m2 d-1) are among the highest rates of GPP ever reported for streams and rivers (Genzoli et al. 2015). The Klamath River may be unique as a highly productive river in that the water is not exceptionally clear (mean summer light attenuation in 2012 = 0.79 m-1; L. Genzoli, unpublished data, as cited in Genzoli et al. 2015).

The Klamath River and some of its tributaries area listed as a Clean Water Act (CWA) Section 303(d) “impaired” waterways in both California and Oregon. The list of impairments varies by state and river reaches within states but includes water temperature, sedimentation, high pH (only in Oregon reservoirs), organic enrichment, low dissolved oxygen, nutrients, ammonia, chlorophyll-a, and microcystin (NCRWQCB 2010b; USDI, USDC, NMFS 2013). Water quality is a concern in the Klamath Basin because it affects culturally and economically important fisheries as well as public health (Genzoli et al. 2015). Water quality ratings for the Klamath River fail to meet CWA Section 303(d) listings in respect to the following fisheries-related beneficial uses (USDI, USDC, NMFS 2013):

- Cold Freshwater Habitat
- Warm Freshwater Habitat
- Rare, Threatened, or Endangered Species
- Migration of Aquatic Organisms
- Spawning, Reproduction, and/or Early Development
- Estuary Habitat
- Marine Habitat

There are currently nine TMDLs established in the Klamath Basin through the CWA that identify the pollutant load reductions that are required to meet water quality standards (see Section 2.4). TMDLs are basin-wide waterbody specific water quality plans established to protect and restore impaired beneficial uses in the Klamath River and its tributaries. These TMDLs are focused on decreasing summer and fall water temperatures, nutrients, chlorophyll-a, algae toxins and pH, and on increasing summer and fall dissolved oxygen concentrations (USDI, USDC, NMFS 2013). Implementation of the TMDLs is intended to result in improvements to water quality in the basin, but under current conditions in the basin (i.e., with the dams in place) it could potentially take decades to fully attain these TMDLs (ODEQ 2017 and NCRWQCB 2010a-c, as cited in USDI, USDC, NMFS 2013).

### 3.2.4 Sediment Supply

Coarse sediment is a fundamental building block of river systems, providing material for construction of riffles, bars, banks, and floodplains. Coarse sediment within a river is supplied from upstream sources (e.g., hillslopes, tributaries) and then transported and deposited downstream. Natural inputs of coarse sediment have been depleted, and its movement and deposition has been affected historically by multiple geomorphic alterations in the Klamath Basin (NRC 2008). These have included historical mining, floating of logs, building of splash dams to push logs downstream, and blasting rock outcrops in the river bed to improve log passage (NRC 2008). Placer gold mine workings in the basin often included displacing the channel and excavating down to bedrock. These past activities had the effect of simplifying the river channel through the elimination of bedrock and other channel irregularities that interfered with the efficient flow of water and through the physical effect of the logs themselves battering the banks (NRC 2008), resulting in changes to sediment routing. Dredging of gravels on the floodplains also simplified the river channel through direct modification, while mine dredging and processing of placer deposits released fine sediments into the water column, with associated damage to fish habitats (NRC 2008). The negative effects of mining on fish abundance were observed as early as 1930 (NMFS and USFWS 2013a-c). Since the 1970s, however, large-scale commercial mining operations have been eliminated in the basin due to stricter environmental regulations, and in 2009 California suspended all instream mining using suction dredges (NMFS and USFWS 2013a-c).

The mainstem Klamath dams and water diversions have had geomorphic effects on the river, but these effects are less than in river systems with larger dams, greater sediment retention behind these dams, and more alluvial downstream channels (NRC 2008). Some of the larger Klamath hydroelectric dams can however trap coarse sediments, resulting in bed coarsening downstream as smaller gravels are transported out of the area without being replaced by gravels supplied from upstream (PacifiCorp 2004a, as cited in NRC 2008). As a result of such a process, the downstream river bed can become dominated by larger gravels and cobbles unsuitable for use by spawning fish (Kondolf and Mathews 1991). Figure 3-4 illustrates areas of the Klamath mainstem that have become starved of bedload sediment downstream of the larger Iron Gate and Copco reservoirs.

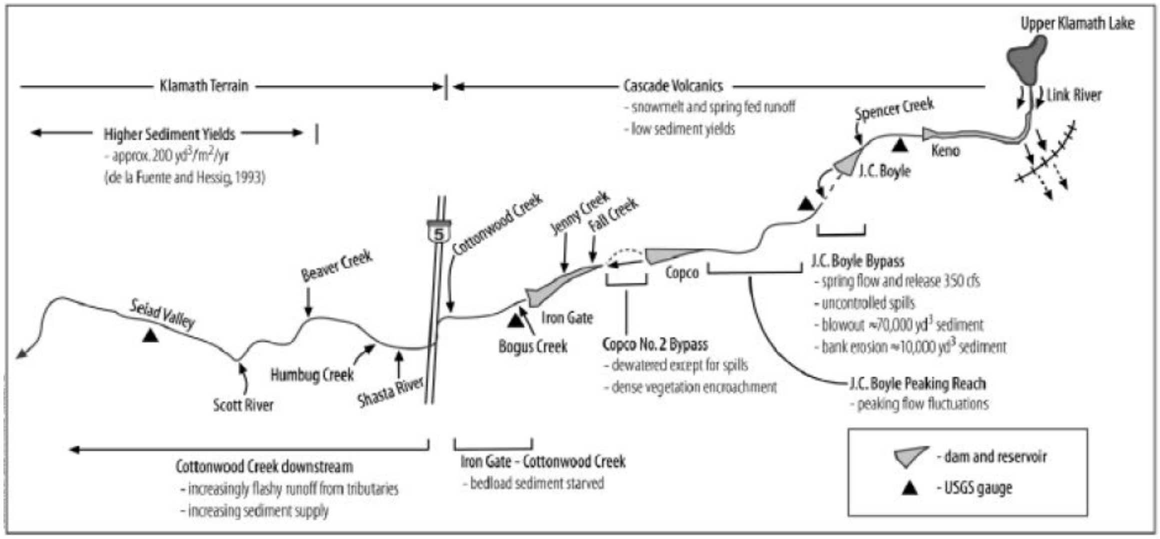



Figure 3-4: Conceptual model of the sediment transport and channel geomorphology in the Klamath River in the reaches affected by PacifiCorp hydroelectric project dams. Figure from Reclamation 2011; original source PacifiCorp 2004a.

Ayres and Associates (1999, as cited by Hetrick et al. 2009) examined the incipient motion (the initiation of motion of the bed material by hydrodynamic forces) for riffles and pools below Iron Gate Dam. Depending on the time of year and distance downstream of Iron Gate, the effects of releases from Iron Gate on sediment mobilization diminish progressively due to significant tributary accretions downstream, with the effects of Iron Gate Dam becoming negligible approximately 18 miles downstream near Cottonwood Creek (USBR 2011).

Most salmon spawning presently occurs between Iron Gate Dam (Bogus Creek) and the Seiad Valley (rkm 214). The USFWS summarized expected increases to sediment mobilization and transport after dam removal (Hetrick et al. 2009). Within much of this key spawning reach, pool flushing flows that scour D50 sized materials would be expected to be exceeded about 65% of the years. Mobilization of sediment finer than very coarse sand (D84) would not be expected to occur during drought years (Ayers and Associates 1999, as cited by Hetrick et al. 2009).

Levels of suspended sediment concentrations are also a concern in the mainstem Klamath River and basin tributaries, especially where fires (NRC 2008) or wide-scale timber harvest has occurred (NMFS and USFWS 2013). High concentrations of fine sediment can fill pools and simplify instream habitats used by fish (NRC 2008). High concentrations of suspended sediment can also disrupt normal feeding behavior by fish, reduce growth rates, and affect survival of juvenile salmonids by interfering with normal development and emergence (Berg and Northcote 1985; Chapman 1988). Sedimentation arising from harvest-related landslides and extensive road networks continues to impact habitat even from modern-day harvesting operations, although at much reduced levels compared to early logging in the Klamath Basin (NMFS and USFWS 2013). Large-scale high intensity fires can also contribute to increased downslope fine sediment deposition into rivers and streams (Moody and Martin 2009; James 2014). Post-fire “salvage logging” (harvest of trees damaged or killed by fire soon after to recover their economic value) can also compound the disturbance and contribute to altered runoff and hydrological patterns (Silins et al. 2008; Wegenbrenner et al. 2015). Currently, concentrations and duration of exposure to fine suspended sediment in the mainstem Klamath can create major physiological stress and reduced growth of coho salmon in most years for certain life stages (NMFS and USFWS 2013). Improved forest practices and management plans have been enacted in the Klamath Basin to combat the severe degradation of fish habitats and reduce impacts to fish caused by historical forest practices. Since adoption of the National Forest Plan (NFP) in 1994, timber harvest and road building on National Forest Service Lands in the Klamath Basin have decreased dramatically and road decommissioning has increased, as part of efforts to recover aquatic habitats adversely affected by legacy timber practices (NMFS and USFWS 2013).

Estimates on the amount of sediment stored behind the four dams vary. An analysis of information previously developed for PacifiCorp estimated 20.4 million cubic yards of sediment is trapped in three of four reservoirs considered for removal and noted that sediments stored behind Copco 2 are negligible (GEC 2006, as cited by Hetrick et al. 2009). USBR (2011) estimated that 15 million cubic yards of sediment will be stored in the reservoirs by 2020, over 80% of which are fine sediments. Dam removal is predicted to release 1/3 to 2/3 of that volume, depending on the water year type immediately following dam removal (USBR 2011). Sediment concentrations are expected to return to background levels by the end of the summer following dam removal (USBR 2011). The bed material within the reservoir footprints is expected to have a high sand content (30% to 50%) and will require a flushing flow of at least 6,000 cfs sustained for several days to weeks before the substrate will return to a cobble and gravel bed (USBR 2011). The rate of geomorphic response to dam removal will depend on the magnitude and duration of high flows the following water year as well as the sequences of high geomorphic-effective flows across multiple future years.

### 3.2.5 Climate Change Effects on Inputs

The 2013 biological opinion (NMFS and USFWS 2013) suggests that in the coming years, climate change will influence the ability to recover some salmon species in most or all of their watersheds. Specific factors of a population or its habitat that could influence its vulnerability to climate change include its reliance on snowpack, current temperature regime (i.e., how close it is to lethal temperatures already), the extent of barriers that block its access to critical habitat and refugia areas, the range of ecological processes that are still intact, and its current life history and genetic diversity (NMFS and USFWS 2013). Climate prediction models for the Pacific Northwest, including Northern California, suggest a wide variety of changes that could affect the Klamath Basin (Thorsteinson et al. 2011; USDI, USDC, NMFS 2013). Predicted basin changes identified in USDI, USDC, NMFS (2013) include:

- increased average air temperature;
- increased number of extreme heat days;
- changes to annual and seasonal precipitation, including diminished snow pack, more winter rain, and lower summer flows;
- increased heavy precipitation events;
- changes to annual and seasonal stream flow and groundwater levels;

- changes in water quality; and
- vegetation changes.

The hydrology of the Pacific Northwest is particularly sensitive to changes in climate because of the role of mountain snowpack on the region's rivers (Woodson et al. 2011). A changing climate affects the balance of precipitation falling as rain and snow and therefore the timing of streamflow over the course of the year (Woodson et al. 2011). While the perception of flow trends can change markedly depending on the selected period of record (NMFS and USFWS 2013) Upper Klamath Lake inflows, particularly base flows, are considered to have generally been in decline over the last thirty years (i.e. trend observed from 1981-2012) (NMFS and USFWS 2013), and inflows to the Sprague and Williamson rivers have also been declining since 1981 (NMFS and USFWS 2013). Inflow to Upper Klamath Lake and flow in the Sprague and Williamson Rivers are strongly dependent on climate, particularly precipitation (Mayer and Naman 2011, as cited in NMFS and USFWS 2013). Between 1970 and 2010, total precipitation for the counties in the upper Klamath Basin decreased by 2 inches (5.08 cm) (USBR 2011, as cited by NMFS and USFWS 2013).While changing patterns of precipitation can explain part of the decline in flows, other factors are likely involved as well, including increasing air temperatures, decreasing snow-water equivalent, increasing evapotranspiration, and increasing surface water diversions or groundwater pumping upstream of Upper Klamath Lake (Mayer and Naman 2011, as cited in NMFS and USFWS 2013; Asarian et al. 2016). Air temperatures in the Klamath Basin have increased by 1.8 to 3.6$^{o}$F over the past 50 years, and water temperatures in some tributaries have also been increasing (Bartholow 2005, Flint and Flint 2012, as cited by NMFS and USFWS 2013).

Air temperatures in the Klamath Basin are predicted to continue to increase, such that by the middle of the 21$^{st}$ century average annual air temperatures in the basin may have increased by about 2 to 4$^{o}$F, and by the end of the century they may have increased by about 4 to 7$^{o}$F (USDI, USDC, NMFS 2013). By the end of the century snowpack in the Klamath Basin is projected to decline to less than 20% of current levels (Woodson et al. 2011). Throughout the Klamath Basin in the coming decade, the snow-water equivalent is expected to decrease. In some parts of the basin there may be as much as a 20 to 100% decrease in snow-water equivalent (USBR 2011, as cited by NMFS and USFWS 2013). Mean annual precipitation in the basin is also projected to change over the coming century, although the uncertainty in these predictions is high, such that model predictions range from an 11 percent reduction in annual precipitation levels to a 24 percent increase (Barr et al. 2010). Predictions of seasonal changes in precipitation in the Klamath Basin are considered more certain, where winter snows will be replaced by winter rains. This is expected to result in earlier and higher winter stream flows during the period from December to March, and lower stream flows during late spring and summer (April-July) (Barr et al. 2010). Projected changes to groundwater hydrology under climate change may also decrease late summer stream flows across the basin, including alterations of the timing and amount of recharge, increases in evapotranspiration, declines in the groundwater table, and increases in pumping demand (USBR 2016b). Increasing air temperatures and decreasing summer flows predicted for the Klamath Basin are expected to cause corresponding increases in water temperatures. Bartholow (2005) predicted that with current conditions (i.e., dams in place) there could be a basin-wide increase in water temperatures of about 0.9$^{o}$F per decade, or 4.5$^{o}$F over the next 50 years. In general, the physical, chemical, and biological properties responsible for controlling the quality of surface waters are likely to be affected by these changing patterns in temperature and precipitation.

Potential environmental implications for the Klamath Basin include extended periods of summer low flows and high stream temperatures, changes in timing of the filling of lakes and reservoirs, and rain on snow events, leading to flooding (Woodson et al. 2011). The effect of seasonal or long-term water deficits will include changes in vegetation, increased forest die-off and faunistic changes (Woodson et al. 2011). Impacts to water quality could include: decreased and fluctuating dissolved oxygen content from more rapid recycling of detritus; increased nutrients, turbidity and organic content from increased runoff; and earlier, longer, and more intense algae blooms due to warmer water temperatures and increased nutrient availability (Barr et al. 2010). These conditions will increase stress on all fishes and most native aquatic animals (Woodson et al. 2011). Higher temperatures could also further impair water quality in the upper basin, affecting growth of resident species and increasing the likelihood of sucker die-offs in Upper Klamath Lake (NMFS and USFWS 2013). Disease incidences in fish will rise, with climate change potentially affecting the severity and distribution of infectious diseases of fish in a variety of ways, including changes in multiple factors that affect disease ecology, such as (Woodson et al. 2011): the growth rate of pathogens; the types or strains of pathogens present; the distribution of carriers and reservoirs; the density or distribution of susceptible species; diets that can alter resistance to disease; the host immune response to disease; stress (increases susceptibility to disease); and physical habitat (water flows, water quality). The period of the year during which cool-water refuges will be needed (for Lost River and shortnose suckers, salmon, steelhead (*Oncorhynchus mykiss irideus*), and resident trout) will increase (Woodson et al. 2011). An expected shorter “wet” season is also likely to alter fish migration timing (e.g., salmon, Lost River and shortnose sucker) and limit the period of the year that important side channel and floodplain habitats are inundated with water (Woodson et al. 2011). These effects are likely to decrease young fish survival, particularly in the Sprague, Lower Klamath, Shasta, Scott, Salmon, and Trinity Rivers (Woodson et al. 2011).

In support of the Secretarial Determination process for evaluating dam removal, USBR (2011) modeled five different climate change scenarios. While each scenario resulted in a different outcome, USBR concluded inflows to Upper Klamath Lake in the later winter and early spring (February to April) will be similar or higher than current flows; however, inflows in May through October will be similar or lower than current flows (USBR 2011). The climate change modeling conducted by USBR did not account for potential changes in agricultural practices or land use resulting from climate change that may impact future Klamath Project water usage.

Warmer winters and longer growing seasons predicted under climate change scenarios may also increase the frequency and intensity of insect pest attacks on Klamath forests and the occurrence and extent of wildfires. Large-scale high intensity "megafires" are expected to increase in occurrence in the Klamath over time as a result of hotter and likely drier conditions in the forest and the consequences of historic (and to an extent, continuing) forest management practices encouraging fire suppression and “plantation-style” high-density stocking. Barr et al. (2010) estimates that by the end of the 21$^{st}$ century the percentage of the Klamath Basin burned annually by wildfires could increase by 11 to 22% compared to current levels. Increased wildfires could trigger future landslides and generate chronic erosion with associated downslope fine sediment impacts on fish habitats (NMFS and USFWS 2013), while also reducing future recruitment of intact LWD to streams. There could also be major shifts in basin vegetation types due to climate-mediated changes in growing conditions (Barr et al. 2010). Coastal redwood and spruce forests could become quite rare or disappear and be replaced by oaks and madrone (Woodson et al. 2011). Plants and animals that currently live in high elevation habitats will decrease in abundance and may die off or be constrained to small refugia (Woodson et al. 2011). Decreased soil moisture and increased evapotranspiration caused by climate change may also result in the loss of wetland and riparian habitats (Barr et al. 2010). Such vegetation-related changes could affect agricultural and grazing practices in the Klamath Basin, requiring additional irrigation and/or pesticide use for maintenance of cropland and livestock (USDI, USDC, NMFS 2013). Management implications to consider related to climate change impacts will include reservoir management, groundwater versus surface water use, agricultural competition, water quality (wildfire, sediment transport, salinity), and declines in both fisheries and species (Woodson et al. 2011).

Table 3-4 highlights some of the major changes to Klamath Basin conditions that may occur during the next century under projected changes in climate (as identified by Barr et al. 2010).

Table 3-4: The range of projected changes to the climate (including air temperature and precipitation) and ecology (dominant vegetation types, fire regime) of the Klamath Basin from three global climate models and a vegetation model. Baseline conditions are based on data from 1961 to 1990. Snowpack projections are based on results from Hayhoe et al. 2004, and Goodstein and Matson 2004. Table from Barr et al. 2010.

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

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

Localized changes within the Klamath Basin, such as timing and intensity of spring freshets, and changes in temperatures and flows, may result from climate change and as a consequence could alter the development and hatching of fish eggs, rate of growth in fry, and timing of emigrational events such as entry to sea. It is thought that these changes could affect various salmonid species differentially in response to the variable freshwater life history strategies that have evolved in Chinook (*Oncorhynchus tshawytscha*), coho, and steelhead (Stanford et al. 2011). In nearshore waters extending offshore across the Continental Shelf, changes in the geographic positioning of Central Valley Low and North Pacific High Pressure Systems may affect wind conditions, storm events, intensity of upwelling, and the amount and quality of habitat available for migrant salmon (Stanford et al. 2011).

Climate change could also significantly impact ocean conditions, which could have broad effects on the survival of anadromous fish populations (most likely negatively, Peterman and Dorner 2012). Marine species will be impacted due to significant changes in ocean conditions which have already begun to occur, decreasing the range of multiple species toward the poles and altering resource distribution (Thorsteinson et al. 2011). Thorsteinson et al. (2011) suggest some Klamath Basin anadromous species such as eulachon (*Thaleichthys pacificus*) may be unable to adapt and are more likely to face extinction as a result of climate change compounded with other factors. It has been hypothesized that the timing and intensity of upwelling events could be beneficial to early marine survival of sub-yearling Chinook from the Klamath and other basins if upwelling occurs later in summer than it does today (Stanford et al. 2011). Conversely, these conditions could have an adverse effect on coho salmon and steelhead in response to a hypothesized earlier entry to ocean and mismatch with coastal habitat conditions (Stanford et al. 2011). Other concerns about climate change for Klamath fish relate to acidification effects on coastal food webs and potential diminishment of useable nearshore habitats associated with changes in circulation, temperature, and occurrence of hypoxia in shelf waters (Stanford et al. 2011).

## 3.3 Changes in Fluvial Geomorphic Processes

Many geomorphic processes at reach and habitat scales are closely linked to hydrology (VanderKooi et al. 2011). The dynamic interaction of a river ecosystem is the interaction of flow, sediment, and riparian vegetation (Trush and McBain 2000). Erosion and mass wasting processes as well as sediment transport and sediment deposition are affected by precipitation, soil saturation, and the flow of surface water and groundwater. Spatial and temporal variability in these geomorphic processes governs patterns of disturbances that influence ecosystem structure and dynamics (VanderKooi et al. 2011). Such geomorphic processes are conspicuous in streams, rivers, and floodplains and drive the formation and evolution of key river features like terraces and alluvial fans at the reach scale and riffles, pools, and cascades at the habitat scale (VanderKooi et al. 2011). While other factors also contribute to the rates and magnitude at which geomorphic processes occur (e.g., local climate, valley width and slope, rock and soil types, upland and riparian vegetation density and types), the volume, duration, and frequency of flow events is critically important (VanderKooi et al. 2011). In the upper Klamath Basin springs and spring complexes also have important influences on stream flow, flood-plain geomorphology and habitat conditions in the basin (O'Connor et al. 2013). For example, spring discharge accounts for more than 60 percent of the annual Sprague River flow near Chiloquin (Gannett et al. 2007). These spring areas, possibly because of modulated water temperatures and stable channel substrate conditions, have been areas of historically high fish use, including redband trout (*O. mykiss newberrii*), sculpin, and suckers (O'Connor et al. 2013).

Sediment transport, deposition, and scour processes regulate the formation of key geomorphic features. The movement of bedload sediment is vital for creating and maintaining functional gravel bars, side channels, pools, riffles and floodplains that provide habitats for fish and support aquatic life (VanderKooi et al. 2011). Coarse sediment in the form of sand, gravels, cobbles, and boulders are naturally delivered to and regularly transported in undammed streams and rivers. Frequent bedload movement is considered essential for creating adult spawning habitats and more complex habitat to support juvenile rearing (USDI, USDC, NMFS 2013). In the Klamath Basin natural flow regimes and associated sediment transport rates in the Hydroelectric Reach and downstream of Iron Gate Dam have, however, been significantly altered (USDI/USBR2011). These alterations have caused long-term depletion of sediments, affecting geomorphic processes and impacting the creation and maintenance of diverse fish habitats in the lower basin (Hamilton et al. 2011). It is widely recognized that rivers regularly require flows sufficient to maintain and shape their channels, to facilitate sediment transport, and to maintain the integrity of aquatic habitats (USFWS and HVT 1999; Bunn and Arthington 2002; NMFS 2010a). Hydrologic alterations throughout the Klamath Basin are considered to have reduced the occurrence of these critical channel shaping flows in the lower basin (NRC 2008).

Trush and McBain (2000) identified 10 attributes of an alluvial river system such as the Klamath River:

- spatially complex channel morphology;
- predictably variable flow and water quality;
- frequently mobilized channel bed;
- periodic channelbed scour and fill;
- balanced fine and coarse sediment budgets;
- periodic channel migration;
- functional floodplains;
- infrequent channel resetting floods;
- self-sustaining diverse riparian plant communities; and
- a naturally fluctuating groundwater table.

As with many dammed river systems, the Klamath River hydroelectric facilities have constrained these alluvial processes. Restoration of these characteristics is a foundational step toward fishery recovery (Trush and McBain 2000).

Occurrence and pervasiveness of fish diseases in the Klamath Basin are also closely linked with sediment transport processes. Flushing flow events are believed necessary to mobilize the bedload within the Klamath River and dislodge or smother polychaete worms that are the intermediate hosts for various fish pathogens (see Section 3.5.1). Flushing flows also decrease the retention of fine sediments associated with the establishment of excessive aquatic vegetation below Iron Gate Dam thereby disrupting microhabitats occupied by polychaete worms, while at the same dispersing the fine organic carbon particulates fed on by the worms.

### 3.3.1 Floodplain Connectivity

Floodplain connectivity is an essential geofluvial habitat function for salmonids in the riverine portions of the Klamath Basin. Floodplain connectivity supports rearing habitat, inclusive of bioenergetic processes, across a range of flows. Dynamic floodplains are essential to fundamental ecological functions for fishery resources, with clear linkages to riparian ecology and large wood storage and recruitment (see Section 3.2.2). In the Klamath River and its tributaries (e.g., Scott and Shasta rivers), the observed lack of floodplain connectivity is a constraint for fisheries restoration.

Within the mainstem Klamath in the 18-mile reach downstream of Iron Gate Dam, hydrology and sediment resulting from the dams have resulted in fossilized bar formations (Hetrick et al. 2009) (Figure 3-5). The Klamath River between Iron Gate Dam and Scott River is in a relatively confined valley. Within this reach, mature riparian vegetation near the water's edge indicates the river has not migrated laterally or vertically for a period equal to or less than the age of mature trees in the area (Ayers and Associates 1999, as cited by Hetrick et al. 2009). This lack of migration impedes floodplain connectivity and is indicative of restricted fluvial geomorphic processes. The USFWS documented evidence of fossilized bars and degradation of the channel in this reach (Hetrick et al. 2009). Key geomorphic features such as islands that existed prior to Iron Gate Dam remain in place. Many of the alluvial features downstream of Iron Gate Dam are relic features of the pre-dam hydrological and geomorphic setting (Ayers and Associates 1999, as cited by Hetrick et al. 2009). The basic planform of the river downstream of Iron Gate has been static since at least 1955 (PacifiCorp 2004a, as cited by Hetrick et al. 2009) and riparian vegetation patterns have remained constant (Ayers and Associates 1999, as cited by Hetrick et al. 2009).

Figure 3-5: Fossilized bars below Iron Gate Dam indicate a lack of coarse sediment and impact floodplain habitat essential for salmonid rearing. Original source Hetrick et al. 2009, USFWS photo.

NRC (2008) noted that high flows route coarse sediments, build bars, erode banks, flush fine sediments, scour vegetation, and undercut and topple large woody riparian vegetation, all of which contribute to the dynamics and channel processes essential for salmonids. During wet years, unimpaired high flows would contribute to floodplain building processes by scouring pools, recruiting large woody debris, flushing fine sediments, and building bars that improve and maintain habitat conditions (NRC 2008). As noted in USBR (2011), these high flows have been attenuated by Iron Gate Dam and the Klamath hydroelectric infrastructure in general.

Floodplain forming processes downstream of Iron Gate Dam are expected to improve after dam removal. Modeled post-dam hydraulics estimate a slight increase in peak flood flows for the 18 miles of river immediately downstream of Iron Gate Dam because of the elimination of storage in the upstream reservoirs, which currently attenuate floods (USBR 2011). Increased flood peaks will result in increased sediment mobility downstream to cottonwood Creek and, over time, will also return to the natural gravel supply (USBR 2011). After dam removal, USBR (2011) predicted the frequency of gravel mobilization will increase from once every four years to every other year. While the coarse sediment deficit is anticipated to be alleviated with dam removal, flood flows will also be required to restore fluvial processes necessary for the rehabilitation of the channel, including floodplain reconnection (Hardy and Addley 2006, as cited by Hetrick et al. 2009).

In the event of dam removal, the future negotiated hydrology throughout the Klamath Basin remains unknown. Flow regulation, including minimum and peak flow guidelines for the mainstem Klamath River downstream of Link River and Keno and inclusive of minimum Upper Klamath Lake elevations, are unforeseen beyond the existing 2013 biological opinion (and recent amendments to the 2013 BiOp to provide supplemental flows to avoid downstream disease outbreaks). Additionally, it is not known if USBR will alter its current allocation to water users in the upper basin through its ongoing Klamath Project operations. Opportunities should exist to manage post-dam hydrology to maximize fluvial geomorphic processes, optimize fish habitat creation and maintenance, and minimize fish disease; however, the extent to which future hydrology will benefit fluvial processes is not yet known. As mentioned earlier, the volume of water available to fish species throughout the basin is affected primarily by USBR's Klamath Project water deliveries to upper basin water users, and this factor would remain in place even with dam removal. Through the regulatory process related to dam removal itself, as well as through future consultation with USBR for its ongoing Klamath Project operations, NMFS and USFWS will need to update flow management requirements for the entire basin.

## 3.4 Changes in Habitat

Habitats are the structural components of ecosystems that are primarily created and maintained by natural processes (Thorsteinson et al. 2011). A diversity of high quality, connected habitats is necessary for fish populations to complete their life cycle and maintain a healthy, reproducing status. Aquatic habitats in the Klamath Basin have been affected by many factors including urbanization, agriculture, forestry, mining, hydropower, and fishing (Thorsteinson et al. 2011). Habitats for fish have become increasingly fragmented by these activities, reducing the ability of species to successfully migrate, forage, avoid predators, reproduce, and complete their life cycles (Thorsteinson et al. 2011). Dams in the basin have blocked access to upstream habitat for migrating fish, created reservoirs that have altered temperature and flow conditions, and affected processes for transporting nutrients and sediments. Land disturbance/conversion and water withdrawals have altered natural flows, increased local thermal loading, reduced natural wood inputs, and increased nutrient inputs and contaminant concentrations (Thorsteinson et al. 2011).

Such changes have simplified and impaired habitat conditions (i.e., reduced the quantity and quality of spawning and rearing habitats) for many fish species in the Klamath Basin, altered food webs, and affected overall biological productivity (Thorsteinson et al. 2011). Hamilton et al. (2011) concluded that the diversity, productivity, and abundance of federally listed, and other depressed fish populations in the Klamath Basin has been severely impacted due to a variety of habitat-related factors. These factors include:

- blockage of over 420 miles of historical spawning and rearing habitat for anadromous species upstream of Iron Gate Dam;
- altered flow regimes, sediment transport, and associated geomorphic and riparian processes that together have limited the creation and maintenance of diverse fish habitats downstream of Iron Gate Dam;
- lack of access to cold springs and cool tributary habitats in the upper Klamath Basin that provided thermal refugia for anadromous species upstream of Iron Gate Dam;
- poor habitat quality throughout many tributaries to the Klamath River; and
- poor water quality in the Klamath River, particularly during summer months.

Additionally, population declines of endangered Lost River and shortnose sucker in the Klamath Basin prior to ESA listing has been attributed to the habitat loss of approximately 75% of sucker historic range and restricted access to spawning habitats (USFWS 2012), as well as overharvest, entrainment in water management structures, and severely impaired water quality.

Blockage of anadromous fish passage beyond Iron Gate Dam has also meant the complete loss of marine-derived nutrients (i.e., nutrients accumulated in the biomass of anadromous salmonids while they are in the ocean) to historical upper basin spawning areas. Various authors (Bilby et al. 1996; Gresh et al. 2000; Wipfli et al. 2004) have documented the role of marine-derived nutrients in enhancing productivity of freshwater habitats (both riverine and terrestrial). The presence of anadromous fish species in the upper Klamath Basin increased the prey base and provided marine derived nutrients that supported the persistence of resident species like bull trout (*Salvelinus confluentus*) (USFWS 2015b). Access for anadromous fish still exists below Iron Gate Dam but, even in the lower basin, the past century of decline in overall salmon abundance has meant that there has been a steady impoverishment in marine-derived nutrients entering the basin (NMFS and USFWS 2013). However, given the abundant supply of nitrogen and phosphorus in the upper basin, which have caused serious problems with water quality, it is not clear that the absence of marine-derived nutrients would be considered a major limiting factor within the Klamath mainstem. However it is likely that smaller tributaries in the basin have been impacted by the historical reduction in marine derived nutrients (R. Turner, pers. comm.).

## 3.5 Other Direct Effects

### 3.5.1 Disease

Hamilton et al. (2011) concluded that salmon in the Klamath Basin have been severely impacted in some years from high incidences of disease in juvenile salmon downstream of Iron

Gate Dam. The principle fish diseases affecting juvenile salmon in the Klamath are caused primarily by the myxozoan parasites *Ceratonova shasta* and *Parvicapsula minibicornis. C. shasta* and *P. minibicornis* are widespread in the lower mainstem of the Klamath River during certain time periods and in certain years and have been shown to adversely affect freshwater abundance of Chinook and coho salmon (USDI, USDC, NMFS 2013). While native salmonids exposed to low doses of the parasite exhibit some degree of resistance (Bartholomew et al. 2001, as cited in Som et al. 2016a) they can become overwhelmed by high infectious doses that result in a diseased state and cause mortality (Bartholomew 1998; Stone et al. 2008, as cited in Some et al. 2016a). Steelhead are generally resistant to or less affected by *C. shasta* (USDI, USDC, NMFS 2013). As described by Bartholomew et al. (1997, 2006 as cited n Alexander et al. 2016), both *C. shasta* and *P. minibicornis* alternate between two waterborne spore stages: myxospores and actinospores. Myxospores infect the polychaete worm *Manayunkia speciosa.* In this host parasites develop into actinospores and are released into the water column where they may encounter and infect salmonids. After salmonid infection, parasites develop into myxospores and are released either as they mature (*P. minibicornis*, shed along with urine) or upon death of infected fish (*C. shasta*). See Figure 3-6 for a representation of the *C. shasta* and *P. minibicornis* life cycles. The polychaete invertebrate host is necessary for completion of the life cycle and neither horizontal (fish to fish), nor vertical (fish to egg) transmissions have been documented under laboratory conditions (Som et al. 2016b).

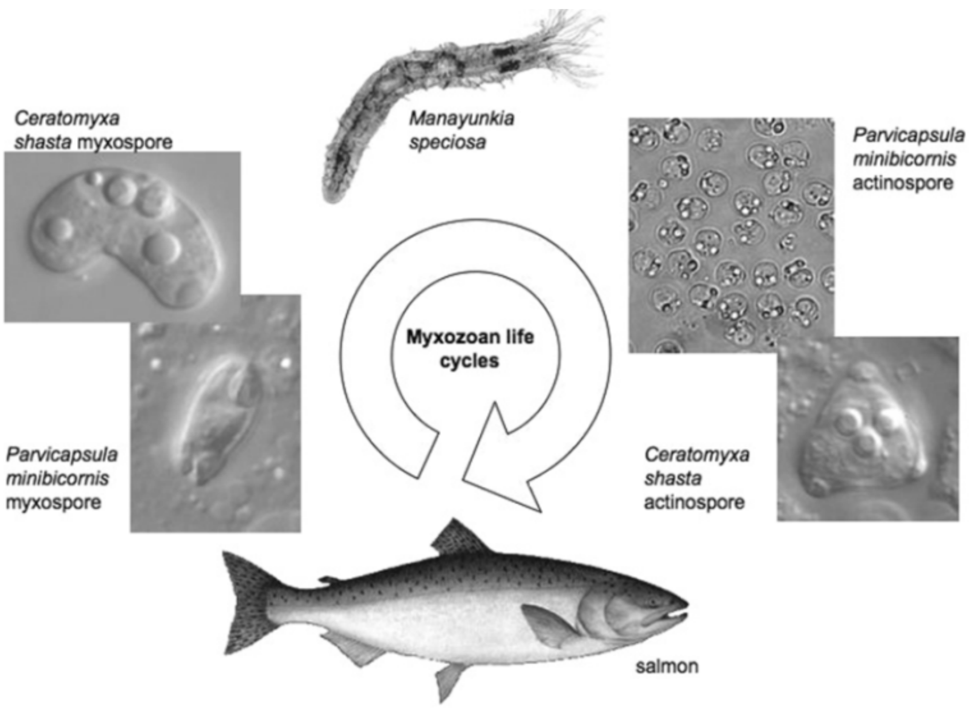



Figure 3-6: The life cycle of *Ceratonova shasta* and *Parvicapsula minibicornis* showing transmission of parasitic life stages to both hosts: polychaete worms and salmon (infects both juveniles and adults). *Manayunkia speciosa* is a small freshwater polychaete worm (3-5 mm in length) and intermediate host of both parasites. Figure source Som et al. 2016a, as provided with permission from J. Bartholomew, Oregon State University.

*C. shasta* causes necrosis of intestinal tissue that can be accompanied by a severe inflammatory reaction (enteronecrosis) and subsequent death of the salmonid host (Bartholomew et al. 1989, as cited in Alexander et al. 2016). *P. minibicornis* causes necrosis of kidney tissue (glomerulonephritis) that has been implicated as a causal factor in elevated salmonid mortality (Kent et al. 1997; St. Hilaire et al. 2002, as cited in Alexander et al. 2016). Interest in understanding and managing *C. shasta* in particular in the Klamath ecosystem is considerable because infection has been linked to population declines in juvenile and adult fall-run Chinook (Fujiwara et al. 2011; True et al. 2013, as cited in Alexander et al. 2016).

Figure 3-7 (while not reflecting all potential water quality factors) presents a conceptual model (from Foot et al. 2011) that illustrates key variables that influence the prevalence of *C. shasta* infections in juvenile and adult salmonids in the Klamath Basin. Habitat conditions which can support proliferation of *C. shasta and P. minibicornis* and their polychaete host (*M. speciosa*) include (USDI, USDC, NMFS 2013):

- stable river flows, with low flow variability and minimal scour;
- a relatively stable stream bed;
- crowding of adult salmon at barriers to fish passage, creating a concentration of carcasses; and
- plankton-rich discharge from reservoirs.

The complexity of the *C. shasta* life cycle may lend itself to a variety of management approaches because actions can be tailored to target the different hosts or parasite spore stages, thus arresting the life cycle. Of particular interest are aspects of the *C. shasta* life cycle that are susceptible to alteration via management actions. Given the nature of the parasite's life cycle, disruption of even a single element of the cycle could have profound beneficial impacts on survival of juvenile salmonids in the Klamath River (Som et al. 2016a).

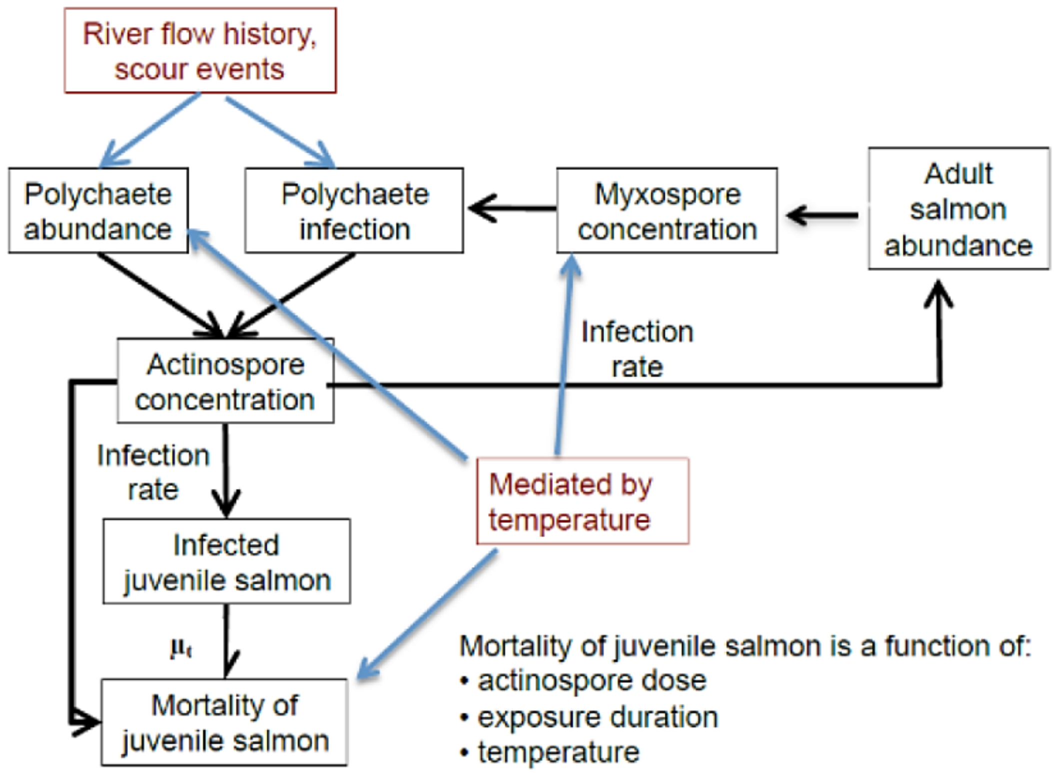



Figure 3-7: Conceptual model for variables that influence infection and mortality of juvenile Chinook salmon by *Ceratonova shasta*, **with** $\mu_t$ being the mortality rate of infected juvenile salmon, estimated from weekly actinospore concentrations in water samples. Figure from Foot et al. 2011, as reproduced in Som et al. 2016b.

Highly infectious disease zones for fish are associated with dense populations of the annelid polychaete host *M. speciosa*. *M. speciosa* feeds on particulate organic matter and its abundance is generally highest in the 100km reach of the Klamath River between the Shasta River and Independence Creek, which also has high abundance and diversity of other filter-feeding macroinvertebrates (Malakauskas and Wilzbach 2012). Reducing organic matter in the Klamath River might therefore help reduce *M. speciosa* abundance. Distributions of *M. speciosa* in the Klamath River is influenced by substrate, depth and flow velocities, with highest densities (>100,000 individuals/m) observed in slow flowing (≤0.05 m/s), shallow areas (1 to 2 m deep), with silt, sand, boulder or bedrock substrates (Alexander et al. 2016). While this suggests that such conditions may be optimal, the distribution of *M. speciosa* has not been fully described along the entire depth-velocity continuum in the Klamath and interannual variation in polychaete densities among substrates suggests suitability is not static (Alexander et al. 2016). Interactions between hydraulics and substrate types likely drive much of the variation in distribution of *M. speciosa* in the Klamath River (Alexander et al. 2016). Assemblages of *M. speciosa* frequently are also associated with *Cladophora*, which may facilitate *M. speciosa* attachment (Stocking and Bartholomew 2008, as cited in Alexander et al. 2016) and persistence during elevated flow conditions (Malakauskas et al. 2013, as cited in Alexander et al. 2016).

High infection rates of *C. shasta* have been documented in some years within the native salmon population (USDI, USDC, NMFS 2013). It appears that there is a host-parasite imbalance downstream of Iron Gate Dam, with large-scale outbreaks of disease in juvenile salmon populations occurring in the Klamath River during late spring to summer when ambient air temperatures increase and tributary and mainstem flows decrease (USDI, USDC, NMFS 2013). Flow manipulation has been proposed as the primary method for reducing polychaete host habitat (Som et al. 2016a) but the degree of manipulation required to alter the suitability of habitat for *M. speciosa* is unknown (Alexander et al. 2016). High flow velocities could influence polychaete distribution by several means including: (1) dislodge polychaetes directly; (2) mobilize the substrate, thereby causing displacement or mortality; or (3) make the environment too turbulent for feeding (Alexander et al. 2016). Dislodgement or displacement are likely explanations for restriction of polychaetes to lower velocities (Alexander et al. 2016). During drought years, managed peak flows of sufficient magnitude and duration along with piggybacking on natural hydrologic events have been implemented in the Klamath River to help deter the establishment of aquatic vegetation and disrupt the life cycle of fish pathogens and their polychaete host (Hetrick et al. 2009). Despite these measures, fish disease as a result of *C. shasta* infection remains a potentially significant stress on the contemporary Klamath River salmonid population. Som et al. (2016a) note that high flow events may not entirely disrupt the polychaete population. Polychaetes have been observed to migrate toward lower velocity zones (e.g., behind rock outcroppings) for cover during significant flow events (Alexander et al. 2014, as cited in Som et al. 2016a). Research is ongoing by Oregon State University and the Arcata Fish and Wildlife Office (J. Bartholomew, pers. comm.) to determine which flow timing events and peak discharge thresholds may be most effective in polychaete disruption. The ability to relate the distribution of *M. speciosa* to the physical environment will be critical for understanding of this host's ecological requirements and will facilitate the development and evaluation of better disease management solutions (Alexander et al. 2016).

Other diseases significantly affecting fish in the Klamath Basin include the external protozoan parasite *Ichthyophthirius multifilis* (Ich) and the bacterial pathogen *Flavobacterium columnare* (columnaris disease). Ich and columnaris have occasionally had a substantial impact on adult salmon downstream of Iron Gate Dam (NMFS and USFWS 2013). In the fall of 2002, an outbreak of Ich and columnaris disease in the Klamath River resulted in the deaths of more than 33,000 adult salmon and steelhead (Figure 3-8), the largest salmon die-off ever recorded in the western U.S. (CDFW 2004b, as cited in USDI, USDC, NMFS 2013). Ich is a protozoan with three distinct life stages that can be completed in as little time as four days at high temperatures (Durborow et al. 1998). The first stage is the feeding stage (a single-celled organism called a trophozoite), in which the protozoan feeds in a nodule formed on the skin or gills of a salmon. After feeding, the protozoan (now called a tomont) falls off the fish and adheres to plants, gravel, or sediment, where it encysts. In the river's substrate, the tomont can divide multiple times by binary fission to produce hundreds of microscopic tomites, which ultimately burst from the cyst and drift into the water column. The tomites develop cilia, producing an infective stage called theronts, which begin actively swimming in search of a new host to begin the life cycle again (The Ich Factor 2017, webpage). Conditions favouring growth of Ich and columnaris disease are created by high densities of returning adult salmon, low fall flows and warm water temperatures that can delay and inhibit migration of adult fish further upstream (USFWS 2003, as cited in USDI, USDC, NMFS 2013).

Figure 3-8: Thousands of adult salmon in the lower Klamath River died during 2002 from Ich and columnaris disease exacerbated by low fall flows, high concentration of returning Chinook salmon, and warm water temperatures. Photo from USDI, USDC, NMFS 2013.

Adequate water quantity and quality are considered critical in controlling or triggering disease epidemics, and degraded condition of these variables may trigger the onset of epidemics in fish that are carrying the infectious agents (Holt et al. 1975, Wood 1979, Maule et al. 1988, as cited in NOAAF 2014). Management for controlling Ich when detected at high levels (i.e., multiple severe confirmed Ich infections are observed) in the lower Klamath Basin includes releases of additional water from the Lewiston Dam on the Trinity River to increase flow rates in the lower Klamath River (TRRP 2012) and (if also needed) increased water releases from Iron Gate Dam on the Klamath River (The Ich Factor 2017, webpage). These pulsed increases in flows for the lower Klamath River are intended to disrupt the disease life cycle by diluting concentrations of Ich theronts searching for hosts while also reducing high concentrations of fish. Releases from Trinity Dam in the late summer can also produce a slight decrease in lower river water temperatures as well, which can reduce stress to fish and potentially bring water temperatures below those creating a migration barrier to salmon (i.e., >22$^{o}$ C) (R. Turner, pers. comm.). Although losses of adult salmonids from Ich and columnaris disease have been substantial in some years, the combination of factors that leads to adult infection are not as frequent as the annual exposure of juvenile salmonids to *C. shasta* and *P. minibicornis*. This is because many juveniles must migrate each spring downstream past established populations of the invertebrate polychaete host (NMFS and USFWS 2013).

In the upper Klamath Basin losses of adult shortnose and Lost River suckers have been associated with diseases caused by several endemic bacterial fish pathogens in fish that were highly stressed by adverse water quality following the collapse of large algal blooms (Thorsteinson et al. 2011). While periodic summer die-offs of these endangered sucker species have been primarily attributed to hypoxia (low levels of dissolved oxygen), it is considered likely that disease outbreaks also contributed to considerable post-hypoxia mortality during these events (Perkins et al. 2000b). A number of pathogens or parasites have been identified from moribund suckers in Upper Klamath Lake, including anchor worm (*Lernaea* species; a parasitic copepod), *Trichodina* species (an external ciliate protozoan), and the bacterium *Flavobacterium columnare*, which produces columnaris disease, among others (Holt 1997, Foott 2004, Foott et al. 2010a,b). Adverse water quality conditions (such as high pH or high ammonia) are known to increase the extent to which pathogens and parasites can negatively impact sucker survival (Perkins et al. 2000b; USFWS 2012b). Disease outbreaks typically do not occur unless stressful environmental conditions have compromised the host defense system and predisposed fish to infection (Perkins et al. 2000b). Endangered species such as Lost River sucker or shortnose sucker populations that are concentrated into a few populations are inherently at risk to demographic and environmental stochasticity and catastrophic events such as disease outbreaks (USFWS 2012b).

Other common pathogens of potential concern for fish health in the basin include viral pathogens such as infectious haematopoietic necrosis and the bacterial pathogen *R. salmoninaum* (bacterial kidney disease). There is however limited information concerning the presence of viral pathogens or *R. salmoninarum* either above or below Iron Gate Dam (Administrative Law Judge 2006, as cited in NMFS and USFWS 2013).

### 3.5.2 Hatcheries

Two fish hatcheries currently supplement Klamath River salmonid fisheries, the Iron Gate Hatchery (IGH) (located just below Iron Gate Dam) and the Trinity River hatchery, producing spring and fall-run Chinook salmon, coho salmon, and steelhead (NRC 2004). A third hatchery, Klamath Hatchery near Upper Klamath Lake in Oregon, was built in 1929 to produce rainbow, brown (*Salmo trutta*), and coastal cutthroat trout to enhance harvest rather than for restoration (ODFW 2017) and so is not discussed further here. IGH was completed in 1966 and was established to compensate for the loss of 16 miles of upstream spawning and rearing habitat caused by the construction of Iron Gate Dam (USDI, USDC, NMFS 2013). IGH currently provides Chinook salmon (*Oncorhynchus tshawytscha*) and coho salmon adding to overall fishery abundance, but there are concerns that IGH production has diluted natural spawning populations and reduced the genetic diversity of Chinook salmon and coho salmon in the basin (USDI, USDC, NMFS 2013).

Natural populations can be negatively influenced by hatcheries through genetic and ecological interactions, and large-scale hatchery supplementation has the potential to result in detrimental effects to naturally spawning populations (Bisson et al. 2002; Buhle et al. 2009)). There are two significant genetic concerns relating to hatchery production: (1) the potential for domestication selection in hatchery populations; and (2) straying by large numbers of hatchery-origin fish (NMFS and USFWS 2013). Hatchery practices can alter genetic population structure of Chinook salmon within a river basin, however the effects of hatchery releases can be highly variable (Kinziger et al. 2013). Spawning by hatchery-origin salmonids in rivers and streams is often not controlled and hatchery strays can transfer genes into naturally spawning populations (ISAB 2002). Genetic interactions between hatchery- and natural-origin fish produced populations can decrease genetic and phenotypic diversity by homogenizing once disparate traits of hatchery- and natural-origin fish.

Data for the Klamath Basin indicates that straying of hatchery fish into Klamath River tributaries does occur (NMFS and USFWS 2013). NRC (2008) has identified reduced genetic integrity from hatchery production as a biological factor contributing to the declines of anadromous populations in the basin. Estimates of hatchery-origin spawners in natural areas in the Klamath Basin are large, specifically for hatchery fish from IGH since until recently fish had not been marked or tagged or were marked at very low rates (Williams et al. 2013). Genetic data provides insight into contributions of hatchery-origin fish to local populations and is useful given the sporadic estimates based on expansion of marked fish observed on the spawning grounds. Genetic data (Kinziger et al. 2013) indicated that that the greatest similarity among populations in natural areas and hatchery stocks occurred in those areas adjacent to hatcheries (e.g., Bogus Creek near-adjacent to Iron Gate Hatchery) and expansion estimates based on low marking rates and few recoveries might lead to estimates of rather large numbers of hatchery-origin fish in natural areas (e.g., 30%) that are not supported by the genetic population structure data (Williams et al. 2013).

Anadromous fish hatcheries in the Klamath Basin have historically targeted a total release of approximately 12 million juvenile Chinook salmon, coho salmon, and steelhead each year, (Hamilton et al. 2011) to mitigate for anadromous fish habitat lost as a result on the construction of dams on the mainstem Klamath and Trinity Rivers. Iron Gate Hatchery has released approximately 6.0 million fall-run Chinook salmon, 75,000 coho salmon, and 200,000 steelhead annually. Trinity River Hatchery has released about 4.3 million Chinook salmon (fall and spring-runs), 0.5 million coho salmon, and 0.8 million steelhead annually (Hamilton et al. 2011), although releases of all species from the Trinity River Hatchery have been lower recently as they have not been able to meet mitigation goals for this hatchery and steelhead have not been released for a number of years (W. Sinnen, pers. comm.). Iron Gate Hatchery originally produced spring-run Chinook as well but abandoned this program by the mid-1970’s as water could not be maintained at cold enough temperatures to maintain spring -Chinook (P.D. Brucker, pers. comm.). Despite recent reductions in hatchery production it has been suggested (Quiñones et al. 2014a) that hatchery-reared adults have at times made up a significant proportion of spawning adults in some parts of the Klamath system.

### 3.5.3 Fishing

Long-term declines in abundance of Klamath River anadromous fish species since 1960 (base year) have been estimated at 92 to 96% for wild fall-run Chinook salmon, 98% for spring-run Chinook salmon, 67% for steelhead, 52 to 95% for coho salmon, and 98% for Pacific lamprey (*Lampetra tridentata)* (USDI, USDC, NMFS 2013). While it is difficult to disentangle the actual effects of harvest from a suite of cumulative effects acting on Klamath fish populations (e.g., dam construction, hydrologic alteration, changing ocean conditions, timber harvest, agricultural development, and mining), overfishing has been identified as a contributing factor in their declines (KRBFTF 1991, as cited in USDI, USDC, NMFS 2013). NRC (2008) also identified commercial exploitation as a contributing factor in the declines of anadromous fish species in the Klamath Basin, suggesting that harvest had affected targeted species through repeated reductions in spawning stock below levels needed for sustained support of the population.

VanderKooi et al. (2011) similarly identified past overharvest, in combination with major alterations of aquatic environments in the basin, as having led to substantial declines in some populations of both native freshwater resident fish species (e.g., lake suckers) and of anadromous salmon species. It is recognized that excessive ocean harvest rates prior to the 1990s seriously reduced salmon stock abundance in the Klamath (UWRL 1999). During the 1980s ocean harvest rates on age-4 Klamath fall Chinook averaged 53% (PFMC 1991, as cited in UWRL 1999) while river-harvest rates averaged 63% (UWRL 1999). New management programs put in place since that time have seen a considerable reduction in both ocean and river harvest, in part due to the recognition of tribal fishing rights in the river, as well as to regulations for conservation of Klamath Basin fall Chinook (UWRL 1999).

Fisheries management plans in the Klamath Basin focus primarily on managing harvest and also include aspects of fisheries enhancement through hatchery supplementation or reintroduction. The harvest of salmonids in the Klamath Basin is managed primarily through the Pacific Coast Salmon Fishery Management Plan administered by the Pacific Fishery Management Council (PFMC). The latest edition of the plan was released in March 2016 (PFMC 2016). The overarching goal of this plan is to perpetuate the coastwide aggregate of salmon stocks covered by the plan in order to rebuild overfished stocks, achieve optimal yield, and prevent future overfishing. This goal is supported by specific quantitative goals for size limits, harvest, escapement, and other parameters for individual stocks of coho and Chinook.  While all species of salmon fall under the jurisdiction of this plan, it currently contains fishery management objectives only for Chinook, coho, pink (odd-numbered years only), and any salmon species listed under the Endangered Species Act (ESA) that is measurably affected by PFMC fisheries.

### 3.5.4 Predation and Exotic Species/ Competition

Pinniped predation on adult salmon can significantly affect escapement numbers within the Klamath Basin (NMFS and USFWS 2013). A study by Hillemeier (1999) determined that fall-run Chinook were the main species consumed by seals and sea lions in the Klamath estuary (with an estimate of approximately 8,800 adult Chinook and 223 adult coho consumed over his three month study period).  The Marine Mammal Protection Act of 1972 protects seals and sea lions from human harvest or take, and as a result, populations of pinnipeds are likely now at historical highs (Low 1991, as cited in NMFS and USFWS 2013).

Approximately 20 fish species have been accidentally or deliberately introduced into the upper Klamath Basin and now comprise a large percent of fish biomass in some basin water bodies (Scoppettone and Vinyard 1991, NRC 2004 as cited in USFWS 2012b). Among these introduced species, the fathead minnow (*Pimephales promelas*) and yellow perch (*Perca flavescens*) are known to affect endangered Lost River sucker and shortnose suckers through predation on young suckers, as well as through competition with them for food or space (Markle and Dunsmoor 2007, as cited in USFWS 2012b). Fathead minnows were first documented in the Klamath Basin in the 1970s and are currently the numerically dominant fish in Upper Klamath Lake (Andreasen 1975, Simon and Markle 1997, as cited in USFWS 2012b). Other non-native, predatory fishes now found in aquatic habitats throughout the upper Klamath Basin (although typically in relatively low numbers) that could represent a threat to suckers include bullheads (*Ameiurus* species), largemouth bass (*Micropterus salmoides*), crappie (*Pomoxis* species), green sunfish (*Lepomis cyanellus*), pumpkinseed (*Lepomis gibbosus*), and Sacramento perch (*Archoplites interruptus)* (USFWS 2012b). Effects on endangered suckers by these latter species are unknown, as little quantitative information exists to indicate their influence on sucker abundance and distribution (USFWS 2012b; Hereford et al. 2016). Introduced brook trout *(Salvelinus fontenalis)*, brown trout (*Salmo trutta*), and non-native strains of rainbow trout (*O. mykiss*) are known to effect resident bull trout and redband trout (*Oncorhynchus mykiss newberrii)* through hybridization, predation, and competition for food and space. These introduced species are considered to represent a continuing threat to the persistence of resident trout in the Klamath Basin, especially if changes in water quality in the basin promote their further expansion (USFSW 2012b).

### 3.5.5 Ocean Survival

Good and bad ocean phases for fish growth and survival in the marine environment appear to cycle in decadal or longer time steps associated with mid-ocean warming and cooling (Pearcy 1992; Mantua et al. 1997; Quinn 2005). In strong upwelling years, ocean productivity is enhanced by abundant, labile nutrients in the upwelling water and the probability of strong salmon runs is thereby increased by a persistent, robust food web (Stanford et al. 2011). Variability in ocean conditions remains a major source of uncertainty in the population dynamics of Klamath salmon (Stanford et al. 2011). While it is difficult to disentangle the effects of changing ocean survival from a suite of cumulative effects that have acted/are acting on the freshwater phases of anadromous fish populations within the Klamath Basin (e.g., dam construction, hydrologic alteration, overfishing, timber harvest, agricultural development, mining), ocean conditions have been identified as a contributing factor in their population declines (KRBFTF 1991, as cited in USDI, USDC, NMFS 2013). The 2013 Klamath Biological Opinion (NMFS and USFWS 2013) also identified ocean conditions as affecting population growth rates, abundance, diversity, and distribution of Klamath salmon populations and noted their reliance on productive ocean environments.

While ocean conditions are not necessarily the only influence on marine survival, in general salmon survival and productivity (i.e., adult returns) are correlated with ocean conditions (Beamish et al. 1997; Peterson et al. 2010; Peterman and Dorner 2012). Changing atmospheric and oceanic processes constantly modify and “reset” ocean conditions, such that salmonids entering the ocean may encounter a different set of conditions every year (Lichatowich et al. 2006). This can have a tremendous effect on the survival of anadromous fish and the number of fish that are able to return to the river. How ocean conditions affect Klamath Basin salmon, with respect to growth and survival, remains unresolved with respect to recovery (Stanford et al. 2011). There is a growing body of evidence that suggests ocean conditions during the first year at sea for salmon are critical for cohort survival (Stanford et al. 2011). Large-scale changes in marine conditions such as the El Niño Southern Oscillation and the Pacific Decadal Oscillation can affect ocean temperature distributions, biological productivity, and availability of foods (Stanford et al. 2011). At present, there is uncertainty about where Klamath Basin salmon smolts go after they enter the ocean (Stanford et al. 2011). It is presumed that most stocks stay in the California current upwelling zone, near the shore between San Francisco and the Fraser River in British Columbia. Some evidence suggests that Chinook salmon from the Klamath will stay in coastal waters between Cape Falcon, Oregon, and San Francisco (Stanford et al. 2011). Productivity in these areas is known to be tied to the strength of the current upwelling (Stanford et al. 2011).

# 4 Fish Species of the Klamath Basin

The purpose of this section is to provide the reader with a concise overview of the fish communities present within the Klamath Basin, and to provide greater detail on the ecology, management, and research needs for a subset of focal fish species.

## 4.1 Historic Native Species

The Klamath Basin is home to 30 native fish species and once had the third-largest runs of salmon in the lower United States (NRC 2008). The basin historically produced an abundance of steelhead (*Oncorhynchus mykiss irideus*), Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus tshawytscha*), green sturgeon (*Acipenser medirostus*), eulachon (*Thaleichthys pacificus*), coastal cutthroat trout (*Oncorhynchus clarki clarki*), Pacific lamprey (*Lampetra tridentata)*, and Lost River (*Deltistes luxatus)* and shortnose suckers (*Chasmistes brevirostris*) that contributed to substantial tribal, commercial and recreational fisheries. Natural populations of harvested native fish species have decreased, in some cases significantly, from the numbers observed in the early 1900s (USDI, USDC, NMFS 2013). For management purposes, the Klamath River basin has traditionally been divided into an upper basin, which extends north and east from Iron Gate Dam on the mainstem of the Klamath River, and a lower basin, which extends south and west to the Pacific Ocean (NRC 2008). The lower basin, which represents approximately 62% of the Klamath Basin land area and 88% of its runoff (Powers et al. 2005), contains mainly fast-flowing, cool-water rivers and streams. By contrast, the upper basin is characterized by many warm streams and rivers of lower gradient, and contains all the large natural lakes and wetlands of the Klamath Basin. As such, the two basins have developed markedly different fish assemblages (NRC 2004). Note however that though the upper Klamath Basin is dominated by warmer streams and lakes it also has groundwater-dominated areas that can serve as key cold water refugia (Close et al. 2010; Hamilton et al. 2011).

**Upper Basin Fishes.** Only five families of fishes – Petromyzontidae, Cyprininidae, Catostomatidae, Salmonidae, and Cottidae – are native to the upper Klamath Basin, and the species in these families have become adapted to the shallow lakes, meandering rivers, and climatic extremes of the upper Klamath Basin (NRC 2004). Most, or possibly all, of the native fish species that live in the upper basin are endemic to the watershed, with relatively abundant or common native species including Klamath tui chub (*Gila bicolor bicolor*), blue chub (*Gila coerulea*), Klamath speckled dace (*Rhinichthys osculus klamathensis*), Upper Klamath marbled sculpin (*Cottus klamathensis klamathensis*), and Klamath Lake sculpin (*Cottus princeps*) (NRC 2008). The absence of major physical barriers to movement of fish before installation of dams allowed for former use of the upper basin by anadromous species and the apparent occasional entry into the upper basin of Klamath small-scale sucker (NRC 2004), which is abundant in the lower basin. Table 4-1 lists the native fishes historically present in the upper Klamath Basin and their current status.

**Lower Basin Fishes.** Native fishes of the lower Klamath Basin are mainly anadromous species that use productive flowing-water habitats, plus a few non-migratory stream fishes typical of cool-water environments (NRC 2004). Relatively abundant or common native species of the lower Klamath Basin include Klamath River lamprey (*lampetra simulus*), Klamath small-scale sucker (*Catostomus rimiculus*), Klamath speckled dace (*Rhinichthys osculus*), threespine stickleback (*Gasterosteus aculeatus*), and Lower Klamath marbled sculpin (*Cottus klamathensis polyporus*).

Of the 19 species of native fishes in the lower basin, 13 are anadromous and two are amphidromous (i.e., larval stages in saltwater), thus 80% of the species require saltwater to complete their life histories. Table 4-1 also lists fishes historically present in the lower Klamath Basin and their current status.

Additional Klamath Basin fish species that are restricted to the river estuary include white shark (*Carcharodon carcharias*), big skate (*Raja binoculata*), northern anchovy (*Engraulis mordax*), Pacific herring (*Clupea pallasi*), surf smelt (*Hypomeus pretiosus*), Pacfic hake (*Merluccius productus)*, Pacific tomcod (*Microgadus promimus*), Jacksmelt (*Atherinopsis californiensis*), topsmelt (*Atherinops affinnis*), bay pipefish (*Syngnathus leptohynchus*), striped bass (*Morone saxatilis*), sharpnose sculpin (*Clinocottus acuticeps*), staghorn sculpin (*Leptocottus armatus*), sturgeon poacher (*Agonus acipenserinus*), redtail surfperch (*Amphistichus rhodoterus*), shiner perch (*Cymatogaster aggregate*), striped surfperch (*Embiotoca lateralis*), walleye surfperch (*Hyperprosopon argenteum*), zebra perch (*Hermosilla axzurea*), arrow goby (*Clevelandia ios*), saddleback gunnel (*Pholis ornate*), Pacific sandlance (*Ammodytes hexapterus*), speckled sandab (*Citharichthys stigmaeus*), starry flounder (*Platichythys stellatus*), and butter sole *(Isopetta isolepis*) (Adams et al. 2011).

Table 4-1:Native fishes of the Klamath Basin. From NRC 2004, 2008; NCRWQCB 2010a-c; Adams et al. 2011; USDI, USDC, NMFS 2013; ODFW 2016; CDFW 2017.

| Family | Species | Status |
|---|---|---|
| Upper Klamath | | |
| | Klamath River lamprey | Common |
| | Miller Lake lamprey | Uncommon |
| | Pit-Klamath brook lamprey | Assumed Common |
| Cyprinidae (minnows) | Klamath tui chub | Abundant |
| | Blue chub | Common, Special Concern (CA) |
| | Klamath speckled dace | Assumed Common |
| Catostomidae (suckers) | Shortnose sucker | Endangered – OR, CA, Federal |
| | Lost River sucker | Endangered – OR, CA, Federal |
| | Klamath large-scale sucker | Special concern - Federal |
| | Klamath small-scale sucker | Uncommon |
| Salmonidae (salmon and trout) | Klamath redband trout | Vulnerable – OR; Special Concern-Federal |
| | Coastal steelhead | Extirpated; Tribal Trust Species |
| | Coho salmon | Extirpated; Tribal Trust Species |
| | Chinook salmon | Extirpated; Tribal Trust Species |
| | Bull trout | Critical – OR, Endangered – CA, Threatened - Federal |
| Cottidea (sculpins) | Upper Klamath mottled sculpin | Common |
| | Klamath Lake sculpin | Common |
| | Slender sculpin | Special Concern - Federal |

| Family | Species | Status |
|---|---|---|
| Lower Klamath | | |
| Petromyzontidae (lampreys) | Pacific lamprey | Declining; Tribal Trust Species |
| | River lamprey | Uncommon |
| | Klamath river lamprey | Common |
| Acipenseridae (sturgeon) | Green sturgeon | Threatened – Federal; Tribal Trust Species |
| | White sturgeon | Uncommon |
| Cyprinidae (minnows) | Klamath speckled dace | Common, widespread |
| Catostomidae (suckers) | Klamath small-scale sucker | Common, widespread |
| Osmeridae (smelts) | Eulachon | Threatened – Federal; Tribal Trust Species |
| | Longfin smelt | Threatened - CA |
| Cottidea (sculpins) | Prickly sculpin | Common |
| | Coastrange sculpin | Common |
| | Lower Klamath mottled sculpin | Assumed Common |
| Gasterosteidae (sticklebacks) | Threespine stickleback | Common |
| Salmonidae (salmon and trout) | Coho salmon | Critical – OR, Threatened – CA, Federal; Tribal Trust Species |
| | Chinook salmon | Much reduced in numbers; Tribal Trust Species |
| | 1) Fall-run | Much reduced in numbers; focus of hatchery supplementation |
| | 2) Late-fall run | Possibly extinct |
| | 3) Spring-run | Endangered but not recognized as ESU* |
| | Chum salmon | Special concern – CA; Tribal Trust Species |
| | Pink salmon | Extirpated; Tribal Trust Species |
| | Steelhead (rainbow trout) | Common, but declining; Tribal Trust Species |
| | Coastal cutthroat trout | Special concern - CA; Tribal Trust Species |

*Note that recent (unpublished) research out of UC Davis suggests that Klamath spring-run Chinook salmon may be genetically distinct from Klamath fall-run Chinook (K. Greenberg, pers. comm.).

The current Klamath Basin fish community is vastly changed from the historical in many ways due to anthropogenic impacts including dams, agriculture, land management activities, hatcheries, and introduced species. These impacts have resulted in a loss of diversity and abundance throughout the Basin (Adams et al. 2011). Upper sub-basin impacts have included damming, diverting, and channelizing rivers and streams, diking and draining of wetlands, overharvest of native fishes like suckers, and introduction of at least 18 non-native fish species. The most obvious cause of lost diversity is the barrier imposed upon anadromous fishes at Iron Gate Dam. In some instances, anthropogenic changes in habitat and population size have resulted in Endangered Species Act (ESA) listings of key species of fish. Conservation or recovery plans are available for each of the major species of concern in the Klamath Basin. These plans all include the overarching goal of recovery of the species to stable, naturally-sustaining populations meeting the criteria for delisting under the ESA. Some plans have a secondary goal of restoring harvesting opportunities for the species. Delisting requires that species meet objectives for both biological recovery (abundance, productivity, spatial structure and diversity) and sufficient reductions in the stressors and threats that led to the listing of the species. Moreover, many of the species recovery plans include adaptive management of recovering populations as an explicit objective (e.g., USFWS 2012a,b; USFWS 2014; NMFS 2014, 2016a).

## 4.2 Invasive Species

**Upper Basin Fishes.** In the last century, the upper Klamath Basin has been invaded by a variety of non-native fish species, most of which were introduced for sport fishing or bait (NRC 2004). Most of the species are not particularly common in the basin, but some are abundant and widespread. Their effects on native fishes are poorly understood (NRC 2004). Introductions or spread of non-native species have the potential to be major threats to native species in both the upper and lower basins (NRC 2004; USFWS 2013). Locally abundant non-native species in upper basin lakes, reservoirs, sloughs and ponds include fathead minnow, Sacramento perch, yellow perch (*Perca flavescens*), brown bullhead (*Ameiurus nebulosus*), largemouth bass (*Micropterus salmoides)* and pumpkinseed (*Lepomis gibbosus*) (NRC 2004, 2008; ODFW 2016). Non-native brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), and non-native strains of rainbow trout (*Oncorhynchus mykiss*) are common in Klamath cold-water streams (NRC 2004, 2008; ODFW 2016). Non-natives dominate numerically in many habitats in the upper basin and potentially threaten native species through competition and predation (NRC 2004, NMFS and USFWS 2013). Table 4-2 lists the non-native fishes present in the upper Klamath Basin and their current status.

**Lower Basin Fishes.** Seventeen non-native fishes have been recorded in the lower Klamath Basin. Only two of these (American shad and occasionally brown trout) are anadromous (NRC 2008). The non-native species are mainly warm- and cool-water species that thrive in slow-current or reservoir environments (NRC 2008). Additionally, non-native fishes are washed down continually from the upper basin (NRC 2004). A listing of the non-native fishes present in the lower Klamath Basin and their current status is provided in Table 4-2.

Table 4-2:Non-native fishes of the Klamath Basin. From NRC 2004, 2008; NCRWQCB 2010a.

| Family | Species | Status |
|---|---|---|
| Upper Klamath | | |
| Cyprinidae (minnows) | Goldfish | Uncommon |
| | Golden shiner | Uncommon |
| | Fathead minnow | Common |
| Ictaluridae (catfish) | Brown bullhead | Common |
| | Yellow bullhead | Common |
| | Black bullhead | Uncommon |
| | Channel catfish | Unknown (may not be established) |
| Salmonidae (salmon and trout) | Kokanee | Uncommon |
| | Rainbow trout (hatchery strains) | Common |
| | Brown trout | Common |
| | Brook trout | Uncommon |
| Centrarchidae (sunfish) | Sacramento perch | Common |
| | White crappie | Uncommon |
| | Black crappie | Uncommon |
| | Green sunfish | Common |
| | Bluegill | Uncommon |
| | Pumpkinseed | Uncommon |
| | Largemouth bass | Uncommon |

| Family | Species | Status |
|---|---|---|
| Percidae (perch) | Yellow perch | Uncommon |
| Lower Klamath | | |
| Clupeidae (herring) | American shad | Uncommon |
| Cyprinidae (minnows) | Goldfish | Uncommon |
| | Fathead minnow | Uncommon |
| | Golden shiner | Uncommon |
| Ictaluridae (catfish) | Yellow bullhead | Common |
| Osmeridae (smelts) | Wakasagi | Locally abundant |
| Salmonidae (salmon and trout) | Kokanee | Locally abundant |
| | Brown trout | Common in some streams |
| | Brook trout | Common |
| Gasterosteidae (sticklebacks) | Brook stickleback | Locally abundant, spreading |
| Centrarchidae (sunfish) | Green sunfish | Common |
| | Bluegill | Common |
| | Pumpkinseed | Uncommon |
| | Largemouth bass | Common |
| | Spotted bass | Locally common |
| | Smallmouth bass | Locally common |
| Percidae (perch) | Yellow perch | Locally common |

## 4.3 Focal Species of Restoration

Efforts to identify important ecological processes and conservation concerns across species can face substantial challenges (USFWS 2015b). When cost or system complexities make it expensive or impossible to directly assess every species or component of a system the use of surrogate approaches may be warranted (USFWS 2015b). Use of "focal" species is one such approach in this regard. Focal species were defined by Lambeck (1997) as a suite of key species whose spatial, compositional, and functional requirements can also be considered representative of the needs of a larger pool of species. An ecosystem managed to meet the needs of these focal species should be expected to encompass the general requirements of other species (Lambeck 1997). One of the functions of a representative focal species approach is to facilitate the organization and synthesis of a suite of broadly representative ecological indicators. However, there is a practical need to constrain such efforts to avoid the paralysis that comes with trying to cover everything. While restoration priorities will continue to evolve in the Klamath, the suite of focal species, habitats and indicators that are ultimately identified should be broadly representative of ecosystem needs. A representative set of focal species that considers stressors at all life-history stages, many locations, and a multitude of physio-chemical impact pathways will be robust in reflecting broad ecosystem needs. A natural focus of fish restoration efforts in the Klamath Basin should be on endangered species and those that support important fisheries (Thorsteinson et al. 2011). Focal species should therefore represent key species for targeted restoration actions and fisheries management within the Klamath Basin. While conservation plans may be species-focused, it is important to remember that most restoration work in the Klamath Basin has been carried out with broad ecosystem benefits in mind, rather than targeting a specific species to benefit.

Focal fish species reviewed within this Synthesis Report are consistent with those identified previously within the Fish Monitoring Plan of the KBRA (Section 12.2.1 of KBRA 2010), are species identified as focal species for restoration planning at the 2010 Klamath Basin Science Conference (Thorsteinson et al. 2011), and are among the species identified as useful surrogates for evaluating achievement of objectives for restoring naturally functioning riverine communities in the Klamath Basin (Athearn et al. 2012). Klamath populations of Lost River and shortnose suckers (endangered), coho salmon (threatened), bull trout (threatened), eulachon (threatened), and green sturgeon (threatened) are all presently listed under the federal ESA; they are the focus of species recovery efforts in the basin. Additionally, it is recognized that existing hydroelectric development has blocked passage of listed coho salmon as well as Chinook salmon, steelhead and Pacific lamprey to the Klamath Basin upstream of Iron Gate Dam (KBRA 2010).

While the numbers of naturally-produced Chinook returning to the Klamath basin have declined, particularly so for the once dominant spring-run, there are still sufficient Chinook to allow harvest, although much of this is dependent on hatchery production. The fall-run Chinook population currently represents the most economically important commercial fishery resource in the Klamath River (USFWS 2013; USFWS Yreka Fish and Wildlife Office 2013, web page). Steelhead runs have also declined but are the Klamath River's highest valued sport fish (USFWS 2013; USFWS Yreka Fish and Wildlife Office 2013, web page). The fishery for Klamath Lake and river populations of redband trout (*O. mykiss newberrii*) is an important recreational resource in the upper Klamath and an important subsistence and cultural resource for the Klamath Tribes (NRC 2004; NCRWQCB 2010a-c). Tribal fishing rights in the Klamath require that fish be able to propagate and produce sufficient numbers for harvest (KBRA 2010). Tribes in the lower Klamath Basin have long relied on their fisheries for anadromous salmon, steelhead, lamprey, eulachon and sturgeon (USFWS 2013; High Country News 2017, web page). In the upper Klamath Basin harvesting of Lost River suckers and shortnose suckers has been important to the culture of the Klamath Tribes and essential to their subsistence (USFWS 2013; Oregon Historical Society 2017, web page).

Based on the considerations described above, Table 4-3 identifies the set of focal species selected for review within this Synthesis Report.

Table 4-3: Klamath Basin focal species selected for review within the Synthesis Report.

| Species | Criteria for focal species selection |
|---|---|
| Chinook salmon (fall- and spring-run) | Commercial Fishery; Tribal Trust Species; Anadromous; Lower Basin |
| Coho salmon | Listed; Tribal Trust Species; Anadromous: Lower Basin |
| Steelhead (winter- and summer run) | Sport Fishery; Tribal Trust Species; Anadromous; Lower Basin |
| Bull trout | Listed; Resident; Upper Basin |
| Redband trout | Sport Fishery; Listed; Resident; Upper Basin |
| Pacific lamprey | Listed; Tribal Trust Species; Anadromous: Lower Basin |
| Green sturgeon | Listed; Tribal Trust Species; Anadromous: Lower Basin |
| Eulachon | Listed; Tribal Trust Species; Anadromous: Lower Basin |
| Shortnose & Lost River suckers | Listed; Resident; Upper Basin |

Selecting too many focal species can undermine the purpose of a focal species approach, which is to organize the discussion in a manner that is still relevant to a wide array of species (Stillwater Sciences 2007). The suite of focal fish species chosen for review within this Synthesis Report are priorities for conservation and management in the Klamath Basin, but also represent a mix of life histories that cover a broad range of habitats, created and sustained by a variety of physical and ecological processes. Evaluating the status of these focal species should provide general insights on the condition of key ecological functions and processes in the basin that will support other fish species with similar life histories and habitat needs. This Synthesis Report takes a broad ecosystem approach (i.e., looking at watershed processes that create and maintain habitats, and the fish communities that use these habitats). However, different fish species will have unique habitat requirements and limiting factors. More detailed assessments of the individual focal species can help to provide greater clarity around particular resource management issues and needs in the basin.

The following sections provide summary information for each of these focal fish species.

## 4.4 Chinook

Chinook salmon (*Oncorhynchus tshawytscha*) (Figure 4-1) were and are the most abundant anadromous fish in the Klamath Basin and represent the most economically important resource in the Klamath River, supporting commercial, sport, and tribal fisheries (NRC 2004). For management purposes, the National Marine Fisheries Services (NMFS) recognizes two Chinook Evolutionarily Significant Units (ESUs) in the Klamath: (1) the Southern Oregon and Coast (SOCC) ESU; and (2) the Upper Klamath and Trinity Rivers ESU. The SOCC ESU includes Klamath Chinook below the Trinity River confluence and is tied to other runs in coastal streams. The Upper Klamath and Trinity Rivers ESU encompass the bulk of the Chinook in the basin, including those of the Trinity River (NRC 2004). This ESU consists of two distinct runs (fall and spring), with runs named for their season of entry and migration up the river. Moyle (2002) indicates that a late fall run may also have existed but it is either poorly documented or extinct. The vast majority of fish in the basin today are fall-run fish of both wild and hatchery origin (NRC 2004).

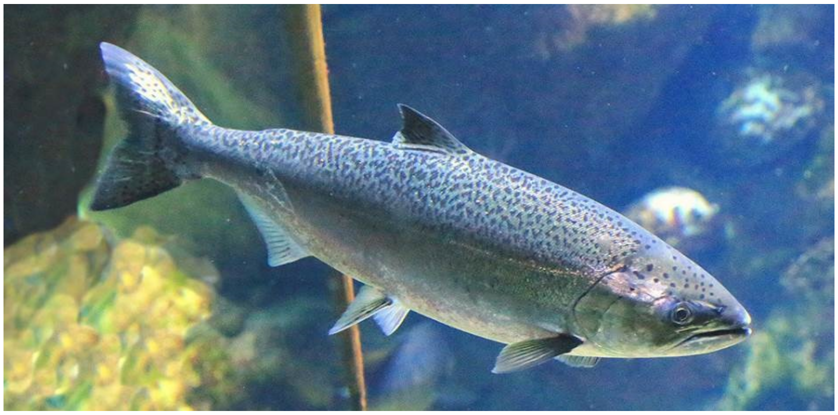


Figure 4-1: Adult Chinook salmon (*Oncorhynchus tshawytscha*). Photo from Ron DeCloux.

### 4.4.1 Population trends

Historically, Chinook salmon runs in the Klamath Basin were much more seasonally diverse (Hamilton et al. 2016), with spring Chinook runs being equal or more abundant than fall-runs prior to the turn of the century (Snyder 1931, as cited in UWRL 1999; NRC 2004). Spring-run Chinook salmon were considered the highest valued fish in the basin as a food source for the Klamath Tribes and were culturally and spiritually significant (K. Greenberg, pers. comm.) Spring Chinook enter the Klamath River early as immatures in good condition and laden with fat, which then remain in the upper tributaries into the fall making them the ideal and preferred salmon species for consumption by all river dependent tribes (K. Greenberg pers. comm.). A shift to a dominant fall run of Chinook began to occur during the early 1900s with loss of habitat that had been used by spring-run Chinook above upper basin dams (W. Sinnen, pers. comm.), a trend likely exacerbated by subsequent hatchery practices in the basin that have promoted monotypical (fall) runs of Chinook salmon (J. Hamilton, pers. comm.). These diverse seasonal migrations of Klamath Basin Chinook, and the life histories associated with these migrations, would have provided various strategies for surviving to reproduce (for salmon, this is referred to as the "portfolio effect" – a spreading of risk and buffering fluctuations in the environment), an important element for increasing resilience and maintaining viable populations (Hamilton et al. 2016). The portfolio effect can increase the ability of salmon to survive local ecological disturbances (such as floods and droughts) and changes ranging from land use activities to years with poor water quality in portions of the river (Hamilton et al. 2016). Dominant fall-run Chinook in the Klamath Basin may have numbered 400,000 to 600,000 fish in the early 1900s, but numbers have fallen much lower in recent decades (Moyle et al. 2008, as cited in USDI, USDC, NMFS 2013). Chinook salmon exhibit a high degree of variability in production, reflecting the large variability in environmental cycles (i.e., ocean conditions and stream flow) and across diverse life histories within each ESU (USDI, USDC, NMFS 2013). Over 1979 to 2010, total returns of fall-run Chinook varied over a 7-fold range. The most recent natural escapement estimates for Klamath wild-run fall Chinook are presented in Figure 4-2.

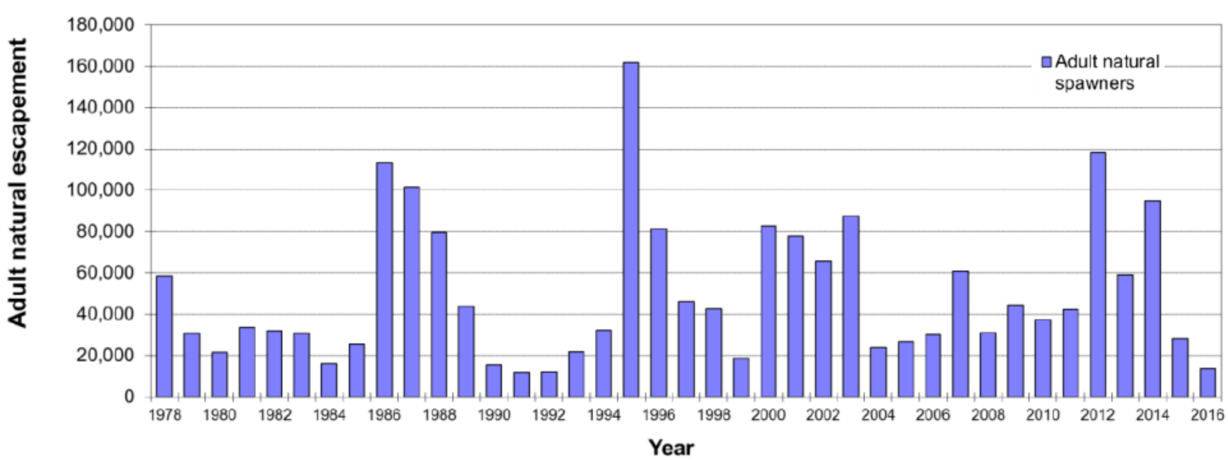



Figure 4-2: Klamath River Basin adult fall-run Chinook salmon natural escapement estimates 1978-2016 (2016 data are preliminary). Figure from CDFW 2016a.

Significant long-term declines of both Klamath wild-run spring and fall Chinook have occurred from historic abundances seen in the basin, with declines estimated at 92 to 96% for wild fall-run Chinook and 98% for wild spring-run Chinook (Table 4-4). Snyder (1931) considered the decline of the spring-run Chinook to have begun prior to the closure of the upper river with construction of the Copco 1 Dam in 1917. He attributed the decline of spring-run Chinook primarily to over-exploitation of the salmon stocks and placer/gravel/suction mining in the basin. Since the construction of dams on the Klamath River, spring-run Chinook have continued this decline and have now been extirpated from a large proportion of their historical range (Moyle et al 2008, as cited in USDI, USDC, NMFS 2013), with the only remaining viable wild population found in the Salmon River. Total numbers of wild-run spring Chinook from the Klamath and Trinity Rivers now range from less than 300 fish to 1,000 fish (Moyle et al. 2008, as cited in USDI, USDC, NMFS 2013). A recent biological review by the National Marine Fisheries Service (Williams et al. 2011) determined that the majority of Klamath Chinook populations in the upper Klamath and Trinity Rivers had generally not declined in spawner abundance over the last 30 years (i.e., late 1970s/early 1980s to 2010). The review concluded that while some populations are extremely low relative to estimates of historical abundance, the current abundance does not constitute a major risk in terms of extinction, and Klamath Chinook therefore did not warrant listing under the Endangered Species Act.

Table 4-4: Estimated declines in Klamath River Chinook returns. Table extracted from USDI, USDC, NMFS 2013.

| Species | Historical Level | Percent Reduction from Historical Levels (estimates of individual runs) | Source |
|---|---|---|---|
| Fall-run Chinook salmon | 500,000[1] | 92% to 96% (20,000-40,000)[2] | Moyle 2002 |
| Shasta River Chinook salmon[3] | 20,000-80,000 | 88% to 95% (a few hundred to a few thousand) | Moyle 2002 |
| Spring-run Chinook salmon | 100,000 | 98% (2000)[1] | Moyle 2002 |

[1] Includes Klamath River and Trinity River Chinook.
[2] Excludes hatchery-influenced escapement.
[3] Shasta River is a subset of the overall Klamath River Chinook population.

## 4.4.2 Historic versus current distribution

The historical distribution of Chinook salmon in the Klamath Basin is known to have extended above Upper Klamath Lake into the Sprague, Williamson and Wood rivers (Hamilton et al. 2005; Hamilton et al. 2016). They were also distributed throughout the lower Klamath Basin in the principle tributaries (i.e., Trinity, Scott, Shasta, and Salmon rivers) and several smaller stream systems (Coots 1962, as cited in UWRL 1999). Currently, distribution of Chinook is limited in the Klamath Basin to the mainstem river, and tributaries downstream of Iron Gate Dam. Upstream distribution of Chinook is currently limited by dams and diversions in several of these tributaries. Access to the upper Klamath Basin was effectively stopped with the completion of Copco Dam 1 in 1917, while access to the upper reaches of the Trinity River and its tributaries was blocked in 1961 with the construction of Lewiston Dam. The final loss of upstream habitat access occurred in 1962 with the completion of Iron Gate Dam (UWRL 1999). The current and historical distributions of Chinook salmon in the Klamath Basin are provided in Figure 4-3.

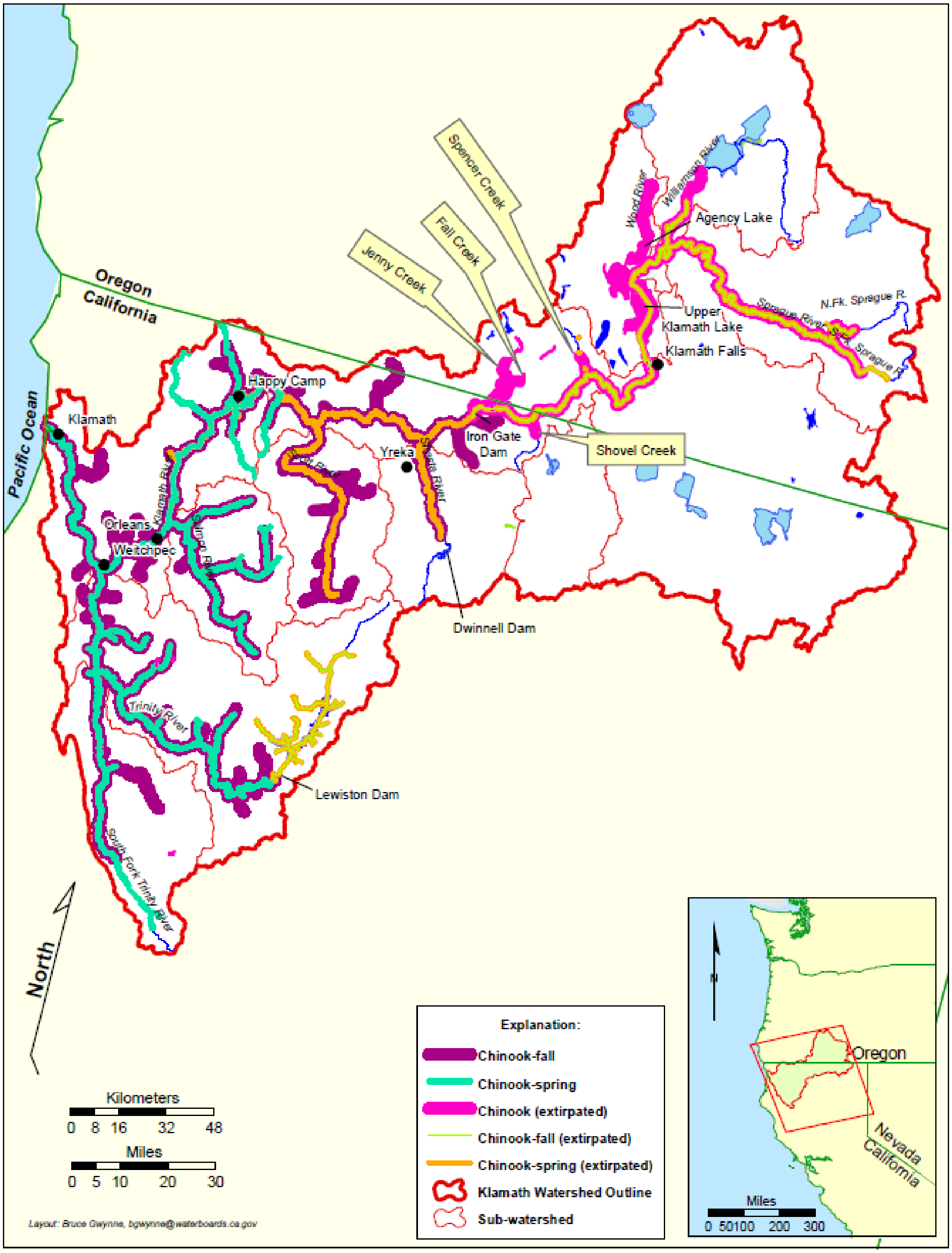



Figure 4-3: Current distribution (purple streams) and areas from which Chinook salmon have been extirpated (pink streams) in the Klamath River Basin. The data for "Chinook extirpated" did not differentiate between fall and spring-run Chinook. Map from NCRWQCB 2010a-c. Data sources for map: Hamilton et al. 2005; Moffett and Smith 1950; Moyle 2002; USFS 1996, USFS 2006; as cited in NCRWQCB 2010a-c.

### 4.4.3 General ecology, life history and periodicity

Chinook salmon spawn and grow primarily in the mainstem of the Klamath River, in the larger tributaries (such as Salmon, Scott, Shasta, and Trinity rivers), Bogus, Indian Elk, and Blue creeks, and also in some smaller tributaries (NRC 2004). Large numbers once spawned in Williamson, Sprague, and Wood rivers above Upper Klamath Lake, but those runs were eliminated by the construction of the Copco Dam 1 in 1917 (NRC 2004).

**Spring Chinook** typically enter the Klamath River from the ocean from early February through to July. Peak immigration generally occurs from March to mid-June. Migrating adults hold in deep pools throughout the summer before spawning in the fall. Spawning may occur from September through mid-October. Deposited eggs incubate for about 40 to 60 days, with alevins remaining in the gravel for a subsequent two to four weeks before fry emerge, beginning in February of the following year. Spring Chinook fry then rear in runs and pools. Spring Chinook will typically hold in freshwater for a year with smolts emigrating to the ocean in the spring following their first winter (i.e., stream-type life history). Outmigration can begin as early as February and continue through mid-June, with peak numbers arriving in the Klamath River estuary during April and May (summary from UWRL 1999). See Table 4-5 for a detailed breakdown of the monthly periodicity of the life history stages of Klamath spring Chinook.

**Fall Chinook** are separated into two runs, fall and late fall runs. The fall run enters the Klamath River from the ocean from mid-July through mid-October while the late fall run occurs from November through January. Egg incubation after spawning generally requires 50 to 60 days with emergence of fry from the gravel typically occurring from February through April. Emergence timing in the tributaries is believed to be earlier than in the mainstem. Due to different life history strategies, outmigration of fall Chinook smolts occurs throughout the year. Type I Chinook outmigrate in the spring and early summer months (i.e., ocean-type strategy), Type II outmigrate in the fall, and Type III hold over the winter and migrate in early spring (i.e., stream-type strategy). The majority of Klamath fall Chinook outmigrate using the Type I strategy. The peak of fall Chinook outmigration is therefore seen from February to August. A wet and cold spring can cause a shift of the peak outmigration up to one month later than occurs during a dry, warm spring (summary from UWRL 1999). See Table 4-5 for a detailed breakdown of monthly periodicity of Klamath fall Chinook life history stages.

Table 4-5: Life history stage monthly periodicity for Chinook salmon in the Klamath River. Table from UWRL 1999.

| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Chinook Salmon Holding and Migration** | | | | | | | | | | | | |
| Adult Fall Run | ■ | | | | | | | | | ■ | ■ | ■ |
| Adult Late Fall Run | | ■ | ■ | ■ | | | | | | | | |
| Spring Run | | | | | ■ | ■ | ■ | ■ | ■ | ■ | | |
| **Chinook Salmon Spawning** | | | | | | | | | | | | |
| Fall Run | ■ | ■ | | | | | | | | | | |
| Late Fall Run | | ■ | ■ | ■ | ■ | | | | | | | |
| Spring Run | ■ | | | | | | | | | | | ■ |
| **Chinook Salmon Emergence** | | | | | | | | | | | | |
| Fall Run | | | | | ■ | ■ | ■ | | | | | |
| Spring Run | | | | | ■ | ■ | ■ | ■ | | | | |
| **Chinook Salmon Rearing** | | | | | | | | | | | | |
| Fall Run | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Late Fall Run | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Spring Run | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| **Chinook Salmon Outmigration** | | | | | | | | | | | | |
| Fall Run | ■ | ■ | ■ | ■ | PEAK | PEAK | PEAK | PEAK | PEAK | PEAK | PEAK | ■ |
| Spring Run | PEAK | ■ | ■ | ■ | ■ | PEAK | PEAK | PEAK | ■ | ■ | ■ | PEAK |
| Yearlings | | | | | ■ | ■ | ■ | ■ | ■ | | | |

## 4.4.4 Habitat requirements and known limiting factors

Habitat requirements and sensitivities for Chinook salmon vary by life history stage.

**Egg:** Chinook eggs require silt-free gravels for development, and are laid in riffles with sufficient sub-gravel flow to bring oxygen to and remove metabolic waste from the eggs (Allen and Hassler 1986). Egg mortality can occur from predation by other fish species or invertebrates, by scouring of gravel during high flows, or due to high concentrations of contaminants (Allen and Hassler 1986).

**Alevin** (newly hatched Chinook with yolk sac still attached): In addition to habitat requirements of the eggs, alevins need adequate amounts of water in the gravel surrounding them. Dewatering of redds (both short events that recur and recurrent prolonged single events) can decrease development rates or cause mortality. Healey (1991) found that the survival rate for alevins experiencing recurrent one hour dewaterings or a single six hour dewatering event was only 4% in both cases.

**Fry** (juveniles): Chinook fry emerge from the gravel and search out suitable rearing habitats in the Klamath mainstem or larger tributaries. Their preferred habitat is fast flowing, low turbidity water with boulder and rubble substrate. Juveniles congregate in areas where they can benefit from both the relatively high velocities in the central part of the channel for drift feeding and the lower velocities behind boulders and large woody debris for resting (Healey 1991). Optimal temperature for Chinook rearing is about 13$^{o}$C but they can feed and grow normally in temperatures as high as 24$^{o}$C in otherwise stress free environments (McCullough 1999). Riparian vegetation is important for providing relief to fry that reside in the freshwater during the hotter summer months, as well as providing cover from predators (Moyle 2002). Predation from other fish species and invertebrates are the two most cited causes of mortality to fry during freshwater residence (Healey 1991). Other salmonids (including hatchery reared Chinook and steelhead) may also increase fry mortality, as they compete for rearing habitat space both in the mainstem and estuary (Kelsey et al. 2002).

**Smolts:** In the Klamath, fall-run Chinook grow to smolt size in their last month of estuarine residence, inhabiting tidal channels with low channel bank elevations and tidal refugia (Healey 1991). By contrast, spring-run Chinook metamorphose into relatively large smolts in the mainstem before they reach the estuary in the spring, and spend only a short time in the estuary before they head to the ocean. The larger spring-run smolts congregate at the river delta front and at near-shore areas close to the river mouth (Healey 1991). Smaller fry in the estuary feed on zooplankton and invertebrates, whereas larger smolts consume invertebrates and other small fish (e.g., chum salmon fry and juvenile herring) (Healey 1991). Cool water temperatures are critical at this time for allowing smoltification and ensuring survival. McCullough (1999) notes that higher water temperatures can prevent smoltification, and the USEPA (1999) found that water temperatures of 17-20$^{o}$C cause decreased growth and impaired smoltification of Chinook juveniles.

**Ocean adults:** Upon leaving the estuary and entering the ocean, Chinook will feed on small marine fishes, crustaceans, and squid until they reach adult size (Healey 1991). Fall-run Chinook will be larger than the spring-run in every subsequent year class due to the slower growth of spring-run Chinook during their first year of life (Healey 1991). Most fall-run Chinook spend almost their entire marine life near shore, close to their home river, whereas many spring Chinook disperse farther offshore (Allen and Hassler 1986). Most adults begin their return to the Klamath River in their third or fourth years (Andersson 2003).

**Spawning adults:** In their last stage of life, Chinook metamorphose from their silvery ocean form into dark spawning colours and return to freshwater to spawn and die. During the upriver migration they stop feeding as their digestive tract degrades and they live increasingly on their body fat. The ability of Chinook to home to their natal stream is based on long-term olfactory memory and vision (Healey 1991), but may be stimulated or impeded by changes in water turbidity, temperature and oxygen content (Allen and Hassler 1986). Adults move upstream searching for deep, relatively cool bedrock holding pools where they can shelter until spawning. Most adult Chinook migrate upstream during the day and can be inhibited by high water temperatures. High temperatures can increase metabolic rates of the adults, depleting their energy reserves. Higher temperatures can also impair the immune system, increasing the susceptibility to disease. Water temperatures above about 15.5$^{o}$C are considered a threshold for the increased onset of diseases, whereas water temperatures above 21$^{o}$C are considered to represent a barrier to Chinook migration in the Klamath Basin (McCullough 1999; Carter 2005). Migrating spring-run Chinook adults appear to have lower temperature tolerances than fall-run Chinook (Allen and Hassler 1986). Exposure of adults to higher water temperatures can inhibit spawning events, lower gamete production, increase pre-hatch mortality, decrease the size of eggs, and result in smaller alevins (Allen and Hassler 1986). An important factor influencing water temperatures for spawning is the amount of shading from surrounding riparian vegetation (Moyle 2002). Additional constraints for migrating Chinook include low dissolved oxygen, shallow water, and/or high sustained water velocity (Allen and Hassler 1986). High levels of suspended sediment may also constrain migration to some extent (Allen and Hassler 1986), but the deposition of fine sediment on gravel spawning areas is likely a greater concern for population effects.

The Klamath River Habitat Assessment Program (led by the USFWS, working closely with agency and tribal partners) has identified a large suite of limiting factors affecting Chinook and other anadromous species (Table 4-6). This program was established by Congress in 2001 to provide a scientific `road map` to help guide restoration of Klamath River anadromous fishes.

Table 4-6: Limiting factors in the Klamath Basin for Chinook salmon and other anadromous species identified by the Klamath River Habitat Assessment Program. Table from USFWS 2013.

| Limiting Factor | Description |
|---|---|
| Water Quality | Excessively high water temperatures, nutrients, and low dissolved oxygen levels |
| Water Quantity | Effects on physical, chemical, and biological factors from alterations of the natural hydrograph (timing, magnitude, duration, and rate of change) |
| Fish Health | Unnaturally high adult and juvenile fish mortalities from disease |
| Fish Passage | Physical constraints (structures) and chemical constraints (such as temperature and dissolved oxygen) to migration |
| Microhabitat | Loss of depth, velocity, and cover availability due to alterations in stream flow |
| Riparian Vegetation | Lack of shade, cover, food production, and large wood recruitment |
| Geomorphology | Loss of the dynamic alluvial processes that form and maintain ecological functions |
| Hatcheries | Competition with natural fish |
| Wetlands | Loss of the distribution, quantity, quality, and diversity of wetlands throughout the Klamath Basin |
| Groundwater | Effects on the stream hydrograph |
| Lake and reservoir operations | Influences on water quantity and quality |
| Unscreened diversions | Effects on survival |
| Fine sediment and high turbidity | Effects on anadromous life stages and river function |
| Contaminants | Effects of fertilizers, herbicides, insecticides, and other contaminants on fish reproduction and survival |
| Coarse Sediment Supply | Reductions in the supply of bed load material due to dams and diversions |
| Thermal Refugia | The presence or absence of cool, clear water entering the Klamath River during periods with adverse temperatures |
| Anadromous juvenile production | Uncertain factors that limit or promote juvenile survival upon ocean entry |
| Non-native species | Effects on the production by native species of competition with non-native species |

### 4.4.5 Management and Recovery Plans

Chinook are considered to be the most abundant salmonid species present in the Klamath Basin. None of the Klamath Basin Chinook populations are listed under the ESA, and no formal recovery plan exists for this species at the state or federal level. Instead, this species is managed primarily through fisheries regulations.

The Pacific Fisheries Management Council (PFMC) is responsible for managing marine migratory or interstate fisheries, and manages Klamath Basin fall Chinook salmon to meet several criteria which can be divided into two main categories: (1) conservation targets; and (2) harvest allocation. The California Fish and Game Commission has authority for in-river fisheries and marine fisheries up to three miles offshore, but has generally adopted a concurrence policy which aligns state regulations with federal regulations. Once allocations have been determined, it is the state's role to hear and adopt regulations tailored to individual allocation levels including bag and possession limits, area closures or restrictions, gear restrictions and seasons.

Currently, the conservation threshold or "floor" for the fall Chinook salmon escapement level is 40,700 adult natural area spawners within the Klamath Basin, including the Trinity River. The floor escapement level was based on stock-recruitment analyses from historical Klamath Basin data to achieve "Maximum Sustained Yield" (MSY) of the stock. The amount of potential harvest opportunity or allocation is known as the "harvestable surplus", which is the number of Klamath adult fall Chinook in excess of the 40,700 natural area adult spawners that are estimated to return to the Klamath Basin in any given year (PFMC 2016).

Annual marine forecasts of abundance are based on cohort relationships and are used to determine initial marine Klamath adult fall Chinook stock size which is the basis for estimating prospective river return levels. Estimated river return levels of the Klamath stock prior to ocean fisheries are made after initial age structure and natural mortality rates by age have been estimated and subtracted from the starting stock size.

The second criterion for management of Klamath fall Chinook stocks is that of harvest allocations between Klamath Basin Tribes that have recognized fishing rights and non-tribal entities. Recently, the harvestable surplus has been split 50:50 between tribal and non-tribal entities. The non-tribal share is split between ocean recreational, ocean commercial and in-river recreational fisheries. The allocation for each non-tribal fishery is determined annually and is influenced by constraints, particularly the Endangered Species Act (ESA), which limits allowable fishing effort and harvest of Klamath stocks due to incidental contact of ESA listed species in marine fisheries. Typically, marine recreational and commercial fisheries receive 85% of the non-tribal allocation, and 15% goes to in-river recreational fisheries. However, as mentioned, these are not fixed percentages and they can fluctuate greatly from year to year.

Recent amendments to the Federal Management Plan for west coast salmon include provisions which do allow for some flexibility to incorporate "*de minimus*" fisheries when Klamath Chinook stocks are projected to be below the 40,700 conservation objective (PFMC 2016). This amendment allows for a sliding scale of harvest rate to be incorporated into Klamath fall Chinook stock management. The main intent of "*de minimus*" fisheries is to allow access to more robust stocks, such as Sacramento fall Chinook stocks, when Klamath stocks are not projected to meet in-river conservation targets (PFMC 2016).

Fall Chinook salmon are managed for a Klamath Basin-wide (including Trinity River) minimum natural area adult escapement of 40,700 adults, with some exceptions (PFMC 2016) (see Table 4-7). Annual recreational harvest quotas are developed by the PFMC. This quota is further divided by the California Fish and Game Commission into sub-quota areas that receive a percentage of the annual allocation. Currently, the Lower Klamath (below the confluence of the Trinity River) receives 50% of the total allocation, 17% goes to the upper Klamath, and the

Trinity River receives 33% which is split into two sub-quota areas (lower and upper). Annual bag and possession limits are developed by the California Fish and Game Commission. Generally, the daily bag limit ranges from two to four fish, of which one to four may be adults (>22 inches total length). If the adult quota is attained, anglers may still harvest jack salmon less than 22 inches total length to fill their daily bag limit. The possession limit is generally three times the daily bag limit.

Table 4-7: Conservation objectives and reference points governing harvest control rules and status determination criteria for Chinook salmon stocks and stock complexes in the Pacific Coast Salmon Fisheries Management Plan (PFMC 2016).

| Species | Stocks In The Fishery | Conservation Objective | $S_{MSY}$ | MSST | MFMT ($F_{MSY}$) | ACL |
|---|---|---|---|---|---|---|
| Chinook | California Coastal Chinook ESA Threatened | NMFS ESA consultation standard/recovery plan: Limit ocean fisheries to no more than a 16.0% age-4 ocean harvest rate on Klamath River fall Chinook. | Undefined | Undefined | Undefined | ESA Consultation Standard Applies |
| | Klamath River Fall Indicator stock for the Southern Oregon Northern California (SONC) Chinook stock complex | At least 32% of potential adult natural spawners, but no fewer than 40,700 naturally spawning adults in any one year. Brood escapement rate must average at least 32% over the long-term, but an individual brood may vary from this range to achieve the required tribal/nontribal annual allocation. Natural area spawners to maximize catch estimated at 40,700 adults. | 40,700 | 30,525 | 71% | Based on $F_{ABC}$ and annual ocean abundance. $F_{ABC}$ is $F_{MSY}$ reduced by Tier 1 (5%) uncertainty. |
| | Klamath River – Spring Chinook | Undefined | Undefined | Undefined | Undefined | Component stock of SONC complex; ACL indicator stock is KRFC |

ACL = annual catch limit, AEQ = adult equivalent, MSST = minimum stock size threshold, MFMT = maximum fishing mortality threshold, MSY = maximum sustainable yield, S = number of adult spawners, KFRC = Klamath River Fall Chinook

## 4.4.6 Conceptual and quantitative models

Scientists have expended considerable effort on developing conceptual and quantitative models of Chinook salmon in the Klamath Basin (e.g., Hendrix 2011, Hendrix 2012, Hardy et al. 2012). Such models can be helpful for predicting population responses to current and potential management manipulations of the system. The Salmonid Population Model (SALMOD) (subsequently updated as SALMOD II for additional functionality) is a foundational one that has been widely employed in the Klamath Basin (Hardy et al. 2012) as a fish production model. It was designed to represent the life cycle of fall-run Chinook salmon from holding adults ready to spawn through to the immature smolt stage preparing to return to the ocean. SALMOD applies the Instream Flow Incremental Methodology (Stalnaker et al. 1995), an approach which links habitat limitations to population attributes such as growth, movement and survival at both microhabitat and macrohabitat scales (Williams et al. 2011). SALMOD has been used in the Klamath in past simulations of the spawning, incubation, rearing, and outmigration of juvenile fall Chinook salmon under different basin conditions.

SALMOD and SALMODII have now been replaced by the new, more versatile Stream Salmonid Simulator (S3), a Chinook production model currently in final stages of development for the Klamath Basin (Perry et al. 2014; R. Perry, pers. comm.). The S3 Model (part of a collaborative effort between the USFWS, U.S. Geological Survey, and Texas State University) retains much of the underlying conceptual framework used within SALMOD and SALMODII (i.e., habitat availability and density dependence drive Chinook population dynamics at a mesohabitat spatial scale and a daily timescale). The S3 decision support tool is an integrated subset of models used to predict the effects of water management alternatives on movement, health, and production of juvenile Chinook salmon (Perry et al. 2016a, Perry et al. 2016b). The model (see Figure 4-4) tracks causes of mortality (i.e., red scour, habitat limitations, disease, water quality, etc.) over time throughout the sub-adult life history of Chinook salmon within the 223-mile section of the mainstem Klamath River spanning from Keno Dam in Oregon to its confluence with the Pacific Ocean in California (USFWS 2013a-c).

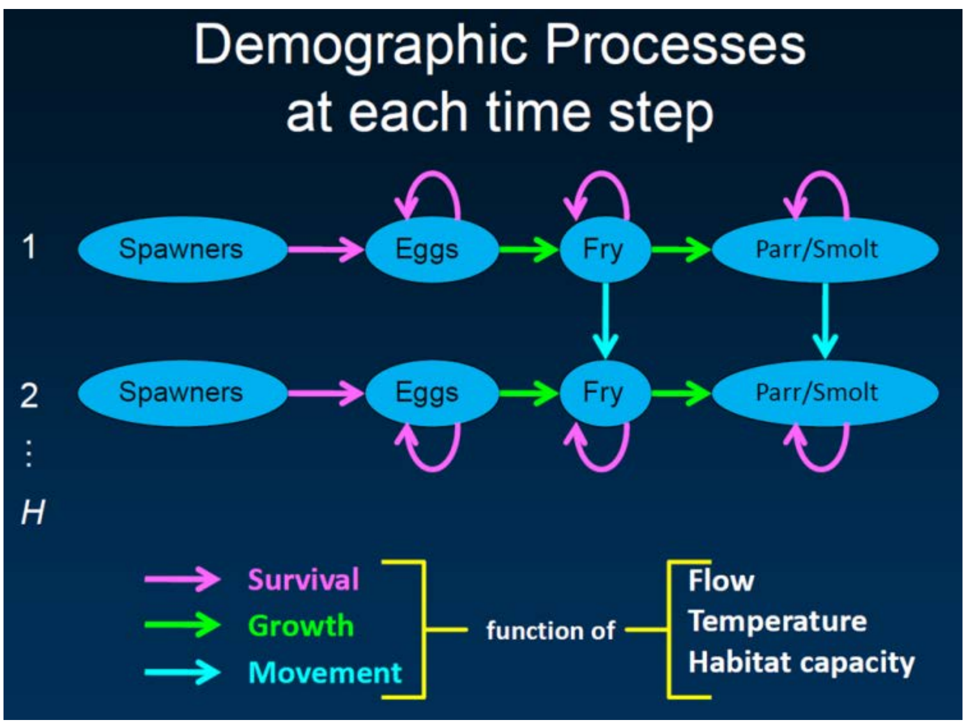



Figure 4-4: Demographic process of the Stream Salmonid Simulator (S3) Model at each time step within sequential mesohabitat units $H_{1\text{-}I}$ in the Klamath River. Graphic provided by USFWS/USGS.

Continued development of the S3 Model includes the construction of a water temperature model that has been used for various other purposes, including to help assess the effects of fall flow augmentation water management alternatives in reducing water temperatures and the associated risk of an adult fish kill in the Lower Klamath River. Another critical component of the S3 Model is its juvenile fish disease sub-model, which was developed through an on-going partnership between the model developers and the Service's California-Nevada Fish Health Center and the Department of Microbiology, and the John L. Fryer Aquatic Animal Health Laboratory at Oregon State University. The S3 disease sub-model simulates the infection prevalence and resulting fish mortality via the fish parasite *C. shasta* in relation to biological and physical factors experienced by juvenile salmon in the Klamath River.

Calibration and validation of the S3 Model to historical abundance estimates of juvenile Chinook salmon has been completed. Next steps include extending the S3 Model into the Trinity Basin, and the addition of an ocean component and an upstream adult migration sub-module. These improvements will transform S3 into a full life cycle model that can be used to evaluate the effectiveness of channel rehabilitation projects, gravel injections, large wood augmentation, differing flow regimes, etc. on both the Klamath and Trinity rivers by isolating ocean versus in river influences on fish production.

### 4.4.7 Critical uncertainties & hypotheses

The expectation is that dam removal would benefit Chinook by restoring access to hundreds of stream miles of historical habitat, and by improving downstream conditions by ameliorating factors that are believed to be limiting Chinook populations (e.g., flow conditions, sediment and bedload transport, water quality, fish disease, toxic algal blooms, and water temperature). Dam removal would most notably provide an opportunity for spring-run Chinook salmon to become re-established in the Upper Klamath Basin. Holding areas with suitable temperatures for spring-run Chinook are thought to exist upstream of Iron Gate Dam in locations such as Big Springs in the J.C. Boyle Bypass Reach, groundwater-influenced areas on the west side of Upper Klamath Lake, and the Wood River (BLM 2003; Gannett et. al 2007, as cited in USDI, USDC, NMFS 2013). The Williamson River, both upstream and downstream of its confluence with the Sprague River, continues to provide deep, coldwater holding habitat (Hamilton et al. 2010). It is also likely that holding habitat exists under the reservoirs where tributaries would join the mainstem. Dam removal would make these habitats available to migrating spring-run Chinook salmon adults (USDI, USDC, NMFS 2013). The best available science indicates that Chinook salmon would (with a high degree of certainty) naturally recolonize useable habitats in areas upstream of Iron Gate Dam in a short period of time (USDI, USDC, NMFS 2013). If however this process failed to occur naturally, it is predicted that a supporting program to actively re-introduce Chinook into the upper basin would be successful (USDI, USDC, NMFS 2013). The expectation is that this would significantly increase Chinook abundance (and associated harvest) relative to leaving the dams in place (multiple authors cited in USDI, USDC, NMFS 2013).

There is some uncertainty however in the likely range of this population response (USDI, USDC, NMFS 2013). Predictions of population responses depend on what is assumed about the amount and quality of useable habitat above Keno Dam, the potential productivity of spring-run Chinook, and the likely population trajectory of Chinook salmon if the dams were left in place (USDI, USDC, NMFS 2013). Modeling results from 50 years (2012 through 2061) do however indicate, with a greater than 95% level of certainty, that dam removal and associated implementation of supporting restoration activities would increase median Chinook adult production by 81% (Hendrix 2012, as cited in USDI, USDC, NMFS 2013). Chinook salmon harvests would also be expected to increase in this period, with median increases of 55% for tribal harvest, 46% for ocean commercial and sport fisheries harvest, and 9% for the river sport fishery harvest (USDI, USDC, NMFS 2013) (see Figure 4-5). Note however that modeling by USDI, USDC, NMFS (2013) included a wide range of intended KBRA restoration activities in addition to dam removal which may not be part of actual future funded restorations in the basin.

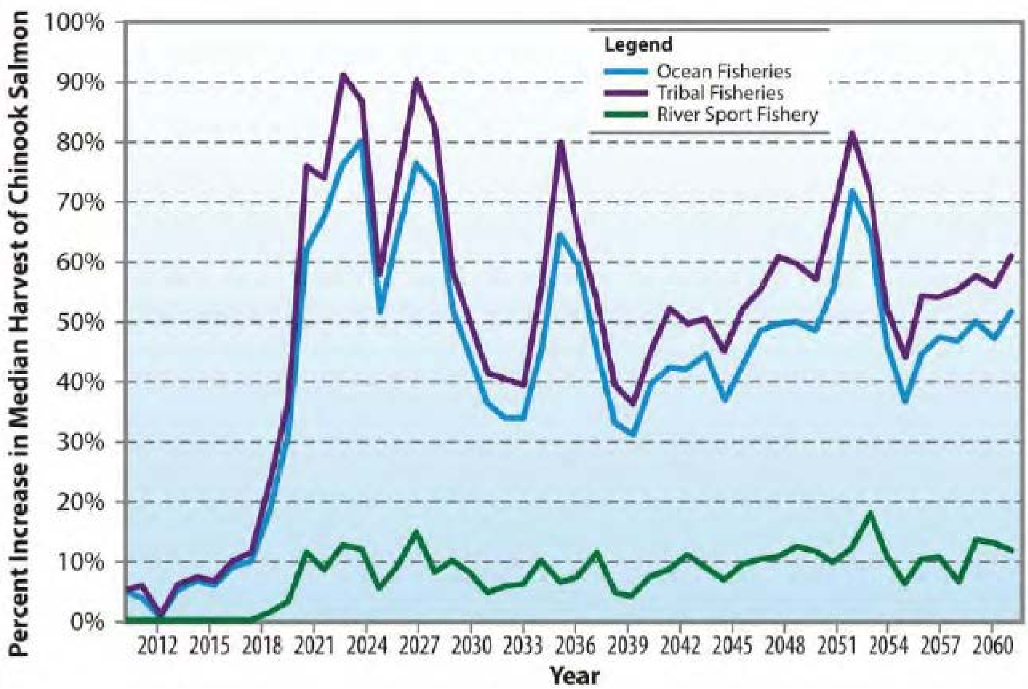



Figure 4-5: Median annual percent increase from 2012 in the harvest of Klamath River Chinook salmon in the ocean (commercial and sport), tribal, and in-river sport fisheries as predicted by the EDRRA (Evaluation of Dam Removal and Restoration of Anadromy) life cycle production model for dam removal and restoration action implementation. Figure from Hendrix 2011, as reproduced in USDI, USDC, NMFS 2013.

There is some uncertainty and associated concern related to the extent of suspended sediment concentrations that could be released from the reservoirs after dam removal, especially if proposed timelines for reservoir drawdown could not be achieved. Proposed plans for removing the four hydroelectric dams calls for reservoir drawdown to occur in a controlled manner beginning in January such that the majority of erodible sediment would be released downstream in the winter and early spring of that year (USDI, USDC, NMFS 2013). In the event that reservoir drawdown cannot be accomplished in expected timelines, continued high levels of suspended sediment in the mainstem of the Klamath River could negatively affect fish into consecutive years, potentially affecting Chinook and their downstream habitats across consecutive year classes (USDI, USDC, NMFS 2013). Although expected to be short in duration, this suspended sediment release is expected to result in some lethal and sub-lethal effects on a portion of fish populations, with corresponding effects on commercial, tribal, and recreational fisheries (USDI, USDC, NMFS 2013). Even if lower concentrations of sediment were alternatively released over multiple years at sub-lethal levels, the cumulative long-term effects on a population of successive cohorts are uncertain but are expected to be detrimental (USDI, USDC, NMFS 2013). The modeled worst case basin-wide mortalities for Chinook (both adults and juveniles) are, however, all less than 10 percent (NMFS and USFWS 2013). In spite of expected short-term mortalities associated with suspended sediment releases, salmon, steelhead trout and other native anadromous species are anticipated to increase in abundance and viability over the long term with removal of the dams (NMFS and USFWS 2013).

### 4.4.8 Candidate research and assessment priorities

The Klamath River Habitat Assessment Program has identified five priority areas for undertaking research in the basin: hydrology, water quality, microhabitat, geomorphology, and fisheries biology (USFWS 2013a). Within each of these areas, there remains a need to prioritize data collection, analysis, and development of predictive models to inform management and restoration decisions. Across the limiting factors for anadromous fish identified by the Klamath River Habitat Assessment Program, program partners identified fish health as the highest priority for studies within the anadromous reach of the lower Klamath Basin. Past assessments have indicated that due to unnaturally high infection rates from *C. shasta mortality rates for juvenile salmon migrating down the mainstem Klamath River have been as high as* 45% in some years (USFWS 2013a). Continuing studies and analyses are considered critical to understanding the mechanisms that cause infection, disease and subsequent mortality of juvenile salmon from the myxozoan parasite *C. shasta*.

The proposed California Coastal Salmonid Monitoring Plan (CMP) (Adams et al. 2011) recommends that a network of permanent Life Cycle Monitoring (LCM) stations be established to provide long term, intensive monitoring of Chinook salmon (as well as coho salmon and steelhead) populations in the Klamath Basin and other key coastal watersheds. Data obtained from LCM stations (i.e., measures of adult abundance from counting facilities, spawning survey estimates of adult abundance, outmigrant smolt counts) would be used to inform assessments of freshwater and ocean survival, essential to understanding whether changes in salmonid numbers are due to recovery from improvements in freshwater habitat conditions or changes in ocean conditions.

As noted, the above list of potential research and assessment activities needs to be further prioritized and sequenced. That effort should focus on those gaps in understanding and data which will most help to reduce critical uncertainties that significantly affect the choices between alternative management decisions on restoration actions and fish management, and/or improve the ability to evaluate the effectiveness of those decisions.

## 4.5 Coho salmon

Coho salmon (*Oncorhynchus kisutch*) (Figure 4-6) in the Klamath Basin belong to the Southern Oregon/Northern California Coast (SONCC) Evolutionarily Significant Unit (ESU), and is federally listed as Threatened (1997) (NMFS and USFWS 2013). In 2005, the NMFS also included ESA protections for hatchery-raised coho salmon produced at the Klamath Basin Iron Gate and Trinity River Hatcheries (CDFW 2017, webpage), Klamath coho are a Tribal Trust species and are state listed as Critical in Oregon and Threatened in California. Coho are extirpated from the upper Klamath Basin (NRC 2008). Williams et al. (2008) described nine coho salmon populations in the Klamath Basin, including the Upper Klamath River, Shasta River, Scott River, Salmon River, Middle Klamath River, Lower Klamath River, and three population units within the Trinity Basin (Upper Trinity River, Lower Trinity River, and South Fork Trinity River). All of these Klamath coho populations are considered to be at a moderate or high risk of extinction because of their small population sizes (i.e., closer to or below depensation threshold) (NMFS and USFWS 2013).

Figure 4-6: Klamath River coho (*Oncorhynchus kisutch*) juvenile. Photo by Jonny Armstrong).

### 4.5.1 Population trends

Historically, substantial runs of coho salmon were an important contributor to regional commercial, recreational, and tribal fisheries in the Klamath Basin (NMFS and USFWS 2013). Although long-term data on coho salmon abundance are scarce, the available monitoring data indicate that spawner abundance has declined for populations in the SONCC coho salmon ESU (NMFS and USFWS 2013). Historical spawning escapement estimates for the Klamath River Basin approximate 15,400 to 20,000 coho, with 8,000 of these fish originating in the Trinity River (NCRWQCB 2010a-c). Long-term declines in abundance from historical levels for coho salmon in the Klamath Basin have been estimated as 52 to 95% (NMFS and USFWS 2013 (Table 4-8). The National Research Council indicated that overall coho salmon returns in the Klamath Basin have declined by 70 percent in the period since the 1960s (NRC 2008). In the Shasta River, two of the three year classes have declined to the point that they are considered to be functionally extinct (NRC 2004) and in the Trinity River, wild coho salmon stocks are estimated to be at only 4 percent of their former abundance (NRC 2004). Such declines have been attributed to the cumulative effects of dam construction, hydrologic modifications, changing ocean conditions, agricultural development, timber harvest, overfishing, and mining (NMFS and USFWS 2013). Commercial fisheries have been identified as a major factor in the past decline of the SONCC coho salmon ESU. However, coho salmon-directed fisheries and coho salmon retention have been prohibited off the coast of California since 1996 (NMFS and USFWS 2013). Incidental mortality occurs as a result of non-retention impacts in California and Oregon Chinook-directed fisheries and in Oregon's mark-selective coho fisheries (NMFS and USFWS 2013). Klamath Basin Tribes (Yurok, Hoopa, and Karuk) harvest a relatively small number of coho salmon for subsistence and ceremonial purposes under federal reserved fishing rights in the Klamath River Basin (NOAAF 2010).

Table 4-8: Estimated declines in Klamath coho salmon returns from historic levels. Table from USDI, USDC, NMFS 2013.

| Species | Historical Level | Percent Reduction from Historical Levels (estimates of individual runs) | Source |
|---|---|---|---|
| Coho salmon | 15,400-20,000 | 53% to 95% (760-9,550) | Moyle et al. 1995; Ackerman et al. 2006 |

## 4.5.2 Historic versus current distribution

Less than 70 percent of streams historically inhabited by coho salmon in the Klamath Basin still contain populations (NRC 2004). It is assumed that all tributaries in the Klamath Basin with sufficient access and habitat at one time supported coho (INSE 1999). Coho salmon were once found at least a short way above Iron Gate Dam, with reports of coho spawning in the Klamath River and its tributaries as far as Spencer Creek in Oregon (Hamilton et al. 2005). There are, however, no known records of coho in the upper Klamath Basin (Hamilton et al. 2005). NOAA Fisheries estimated that within the Klamath River Basin, the construction of Iron Gate Dam blocked access to approximately 48 km (30 miles) of mainstem habitat, about 8% of the historical coho salmon habitat in the entire Klamath River Basin (NMFS 1997). The current and historical distributions of coho salmon in the Klamath Basin are provided in Figure 4-7.

## 4.5.3 General ecology, life history and periodicity

Coho salmon is an anadromous fish species that generally exhibits a relatively simple 3-year lifecycle (summary below primarily from NMFS and USFWS 2013).

**Spawning Adults:** Coho typically migrate into the Klamath River during mid-September through mid-January. Upstream migrations are typically associated with pulse flows due to fall rain events (INSE 1999). Spawning usually occurs during mid-September through mid-January (INSE 1999) in small, low gradient tributary streams, although they have been observed spawning in side channels, at tributary confluences, and suitable shoreline habitats in the river mainstem (INSE 1999).

**Eggs:** About 100 or more eggs are deposited in each coho redd (gravel nests excavated by spawning females). Eggs incubate in the gravels from November through about April before hatching as alevins. The incubation timing is inversely related to water temperature (CDFW 2017, webpage).

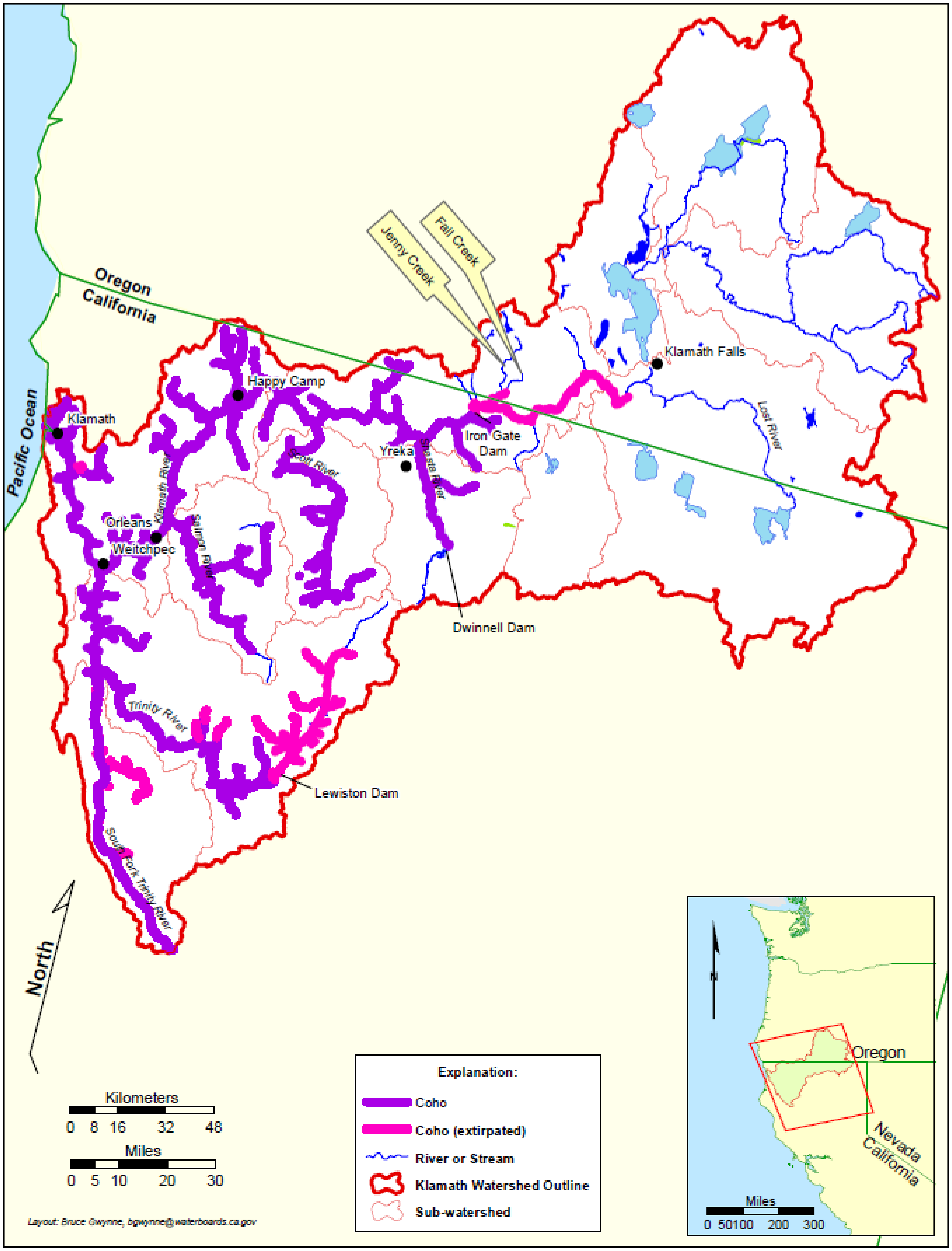



Figure 4-7: Current distribution (purple streams) and areas from which coho salmon have been extirpated (pink streams) in the Klamath River Basin. Map from NCRWQCB 2010a-c. Data sources for map: Brown and Moyle 1991; Brown et al. 1994; CDFW 2002; Cyr 2006; Hamilton et al. 2005; USFS 1996; as cited in NCRWQCB 2010a-c.

**Alevins** (a larval life stage dependent on food stored in a yolk sac): After hatching from the eggs the alevins likely represents the most vulnerable coho life stage, during which they are susceptible to being buried in silt, freezing, gravel scouring and shifting, desiccation due to redd exposure, and predation. Alevins remain in the interstices of the gravel for two to 10 weeks until their yolk sacs are absorbed (CDFW 2017, webpage).

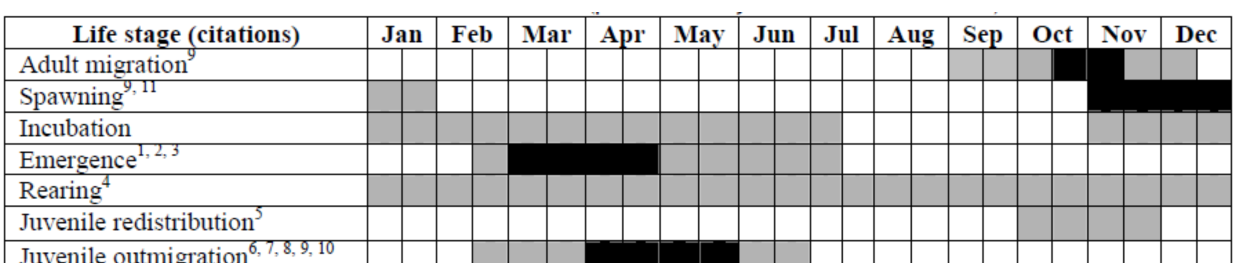
**Fry/Juveniles:** Coho fry typically emerge from the gravel and begin actively feeding between March and July, depending on when eggs were fertilized and the water temperature during development (CDFW 2017, webpage). Upon emergence they seek out shallow water, usually moving to the stream margins, where they form schools. Juveniles may spend one to two years rearing in freshwater, or emigrate to the estuary shortly after emerging from spawning gravels. Coho salmon juveniles are also known to “redistribute” into non-natal rearing streams, lakes, or ponds, where they continue to rear. Optimal water temperature ranges for coho are 3.3 to 20.5 $^{o}$C, although preferred rearing temperatures are 12.0 to 14.0$^{o}$C. Upper lethal temperatures have been reported as 25.6$^{o}$C (INSE 1999).

**Smolts:** Juveniles rear in fresh water for up to 15 months, and then migrate downstream to the Klamath estuary and ocean as smolts in the spring. In some years smolt emigration can begin prior to March and can persist into July. Factors that affect the onset of emigration include fish size, flow conditions, water temperature, dissolved oxygen levels, day length, and food availability (CDFW 2017, webpage). The amount of time coho spend in the river estuary prior to entering the ocean is variable.

**Ocean adults:** Coho salmon typically spend about another 15 months in the ocean before returning to their natal stream to spawn as 3 year-olds. Some precocious males, called ‘‘jacks,’’ return to spawn after only six months at sea. Data on ocean distribution of California coho salmon are sparse, but it is believed that the coho scatter and join schools from Oregon and possibly Washington (CDFW 2017, webpage).

Coho salmon life history stage periodicity within the Klamath River is detailed in Table 4-9.

Table 4-9: Life history stage timing of coho salmon in the Klamath River Basin downstream of Iron Gate Dam (peak activity indicated in black). Table from Stillwater Sciences 2010b.




[1] CDFG (2000, unpubl. data, as cited in NRC 2004); [2] CDFG (2001, unpubl. data, as cited in NRC 2004); [3] CDFG (2002, unpubl. data, as cited in NRC 2004); [4] Sandercock (1991); [5] T. Soto, Fisheries Biologist, Yurok Tribe, pers. comm., 2008; [6] Scheiff et al. (2001); [7] Chesney and Yokel (2003); [8] T. Shaw (USFWS, unpubl. data, 2002, as cited in NRC (2004); [9] NRC (2004); [10] Wallace (2004); [11] Maurer (2002)

## 4.5.4 Habitat requirements and known limiting factors

Coho salmon require streams that provide suitable spawning gravels and good juvenile rearing habitat. Coho require clean, well oxygenated flows in their spawning streams to ensure good aeration of eggs and embryos in their redds and the flushing of waste products (CDFW 2017, webpage). Typical rearing areas used by juvenile coho are quite mixed and can include low-gradient coastal streams, sloughs, side channels, alcoves, estuaries, low-gradient tributaries, large rivers, beaver ponds, and large slack waters (NRC 2004). The most productive juvenile habitats are found in smaller streams with low-gradient alluvial channels containing abundant pools formed by large woody debris (CDFW 2017, webpage). However, the mainstem Klamath River also contains habitat suitable for all freshwater life stages. For example, juvenile coho salmon utilize thermal refugia habitat in the mainstem Klamath River through periods of temperature stress (Stillwater Sciences 2010b). These refugia are generally located at the confluence of tributaries with the mainstem and in locations of hyporheic flow and groundwater infiltration (Stillwater Sciences 2010b). Recent studies in the Lower Klamath, Middle Klamath and Shasta sub-basins confirm that beaver ponds provide high quality summer and winter rearing habitat for coho salmon (Chesney et al. 2009, Silloway 2010, as cited in NOAAF 2014). Adequate winter rearing habitat is important to successful completion of coho life history and, due to agricultural land development and other human activities that have impacted traditional floodplain and riparian areas, is often lacking in many California streams (CDFW 2017, webpage).

Human activities have been implicated in the decline of coho salmon in California through the loss and degradation of suitable freshwater and estuarine habitats. This has occurred through land and water developments associated with agriculture, forestry, gravel mining, urbanization, water supply, and river regulation (Moyle 2002). Depletion of stream flows resulting in reduced coho juvenile rearing habitat availability and stranding of juvenile coho can be a significant problem in some Klamath Basin tributaries during the irrigation season in average and below average water years (INSE 1999). Coho salmon spend an extended period rearing in freshwater habitats and, being near the southern end of their distribution in the Klamath Basin, often reside in streams already near the upper limits of their thermal tolerance (NOAAF 2014). Through effects on air temperatures and stream flows, climate change is expected to increase water temperatures to the detriment of coho salmon. Climate change effects on stream temperature may already be apparent (Isaak et al. 2012). For example, in the Klamath River, Bartholow (2005) observed that there has been a 0.5ºC per decade increase in water temperature since the early 1960s, and model simulations predict a further increase of 1-2ºC over the next 50 years (Perry et al. 2011, as cited in NOAAF 2014).

River regulation from dam operations is considered a primary factor in the proliferation of fish diseases that are now widespread in the mainstem Klamath River during certain time periods and in certain years, and have been shown to adversely affect freshwater abundance of coho salmon. High infection rates have been documented in emigrating juvenile coho salmon downstream of Iron Gate Dam during the spring and summer in some years, primarily by one or both of the myxozoan parasites *C. shasta* and *P. minibicornis* (NMFS and USFWS 2013). NOAA Fisheries Service (2010) determined that the lack of fall and winter flow variability in the Lower Klamath River due to dam operations has reduced the effectiveness of environmental cues for juvenile coho salmon to redistribute in the mainstem river, resulting in individuals using less favorable habitat throughout the winter. Additionally, they determined that this lack of fall and winter flow variability increased disease risk for juvenile salmon by creating optimal steady flows and temperatures for the proliferation of the pathogens *C. shasta* and *P. minibicornis* (NOAAF 2010). Ceratomyxosis, which is caused by *C. shasta*, is one of the most significant diseases affecting juvenile coho salmon due to its prevalence and impacts in the Klamath Basin (Nichols et al. 2003). Bartholomew et al. (2006) believes that the recent increases in air temperature may be compounding the disease potential in the Klamath Basin. High water temperature, low dissolved oxygen, high pH (alkalinity) and possibly unionized ammonia in the mainstem Klamath River create stressful conditions for all ages and types of salmonids and possibly compound the disease potential in the Klamath Basin (NOAAF 2014). These stressors can then increase disease transmission to coho salmon. Severe infection of juvenile coho salmon by *C. shasta* may be contributing to declining adult coho salmon returns in the Klamath Basin (Foott et al. 2010a,b). *C. shasta* has been responsible for most of the mortality of Klamath River juvenile salmonids in recent years. Mortality rates from temporary and longer term exposures at various locations in the Klamath River vary based on location, time of year, year, and water temperature, but are consistently high (10 to 90%) (Bartholomew 2008, as cited in NOAAF 2014). Additionally, parasitic infections by *P. minibicornis* have been detected in high levels in young of the year and yearling coho salmon in the mainstem Klamath River in at least some years (e.g., Nichols et al. 2008, as cited in NOAAF 2014).

The Final Recovery Plan for the SONCC coho salmon ESU (NOAAF 2014) lists a series of Key Limiting Stresses and Key Limiting Threats across the nine Klamath Basin coho salmon populations (Table 4-10). Key limiting stresses and threats are those stresses and threats considered by NOAA Fisheries to be those that are the most pressing factors limiting recovery of salmon populations. Recovery actions to address key limiting stresses and threats often have a higher priority than those that would address other stresses and threats (NOAAF 2014).

Table 4-10: Klamath Basin coho salmon populations and their key limiting stresses and threats. Table extracted from NOAAF 2014.

| Stratum | Population | Key Limiting Stresses | | Key Limiting Threats | |
|---|---|---|---|---|---|
| Central Coast Basin | Lower Klamath River | Structure | Sediment | Channelization | Agriculture |
| Interior Klamath | Middle Klamath River | Structure | Water Quality | Dam/Diversion | Fire |
| | Upper Klamath River | Hydro Function | Barriers | Dam/Diversion | Roads |
| | Shasta River | Hydro Function | Water Quality | Dam/Diversion | Agriculture |
| | Scott River | Hydro Function | Riparian | Dam/Diversion | Agriculture |
| | Salmon River | Structure | Riparian | Fire | Climate Change |
| Interior Trinity | Lower Trinity River | Structure | Hydro Function | Channelization | Hatcheries |
| | South Fork Trinity River | Hydro Function | Water Quality | Dam/Diversion | Roads |
| | Upper Trinity River | Hydro Function | Hatchery Effects | Dam/Diversion | Hatcheries |

The Final Recovery Plan for the SONCC coho salmon ESU (NOAAF 2014) also identifies and ranks the current severity of individual stresses and threats effecting each life history stage of coho salmon within the lower Klamath Basin (see Table 4-11 (stresses) and Table 4-12 (threats)).

Table 4-11: Severity of stresses affecting each life stage of coho salmon in the Lower Klamath River. Table from NOAAF 2014.

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

[1]Key limiting stresses and limited life stage.

Table 4-12: Severity of threats affecting each life stage of coho salmon in the Lower Klamath River. Table from NOAAF 2014.

| | Threats | Egg | Fry | Juvenile[1] | Smolt | Adult | Overall Threat Rank |
|---|---|---|---|---|---|---|---|
| 1 | Agricultural Practices[1] | High | High | Very High[1] | Very High | High | Very High |
| 2 | Channelization/Diking[1] | Medium | Medium | Very High[1] | Very High | Medium | Very High |
| 3 | Roads | High | High | High | High | High | High |
| 4 | Timber Harvest | High | High | High | High | Medium | High |
| 5 | Dams/Diversions | Low | Medium | High | High | High | High |
| 6 | Climate Change | Low | Low | Medium | Medium | Medium | Medium |
| 7 | Hatcheries | Medium | Medium | Medium | Medium | Medium | Medium |
| 8 | Urban/Residential/Industrial Dev. | Low | Low | Medium | Medium | Medium | Medium |
| 9 | Road-Stream Crossing Barriers | - | Medium | Medium | Low | Low | Medium |
| 10 | Invasive Non-Native/Alien Species | Low | Low | Medium | Medium | Low | Medium |
| 11 | Mining/Gravel Extraction | Low | Low | Medium | Medium | Low | Medium |
| 12 | Fishing and Collecting | - | - | Low | Low | Medium | Low |
| 13 | High Severity Fire | Low | Low | Low | Low | Low | Low |

[1]Key limiting stresses and limited life stage.

Genetic and life history diversity for some Klamath coho populations may be at risk due to low population abundance and the influence of hatcheries and out-of-basin introductions (NOAAF 2014). Although the operation of a hatchery tends to increase the abundance of returning adults, Williams et al. (2008) considered a population to be at least at a moderate risk of extinction if the contribution of hatchery coho salmon spawning in the wild exceeds 5 percent. Six of the nine coho populations in the Klamath Basin are considered at high to very high risk from hatchery effects (NOAAF 2014). Table 4-13 shows the Klamath Basin coho populations with hatchery stress and threat ranks of high (greater than 10 percent and less than 30 percent hatchery-origin adults) and very high (greater than 30 percent hatchery-origin adults) as assessed by NOAAF (2014).

Table 4-13: Coho populations in the Klamath River Basin with hatchery effects rated as high or very high stress and threat. Table extracted from NMFS 2014. The table shows the percent of hatchery spawners and the source of those data (as cited in NMFS 2014).

| Population | Stress and Threat Rank | Average Percentage Hatchery Origin Adults |
|---|---|---|
| Upper Klamath River | Very High | 47% at Bogus Creek from 2004 to 2012, excluding 2006 and 2009; Knechtle and Chesney (2014) |
| Shasta River | High | 16% in 2001, 2003, 2004; Ackerman and Cramer (2006)<br>23% from 2001 to 2004; Ackerman et al. (2006)<br>43% from 2007 to 2012; Chesney and Knechtle (2013) |
| Lower Trinity River | Very High | 85-97% from 1997 to 2002; Sinnen et al. 2009<br>60-100% from 1998 to 1999; Dutra and Thomas (1999) |
| South Fork Trinity River | Very High | 36% in 1985; Jong and Mills (1992) |
| Upper Trinity River | Very High | 97%, USFWS and HVT (1999) |

## 4.5.5 Management and Recovery Plans

Southern Oregon/Northern California Coast (SONCC) coho salmon have been the subject of the greatest recovery planning efforts in the Klamath Basin, in part due to the early listing of this Evolutionarily Significant Unit (ESU) as a threatened species in 1997, a ruling which was reaffirmed in 2005 (NMFS 2014). In California, northern populations of coho were listed as threatened under the California Endangered Species Act in 2002, spurring the release of a recovery strategy and recommendations for coho in the Shasta and Scott rivers in 2003 (Shasta-Scott Coho Salmon Recovery Team 2003). The recovery strategy for Shasta and Scott rivers in turn informed the subsequent release of a statewide Recovery Strategy for California Coho Salmon in 2004 (CFWS 2004). In Oregon, coho recovery was considered as part of the Oregon Coastal Salmon Restoration Initiative (OCSRI) started in 1995, and it culminated in the release of The Oregon Plan in 1997, which aims to restore all salmon populations and fisheries to productive and sustainable levels. These plans have been incorporated into a single regional Recovery Plan for the Southern Oregon/Northern California Coast Evolutionarily Significant Unit of Coho Salmon (NMFS 2014). The ultimate goal of these plans is coho delisting, supported by a wide range of underlying objectives covering threats and stressors for the species. In addition to the formal recovery plan, PacifiCorp has established its own Habitat Conservation Plan for Interim Operations Habitat Conservation Plan for Coho Salmon in the upper basin (PacifiCorp

2012). This plan has seven overarching goals and a range of supporting objectives focused on improving population viability, instream flows, water quality, and disease incidence as well as enhancing spawning and rearing habitat downstream of Iron Gate Dam in the Klamath River mainstem corridor, and in key tributaries. As coho salmon are listed as threatened in the Klamath River under both state and federal ESA statutes, the take of coho salmon is prohibited in river recreational fisheries.

Conservation objectives for Pacific coast coho salmon are outlined in Table 4-14.

Table 4-14: Conservation objectives and reference points governing harvest control rules and status determination criteria for coho salmon stocks and stock complexes in the Pacific Coast Salmon Fisheries Management Plan (from PFMC 2016).

| Species | Stocks In The Fishery | Conservation Objective | $S_{MSY}$ | MSST | MFMT ($F_{MSY}$) | ACL |
|---|---|---|---|---|---|---|
| Coho | Southern Oregon/Northern California Coast ESA Threatened | NMFS ESA consultation standard/recovery plan: No more than a 13.0% AEQ exploitation rate in ocean fisheries on Rogue/Klamath hatchery coho. | Undefined | ESA Consultation Standard Applies | Undefined | ESA Consultation Standard Applies |

ACL = annual catch limit, AEQ = adult equivalent, MSST = minimum stock size threshold, MFMT = maximum fishing mortality threshold, MSY = maximum sustainable yield, S = number of adult spawners

## 4.5.6 Conceptual and quantitative models

An early example of a coho lifecycle model that integrates a series of quantitative relationships that determine coho life-stage survival and abundance in the Klamath Basin, based on coho population structure and the influence of certain environmental variables such as flow and temperature, was developed by Cramer Fish Sciences (2008) for the U.S. Bureau of Reclamation (USBR). The intent of this life-cycle model was to simulate the likely response of Klamath Basin coho to water management actions, based on a synthesis of what was known about the function of coho salmon populations in general, coupled with what was known specifically about coho populations in the Klamath Basin.

More recently, the USBR has funded the USFWS beginning in 2016 to integrate coho salmon into the S3 Salmon Production Model developed for Chinook in the Klamath Basin (USFWS 2013; Perry et al. 2014), so that it can also be used for modeling coho life histories and sensitivities (CACFWRU 2015). To date, various tributary and mainstem production and movement functions and predictors for coho have been developed within a recently completed Post-doctoral Fellowship for the USFW's Arcata office through Humboldt State University (N. Hetrick, pers. comm.). Results of this research (unpublished) done in collaboration with the USFWS, USGS, and Texas State University are currently in the process of being coded into the S3 Model structure (N. Hetrick, pers. comm.).

### 4.5.7 Critical uncertainties & hypotheses

The expectation is that dam removal would benefit coho by restoring access to historical upstream habitat, improving downstream habitat, and improving key biological and physical factors that heavily influence coho populations (e.g., flow conditions, sediment and bedload transport, water quality, fish disease, toxic algal blooms, and water temperature). Based on available science, it is anticipated (with a high degree of certainty) that coho salmon will benefit from dam removal by restoring fish access to about 76 additional miles of historical habitat (mainstem river and tributaries) above Iron Gate Dam (NRC 2004; FERC 2007; Dunne et al. 2011; and Hamilton et al. 2011, as cited in USDI, USDC, NMFS 2013). This would provide better access to thermal refuges from high water temperatures by allowing coho to access mainstem cold groundwater springs and spring-dominated tributaries in the Upper Klamath Basin (Dunne et al. 2011).

There is some uncertainty as to the magnitude of predicted coho population increases subsequent to dam removal, based on the level of population response considered possible, and the magnitude in reduction of juvenile coho disease below Iron Gate Dam if dams were removed (USDI, USDC, NMFS 2013). The Coho Salmon and Steelhead Expert Panel (Dunne et al. 2011) concluded that, while there would likely be some increase in distribution and abundance of coho salmon if dams were removed, the increase would likely be small, especially in the short term (i.e., 0-10 years following dam removal). It is anticipated however (with a high degree of certainty) that dam removal and associated habitat restoration actions within the basin would increase population resilience and could help reduce the future risk of coho salmon extirpation from the Klamath Basin (USDI, USDC, NMFS 2013). Dam removal would be expected to lead to an increase in coho abundance, spatial distribution, productivity and life-history diversity, all of which would improve viability of future populations (NMFS and USFWS 2013).

The extent of suspended sediment released from the reservoirs in the short term following dam removal is uncertain, especially if proposed timelines for reservoir drawdown could not be achieved. Although short in duration, suspended sediment release could result in some lethal and sub-lethal effects on a portion of fish populations downstream. The worst case basin-wide mortalities for coho (both adults and juveniles) predicted from this are, however, less than 10 percent (NMFS and USFWS 2013). In spite of some short-term mortalities associated with suspended sediment releases, salmon, steelhead trout and other native anadromous species are anticipated to increase in abundance and viability in the long term with removal of the dams (NMFS and USFWS 2013).

### 4.5.8 Candidate research and assessment priorities

An extensive list of research needs for improving understanding of the ecology and status of coho has been developed as part of the Final Recovery Plan for the SONCC coho salmon ESU (NOAAF 2014). These include:

- Obtain better information on the extent and distribution of coho spawning in each Core and Non-Core population area.
- Develop efficient survey designs for assessing patchily-distributed populations.

- Consider carrying out abundance surveys in consistently occupied, higher abundance patches and spatial structure surveys outside these patches.
- Further develop a spatial structure monitoring protocol, as outlined by Adams et al. (2011).
- Determine how juvenile distribution is influenced by streamflow, temperature, and sediment barriers.
- Annually estimate the infection and mortality rate of juvenile coho salmon from pathogens, such as *C. shasta* in the mainstem Klamath River at Beaver Creek during May and June.
- An assessment of all means possible to disrupt the life cycle of the *C. shasta* parasite should be completed and a plan developed and implemented in the Upper Klamath River based on the results of the assessment.
- Develop cost-effective survey designs and methods for assessing spawning populations in streams where conditions (stream size, turbidity, cover) reduce the efficacy of traditional visual survey methods.
- Develop an estimator for the number of redds within a sample reach.
- Estimate total redd construction over regional space, incorporating within and between-sample uncertainty.
- Develop an estimator for the number of spawners from estimates of redds.
- Determine the number of reaches that should be sampled within a population to achieve a target coefficient of variation in annual status, and determine over what time period a trend of a specified magnitude can be detected at what spatial scale given specified sample rates.
- Develop techniques to estimate spawner abundance in remote areas.
- Evaluate the potential to restore extirpated populations.
- Research supplemental or alternative means to develop population targets.
- Monitor water quality to document existing conditions, track changes, and determine the impact of programs and actions.
- Determine whether the abundance targets for independent populations could be decreased if other viable salmonid population (VSP) parameters are well-estimated.
- Develop hatchery and genetic management plans to reduce the potential ecological and genetic impacts of fish produced by the Trinity River Hatchery and Iron Gate Hatchery.
- Determine how to differentiate salmonid species observed using Dual Frequency Identification Sonar (DIDSON).
- Determine whether chosen Life Cycle Monitoring (LCM) locations for coho capture existing spatial differences in marine survival due to different “marine environments”.
- Refine understanding of the accuracy of field protocols to detect juvenile occupancy.
- Develop a quantitative limiting factors life cycle model.

- Track ocean productivity.
- Determine which life-history traits or other diversity parameters are the most meaningful measures of diversity, particularly in the context of future climate change impacts.
- Determine best approach to conduct effectiveness and validation monitoring.
- Prioritize areas most in need of increased flow for coho, and identify the water conservation projects that could provide for the most efficient use of water extracted from the stream and result in increased flows that benefit coho and other aquatic species. Such water conservation measures may include off-channel water storage, changes in the timing or source of water supply, moving points of diversion, irrigation ditch lining, piping, stock-water systems, and agricultural tailwater recovery/management systems.
- Develop conservation plans including restoration projects that utilize beaver engineering skills to create coho salmon habitat and restore hydrologic function to streams. Alternatively, in locations that beavers are unlikely to occupy in the near future, identify techniques that could be employed for construction of beaver dam analogues that will simulate the beneficial effects of beaver dams.
- When habitat above Klamath dams becomes accessible to coho, it should be restored as necessary.

The proposed California Coastal Salmonid Monitoring Plan (CMP) (Adams et al. 2011) recommends that a network of permanent Life Cycle Monitoring (LCM) stations be established to provide long-term, intensive monitoring of coho salmon (as well as Chinook salmon and steelhead) populations in the Klamath Basin and other key coastal watersheds. Data obtained from LCM stations (i.e., measures of adult abundance from counting facilities, spawning survey estimates of adult abundance, outmigrant smolt counts) would be used to inform assessments of freshwater and ocean survival, essential to understanding whether changes in salmonid numbers are due to recovery from improvements in freshwater habitat conditions or to changes in ocean conditions.

As noted for other species, the above list of potential research and assessment activities needs to be further prioritized and sequenced. That effort should focus on those gaps in understanding and data which will most help to reduce critical uncertainties that significantly affect the choices between alternative management decisions on restoration actions and fish management, and/or improve the ability to evaluate the effectiveness of those decisions.

## 4.6 Steelhead

Steelhead (*Oncorhynchus mykiss irideus*) (Figure 4-8) are rainbow trout that follow an anadromous life history pattern. Steelhead are the Klamath River's highest valued sport fish (USFWS 2013, webpage) with the current total annual economic value of the fishery estimated to be about $1.4 million (USDI, USDC, NMFS 2013). Klamath Basin summer and winter steelhead populations both belong to the Klamath Mountain Province (KMP) Evolutionarily Significant Unit (ESU). In a 2001 status review, NOAA Fisheries determined that steelhead in the Klamath River Basin did not warrant listing under the ESA, despite acknowledging that their numbers were declining (NMFS 2001). Klamath steelhead are a Tribal Trust species.

Figure 4-8: Steelhead (*Oncorhynchus mykiss irideus*). Photo from Marlin Harms.

## 4.6.1 Population trends

The spawning runs of steelhead in the Klamath Basin prior to the 1900s are difficult to ascertain, but probably exceeded several million fish (Hardy and Addley 2001). Subsequent steelhead runs declined steadily to 400,000 fish by 1960 and an estimated 100,000 fish in the 1980s (NRC 2004). Long-term historic declines in steelhead abundance (summer and winter runs combined) in the Klamath Basin have been estimated at 67% (since 1960) (USDI, USDC, NMFS 2013). These declines have been attributed to the cumulative effects of dam construction, hydrologic modifications, changing ocean conditions, agricultural development, timber harvest, overfishing, and mining (USDI, USDC, NMFS 2013). Historic abundance of Klamath steelhead and percent reduction from historic levels is shown in Table 4-15.

Table 4-15: Declines in Klamath River steelhead abundance. Table extracted from USDI, USDC, NMFS 2013.

| Species | Historical Level | Percent Reduction from Historical Levels (estimates of individual runs) | Source |
| --- | --- | --- | --- |
| Steelhead | 400,000[1] | 67% (130,000) | Leidy and Leidy 1984; Busby et al. 1994 |

[1] This estimate is from 1960. Anadromous fish numbers were already in decline in the early 1900s (Snyder 1931).

### 4.6.2 Historic versus current distribution

Spring and summer steelhead are considered to have once been widely distributed in the Klamath River and Trinity River basins and were present in the headwaters of most larger basin tributaries (NCRWQCB 2010a-c). Although documentation is limited, Hamilton et al. (2005) suggests that there is sufficient information and reasoning to indicate that steelhead historically migrated to the Klamath upper basin above the current location of Iron Gate Dam. Determination of the upstream extent of distribution for steelhead is uncertain, but available documentation indicates that steelhead accessed habitat in the tributaries of Upper Klamath Lake as well (Hamilton et al. 2005). Figure 4-9 shows the current distribution of steelhead in the Klamath Basin and the areas of the basin once occupied by steelhead but from which they have been extirpated.

Both summer and winter steelhead are now widely distributed throughout the Lower Klamath River downstream of Iron Gate Dam, and in its tributaries. On average around 53% of the summer steelhead population currently spawn in tributaries to the Klamath River upstream of the confluence with the Trinity River (Stillwater Sciences 2010b). The Trinity, Scott, Shasta, and Salmon rivers are the most important spawning streams for winter steelhead. Supporting data are limited but it is thought that greater than 80% of adult winter steelhead currently spawn in tributaries upstream of the confluence with the Trinity River (Stillwater Sciences 2010b).

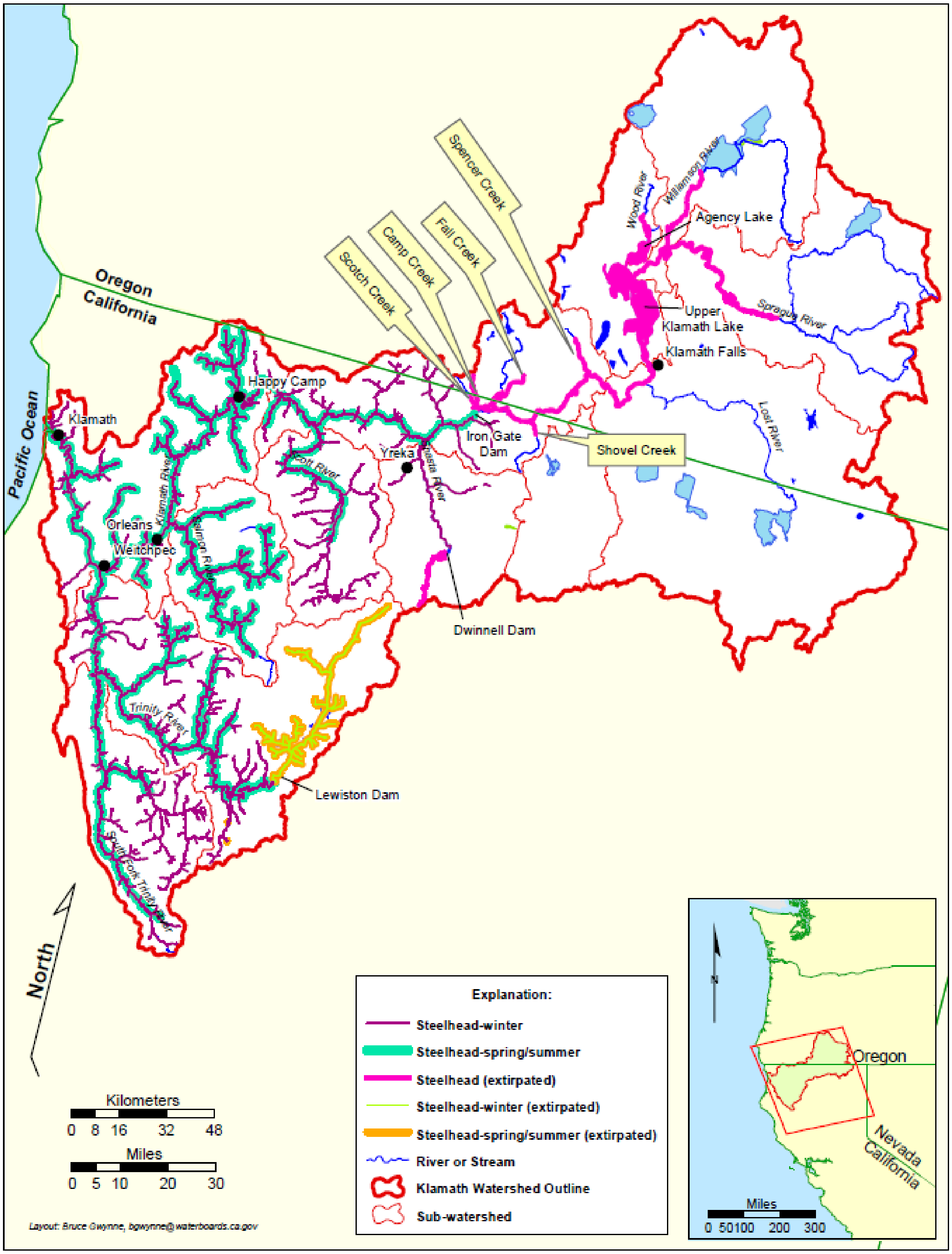



Figure 4-9: Current distribution and areas where steelhead have been extirpated in the Klamath Basin. Note that the data for "Steelhead extirpated" does not differentiate between seasonal steelhead runs. Map from NCRWQCB 2010a-c. Data sources for map: USFS 1996, Hamilton et al. 2005, Rushton 2005, Hardy and Addley 2006, as cited in NCRWQCB 2010a-c.

### 4.6.3 General ecology, life history and periodicity

Two distinct life-history patterns are recognized in the Klamath River basin: summer steelhead (stream-maturing) and winter steelhead (ocean-maturing) (NRC 2004). A third group exists in the Klamath, called the fall run (NRC 2004; Hopelain 2001), of sexually mature steelhead migrants in the Klamath mainstem between July and October, but may be an extension of a summer (Busby et al. 1994; Papa et al. 2007). Life histories of summer and winter steelhead differ in smolt age, length of marine residency, and patterns of reproduction (Quiñones et al. 2014b). Both summer and winter steelhead have a life history stage called the half-pounder, which is an immature fish that migrates to the sea in the spring but returns to freshwater in the late summer (Moyle 2002). Steelhead adults are capable of spawning once a year but often spawn every other year, up to four times (Moyle 2002). Adults become reproductively mature from age 1 to 5 (Moyle 2002). Juveniles will spend one to two years in cold fast-flowing perennial streams and are often associated with riffle habitats (Quiñones et al. 2014b). A brief summary of Klamath summer and winter steelhead life-histories is provided below, derived from a more extensive summary in Stillwater Sciences (2010b). Detailed life-history timing of summer steelhead and winter steelhead in the Klamath Basin (as summarized by Stillwater Sciences 2010b) are presented in Table 4-16 and Table 4-17 respectively.

#### *Summer steelhead*

Summer steelhead enter the Klamath River earlier than either the fall or winter runs, and unlike the other Klamath steelhead runs, enter sexually immature (Barnhart 1994; Moyle 2002). Although data are limited, it is believed that summer steelhead adults enter the mainstem Klamath River from March to June, and migrate to cooler tributaries to spawn (Barnhart 1994; Hopelain 1998; Moyle 2002).

Spawning probably occurs slightly earlier for summer steelhead than for the other runs, with timing thought to be from December through February (KRSIC 1993; USFWS 1998). Adult steelhead downstream migrants (run-backs) are thought to migrate to the ocean from mid-March to late May (USFWS 1998).

Age-0, 1, and 2 juveniles all rear to some extent in the mainstem during fall (Stillwater Sciences 2010b). Rearing also takes place in tributaries to the Klamath River, as well as the estuary during fall. Summer steelhead juveniles share a similar life-history pattern to fall and winter steelhead, with over 90% smolting at age-2 (Hopelain 1998). Smolts appear to outmigrate from the spring through to the fall, with peak smolt outmigration occurring in April, May, or June, based on estuary captures (Wallace 2004). Although the majority of mid-Klamath steelhead outmigrants are age-1 (Scheiff et al. 2001), the most successful life history patterns for summer steelhead in the Klamath River appear to be those where juveniles spend two years rearing in fresh water prior to smolt outmigration. The age (and size) at entry to salt water appears an important factor for being successful in the marine environment (Stillwater Sciences 2010b).

Table 4-16: Life-history timing of summer steelhead in the Klamath Basin downstream of Iron Gate Dam. Peak life history periods are shown in black. Table from Stillwater Sciences 2010b.

| Life stage (citations) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Adult migration in mainstem[4] | | | | | | | | | | | | |
| Adult holding in tributaries[1, 5, 8, 9] | | | | | | | | | | | | |
| Spawning[1, 10] | | | | | | | | | | | | |
| Incubation | | | | | | | | | | | | |
| Emergence[1] | | | | | | | | | | | | |
| Rearing[2, 3] | | | | | | | | | | | | |
| Juvenile outmigration[3, 4, 5] | | | | | | | | | | | | |
| Half-pounder residence[4, 6, 7] | | | | | | | | | | | | |
| Run-backs[5] | | | | | | | | | | | | |

[1] PacifiCorp 2004; [2] NRC 2004; [3] PacifiCorp 2004; [4] Hopelain 1998; [5] Wallace 2004; [5] USFWS 1998; [6] CDFG 1988, as cited in USFWS 1998; [7] NRC 2004; [8] USFWS 1996, as cited in USFWS 1998; [9] Dean 1995; [10] Klamath River Stock Identification Committee (KRSIC) 1993, as cited in USFWS 1998

### *Winter steelhead*

In contrast to summer steelhead, winter steelhead are sexually mature upon freshwater entry. Adults typically enter the Klamath River from July to October (sometimes called the "fall run") and from November through March (the "winter run") (Hopelain 1998; USFWS 1998). The earlier portion of the run may hold in the mainstem Klamath River from a few weeks to nearly five months (W. Sinnen, pers. comm.). Fall steelhead adults will utilize areas of the mainstem Klamath River generally from September to December, and winter steelhead adults utilize the same areas from late December through mid-April (USFWS 1998). Winter steelhead primarily spawn in tributaries, but also spawn in the mainstem, with peak spawn timing in February and March (ranging from January to April) (NRC 2004). Adults may repeat spawn in subsequent years after returning to the ocean. Fry emerge in spring (NRC 2004). Some juveniles rear in the mainstem during fall, and likely to some extent in the winter and spring. Smolt outmigration appears to primarily occur between May and September with peaks between April and June, although smolts are captured in the estuary as early as March and as late as October (Wallace 2004). Most adult returns (86%) originate from fish that smolt at age 2+, representing 86% of adult returns, in comparison with only 10% for age-1 juveniles and 4% for age 3+ juveniles (Hopelain 1998).

Table 4-17: Life-history timing of winter steelhead in the Klamath Basin downstream of Iron Gate Dam. Peak life history periods are shown in black. Table from Stillwater Sciences 2010b.

| Life stage (citations) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Adult migration | | | | | | | | | | | | |
| Spawning[1, 9, 10] | | | | | | | | | | | | |
| Incubation | | | | | | | | | | | | |
| Emergence[1, 2] | | | | | | | | | | | | |
| Rearing | | | | | | | | | | | | |
| Juvenile outmigration | | | | | | | | | | | | |
| Half-pounder residence[1, 3, 4, 5] | | | | | | | | | | | | |
| Run-backs[11] | | | | | | | | | | | | |

[1] NRC (2004); [2] Dean (1994); [3] Busby et al. (1994), [4] Moyle (2002); [5] CDFG (1988, as cited in USFWS 1998); [9] KRSIC (1993, as cited in USFWS 1998); [10] West et al. (1990); [11] Nels Brownel (USFS, pers. comm., 1997, as cited in USFWS 1998)

### 4.6.4 Habitat requirements and known limiting factors

Primary factors limiting winter steelhead populations in the mainstem Klamath River include density-independent effects of high summer water temperature and associated disease of rearing juveniles and outmigrants caused by the myxozoan *C. shasta* (Stillwater Sciences 2010b).

In Klamath Basin tributaries, the primary limiting factors for steelhead include density-independent mortality related to high summer water temperatures and the effects of fine sediment in spawning gravel on developing eggs (Stillwater Sciences 2010b). Redd scour resulting from high peak flows may also contribute to significant mortality in some years. Density-dependant mortality related to summer rearing and winter refuge habitat limitations can also be a factor (Stillwater Sciences 2010b). In tributaries with suitable summer water temperatures, density-dependant factors limit population abundance. During winter, steelhead use the interstitial spaces in substrate when water temperatures are cold and for refuge from high flow. In tributaries with degraded habitat conditions where fine sediment has increased, winter refuge habitat is likely limiting. In tributaries with abundant winter refuge habitat, summer rearing habitat conditions for age-2 juveniles may be limiting (Stillwater Sciences 2010b).

### 4.6.5 Management and Recovery Plans

Recovery of steelhead populations in the Klamath Basin is guided by a Steelhead Restoration and Management Plan in California released by CDFW in 1996 (McEwan 1996). As Klamath steelhead populations are not listed under the ESA, the overarching goals of this plan are simply to increase natural production of self-sustaining steelhead populations to levels that can enhance angling opportunities and non-consumptive uses. Underlying objectives for achieving these goals include habitat restoration, restoring fish passage to historically accessible habitats, regulating harvest, maintaining and improving hatchery runs, and conducting research. For Klamath populations in particular, the plan calls for increased dam releases, improvements in irrigation, grazing, and timber harvesting practices, habitat restoration, and regulation of harvesting. Steelhead fishing is allowed all year and is not subject to quotas. Current regulations allow for the harvest in the Klamath River mainstem of two hatchery marked steelhead or trout per day, four in possession.

### 4.6.6 Conceptual and quantitative models

We are not aware of any conceptual models for steelhead in the Klamath Basin that link environmental changes to steelhead life history responses and production. There are examples of life-cycle models that have been developed for steelhead in other basins that conceptually and quantitatively link various elements of food supply, stream flows, temperature and other factors to predict steelhead growth, survival, capacity, and reproductive success by life history tactic (e.g., Cramer and Beamesderfer 2002, Satterthwaite et al. 2009, 2010). An example of a generalized steelhead conceptual model illustrating some of the key elements to consider for steelhead life history linkages is provided in Figure 4-10 (from Kendall et al. 2014). There have been some earlier efforts to explore development of a state-dependent life-cycle-based fish production model specifically for Klamath steelhead, by adjusting the structure and parameters of the SALMOD model (NRC 2008). SALMOD has been commonly used in the basin for modeling production of fall Chinook salmon. SALMOD is designed to simulate the dynamics of the freshwater phase of either anadromous or resident salmonid fish species (NRC 2008) (see Chinook write-up in this report for greater description of the SALMOD model). Stream flow, water temperature, and mesohabitat type are the physical variables included in SALMOD. The biological resolution uses a typical categorization of fish life history related to physical morphology, behavior, and reproductive potential. The model has been used to predict the population consequences of alternative flow and temperature regimes, to understand the relative magnitude of mortality in determining the timing and degree of habitat "bottlenecks," to design flow regimes to mitigate habitat bottlenecks, and to explore the effectiveness of stocking programs (NRC 2008). Some limited initial exploration of SALMOD modeling for Klamath steelhead has been undertaken (Hardy and Addley 2001) but has not been fully developed, as it would require incorporation of additional life cycle elements and an expansion of the spatial modeling frame to incorporate Klamath tributaries used by steelhead (and not just Klamath mainstem) (NRC 2008). The SALMOD conceptual framing has now been incorporated into the more powerful, more versatile Stream Salmonid Simulator (S3) model (USFWS 2013a-c), which may provide future opportunities to fully develop a life-cyle-based steelhead production model for the Klamath.

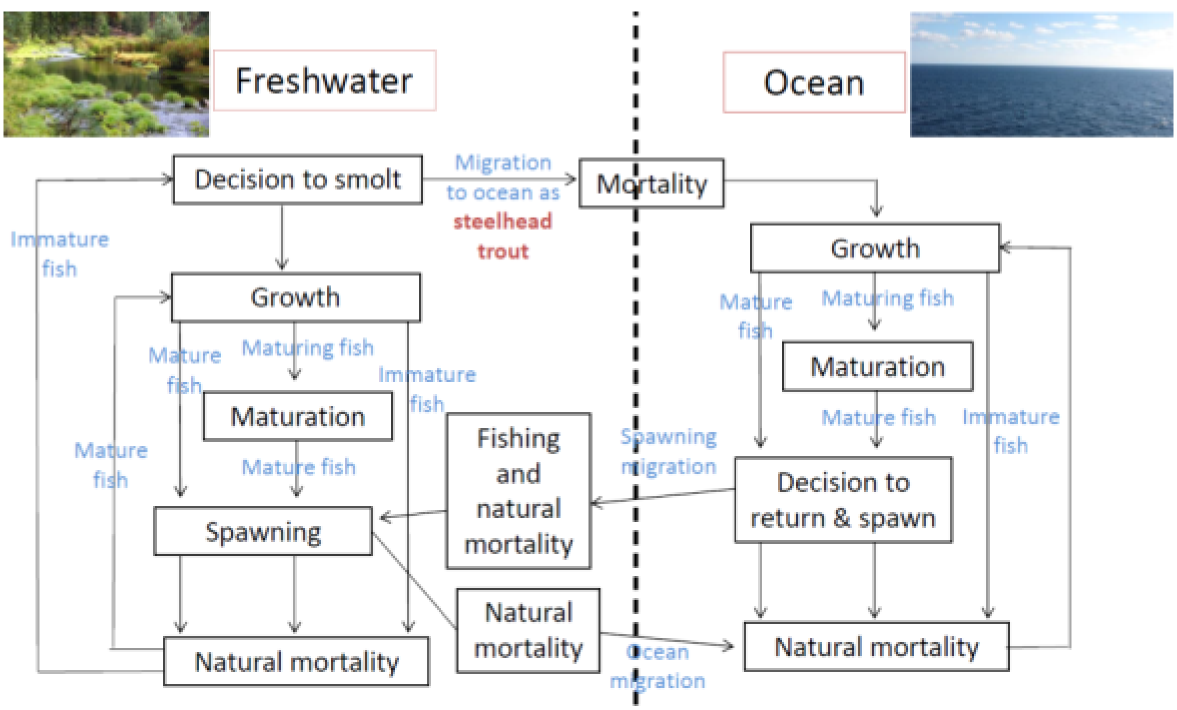



Figure 4-10: An example structure of a generalized conceptual model for steelhead, illustrating some of the key elements to consider within its full life cycle for modeling survival and productivity. Figure from Kendall et al. 2014.

## 4.6.7 Critical uncertainties & hypotheses

The available science suggests (with a high degree of certainty) that removal of Klamath dams would benefit steelhead by allowing recolonization of historical steelhead habitat upstream of Iron Gate Dam (Fortune et al. 1966, Chapman 1981, Huntington et al. 2006a,b, FERC 2007, Dunne et al. 2011, Hetrick et al. 2009, Hamilton et al. 2011, as cited in USDI, USDC, NMFS 2013). Because of their ability to navigate steeper gradient channels and spawn in smaller, intermittent streams (Platts and Partridge 1978), and their ability to withstand a wide range of water temperatures (Cech and Myrick 1999; Spina 2007), steelhead distribution in the basin would be expected to expand with dam removal to a greater degree (i.e., over 420 miles of historical steelhead habitat in upper basin streams) (Huntington et al. 2006) than any other anadromous salmonid species in the basin (USDI, USDC, NMFS 2013). Dunne et al. (2011) also suggest that allowing fish to access mainstem cold groundwater springs and spring-dominated tributaries in the upper Klamath Basin through dam removal would provide thermal refuge for steelhead from generally increasing water temperatures under future climate change scenarios.

Several factors point to a high degree of recolonization certainty for steelhead. These factors include: steelhead are genetically resistant to the juvenile fish disease *C. shasta*, they are relatively tolerant of warmer water temperatures, their life-history strategy does not include “spawn and die” thereby increasing their opportunity to utilize all of the reopened historical habitat, and a similar species (i.e., resident redband trout) are doing well in the upper basin (Hetrick et al. 2009; Hamilton et al. 2011; Huntington et al. 2006, as cited in USDI, USDC, NMFS 2013).

There are, however, uncertainties associated with the magnitude of the likely benefits of dam removal. Dunne et al. (2011) were optimistic that dam removal coupled with additional habitat restoration activities would increase steelhead abundance and distribution compared to current conditions. The degree of success would center on the full suite of restoration actions actually implemented, to what degree poor summer and fall water quality conditions affected steelhead migration, the outcome of their interactions with resident redband trout, and the impact of hatcheries (Dunne et al. 2011). More immediately, there is uncertainty and associated concern related to the extent of suspended sediment concentrations that would be released from the reservoirs in the short term following dam removal, especially if intended proposed timelines for reservoir drawdown could not be achieved. Although short in duration, suspended sediment release could result in some lethal and sub-lethal effects on a portion of fish populations downstream. There is a high degree of certainty that suspended sediment released during dam removal would produce short-term lethal conditions for steelhead (USDI, USDC, NMFS 2013). Steelhead adults and juveniles would be expected to have the highest 1-year basin-wide mortalities from suspended sediment releases of all salmonids in the basin (predicted to be about 14 percent in a median flow year (USDI, USDC, NMFS 2013)). Steelhead downstream of Iron Gate Dam might be expected to experience as much as a 28 percent basin-wide mortality for adults and 19 percent mortality for juveniles if dams were removed in a dry year (anticipated worst case scenario) (USDI, USDC, NMFS 2013). However, in spite of short-term mortalities associated with suspended sediment releases, steelhead would be expected to increase in abundance and viability over the long term if Klamath dams were removed (USDI, USDC, NMFS 2013).

The movement of native steelhead upstream of Iron Gate Dam may also present an uncertain risk of residualization (i.e., steelhead reverting to a resident rainbow trout life history strategy), but this risk is considered low (Administrative Law Judge 2006, as cited in NMFS and USFWS

2013). Hodge et al. (2016) suggest that steelhead and rainbow trout can give rise to progeny of the alternate form and thus potentially interbreed, suggesting that dam removal might lead both to a facultatively anadromous *O. mykiss* population in the upper Klamath Basin and to the co-occurrence of, and reproductive exchange between, coastal steelhead–rainbow trout (*O. mykiss irideus)* and inland redband trout (*O. mykiss newberri*).

### 4.6.8 Candidate research and assessment priorities

The National Research Council (NRC 2008) suggested that it would be beneficial to develop fish production models for steelhead in the Klamath Basin (as has been done for Chinook). Future studies modeling steelhead populations should look to include explicit analyses of the habitat, water, and sediment contributions of tributary streams in the context of steelhead life histories and movements throughout the entire Klamath River Basin (NRC 2008). Such models should assess the ability of tributaries to facilitate juvenile fish production and provide thermal refugia, and generate estimates of tributary habitat, their areal extent, and the extent of overcrowding of fish in them (NRC 2008).

Quiñones et al. (2014b) also identified some key research questions to be resolved to improve current management of steelhead in the Klamath Basin:

- Is spawning gravel a limiting resource in some watersheds?
- What is the proportion of fish straying from hatcheries in naturally spawning populations?
- Does competition between summer steelhead and spring Chinook salmon limit abundance of either species?

The proposed California Coastal Salmonid Monitoring Plan (CMP) (Adams et al. 2011) recommends that a network of permanent Life Cycle Monitoring (LCM) stations be established to provide long-term, intensive monitoring of steelhead (as well as Chinook and coho salmon) populations in the Klamath Basin and other key coastal watersheds. Data obtained from LCM stations (i.e., measures of adult abundance from counting facilities, spawning survey estimates of adult abundance, outmigrant smolt counts) would be used to inform assessments of freshwater and ocean survival, essential to understanding whether changes in salmonid numbers are due to recovery from improvements in freshwater habitat conditions or changes in ocean conditions.

As noted for other species, the above list of potential research and assessment activities needs to be further prioritized and sequenced. That effort should focus on those gaps in understanding and data which will most help to reduce critical uncertainties that significantly affect the choices between alternative management decisions on restoration actions and fish management, and/or improve the ability to evaluate the effectiveness of those decisions.

## 4.7 Bull trout

Bull trout (*Salvelinus confluentus*) (Figure 4-11) are predatory char that are widely distributed in the northwestern US, but are considered a relic species in the Klamath Basin, with genetic evidence reflecting this past isolation (NRC 2004). The Klamath Basin is at the southern extent of the species range and the population is considered genetically distinct (ODFW 2016). Bull trout apparently entered the Klamath Basin when it was connected to the Snake River and then became isolated (NRC 2004). Bull trout populations in the Klamath Basin are currently fragmented with little or no connectivity between populations (ODFW 2010a). Because of its historical isolation, bull trout in the Klamath Basin are considered a distinct stock, separate from bull trout native to the Columbia Basin (ODFW 1997). Bull trout in the Klamath Basin are listed as Federal ESA Threatened (1998), and ODFW State Sensitive (ODFW 2016). Threats to the existence of bull trout are not unique to the Klamath Basin; they occur throughout its range.

Figure 4-11: Long Creek bull trout (*Salvelinus confluentus*). Photo from ODFW 2016).

### 4.7.1 Population trends

Bull trout in the Klamath Basin have become increasingly rare (NRC 2004). The current abundance, distribution, and range of bull trout in the Klamath are greatly reduced from historical levels (USDI, USDC, NMFS 2013). Bull trout are considered extinct in California (Rode 1990, as cited in USDI, USDC, NMFS 2013). The 2016 assessment of stock status by ODFW indicates that there has likely been a recent downward trend in existing Oregon bull trout populations within the Klamath Basin, due to multiple years of extensive drought, in conjunction with higher than normal water temperatures; there is however a good adult age class arising from a mild year in 2011 (ODFW 2016). All bull trout populations in the Klamath are considered to have moderate to high risk of extinction under current conditions (ODFW 2010a). Most of the existing bull trout populations (Brownsworth, Leonard/Hammond, Boulder/Dixon, Long, Sun, and Threemile creeks) are designated as having a high risk of extinction. The remaining population (Deming Creek) is designated as having a moderate risk of extinction (ODFW 2016). The Sun Creek population has increased its abundance and distribution in recent years, which may reduce its risk of extinction (ODFW 2016). The Brownsworth and Leonard populations have also recently expanded their distributions, and show indications of increased genetic exchanges, which may reduce their risks of extinction (ODFW 2016).

### 4.7.2 Historic versus current distribution

Populations of bull trout in the Klamath Basin are numerically small and have little connection between populations (ODFW 2016). All current populations have limited geographic distribution and limited reproductive potential due to low abundance and low fecundity of spawners (ODFW 2016). Complete historical distribution data are unavailable (ODFW 2005a) but bull trout likely once had a much wider distribution within the Klamath Basin, possibly occupying most of the Oregon portion of the basin (Buchanan et al. 1997). They are now found only in the headwaters of a few isolated spring-fed streams (ODFW 2016). Bull trout in the Klamath Basin currently exist as stream resident forms in isolated headwater streams within six small drainage basins (ODFW 2016), representing a total distribution of only 21 miles of the upper Klamath Basin (ODFW 2010). The Species Management Unit (SMU) for Klamath Lake bull trout is comprised of 11 populations, four of which are considered extinct (ODFW 2005a) (Table 4-18). Basins with bull trout include Sun, Threemile, Long, Boulder, Brownsworth, and Deming creeks. Long Creek continues to maintain a small component of the fluvial form (i.e., migration from small natal streams to larger rivers for adult rearing) and the Sun Creek population also shows migratory behavior. Bull trout were also historically observed within Cherry and Coyote creeks, and the upper Sycan River but these former populations are considered extinct (ODFW 1997; ODFW 2005a). Streams with bull trout occur in three general locations: tributaries of the Sprague and Sycan rivers, and tributaries of Agency Lake (ODFW 2016). The spawning distributions of most of the remaining bull trout populations are much restricted compared to known historical distributions (Table 4-19).

Table 4-18: Populations, existence status, and life history of the Klamath Lake Species Management Unit (SMU). Table from ODFW 2005a.

| Exist | Population | Description | Life History |
|---|---|---|---|
| Yes | Sun | Sun Creek | Resident |
| Yes | Threemile | Threemile Creek | Resident |
| Yes | Long | Long and Calahan creeks | Resident |
| Yes | NF Sprague | Upper North Fork Sprague River and tributaries including Sheepy, Boulder and Dixon creeks | Resident |
| Yes | Deming | Deming Creek | Resident |
| Yes | Leonard | Leonard Creek | Resident |
| Yes | Brownsworth | Brownsworth Creek | Resident |
| No | Sevenmile | Sevenmile Creek | |
| No | Cherry | Cherry Creek | |
| No | Coyote | Coyote Creek | |
| No | Upper Sycan | Upper Sycan River above Sycan Marsh | |

Table 4-19: Current spawning distributions of Klamath bull trout populations relative to historical (pre-1990) distributions. Table from ODFW 2005a.

| Population | Spawning Distribution (km) | % of Historical | Connected to Other Populations |
|---|---|---|---|
| Sun | 14.5 | 59 | No |
| Threemile | 1.4 | 25 | No |
| Long | 23.2 | 77 | No |
| NF Sprague | 9.0 | 15 | No |
| Deming | 6.4 | 37 | No |
| Leonard | 2.7 | 44 | Yes |

| Population | Spawning Distribution (km) | % of Historical | Connected to Other Populations |
|---|---|---|---|
| Brownsworth | 15 | 100 | Yes |
| Sevenmile | | *Extinct Population* | |
| Cherry | | *Extinct Population* | |
| Coyote | | *Extinct Population* | |
| Upper Sycan | | *Extinct Population* | |

### 4.7.3 General ecology, life history and periodicity

Bull trout are stenothermal, requiring a narrow range of cold temperature conditions to rear and reproduce (Buchanan and Gregory 1997). Resident bull trout in the Klamath Basin spawn in the fall, generally September and October (Buchanan et al. 1997) after temperatures have dropped below 48$^{o}$F. Most spawning occurs in cold headwater or spring-fed streams. Bull trout eggs require a long incubation period compared to other salmon and trout, hatching in late winter or early spring. Fry will then remain in the stream gravel for up to three weeks before emerging (USFWS 2017, webpage). Bull trout may be either stream resident or migratory. Resident bull trout live their entire life in or near the streams where they were spawned (USFWS 2017, webpage). Resident juvenile bull trout are thought to generally confine their migrations to within their natal stream (Buchanan et al. 1997). Migratory fish are larger, and are usually spawned in small, headwater streams. Juveniles may migrate to larger streams/rivers (i.e., fluvial life history), or to lakes or reservoirs (i.e., adfluvial life history), or to the ocean (i.e., anadromous life history) where they grow to maturity. While anadromous bull trout forms no longer exist in Oregon, it is believed that this life history type was important historically, and may have acted as a mechanism driving coastal distribution patterns (Bond 1992, as cited in Buchanan et al. 1997). All remaining Klamath bull trout populations are stream resident forms, although as mentioned earlier, some fluvial migratory behaviors may still exist in some populations (i.e., Long and Sun creeks) (ODFW 2016).

Juveniles of resident bull trout such as those in the Klamath eat aquatic insects, but as they grow into adults they shift to a piscivorous diet consisting of available fish species in their natal streams, including juvenile suckers, salmonids, sculpins, and minnows (Buchanan et al. 1997). Bull trout in turn are eaten by larger fish and other predators (Buchanan et al. 1997).

### 4.7.4 Habitat requirements and known limiting factors

Bull trout in the Klamath Basin are found typically in small, spring fed-streams with steep gradients (ODFW 2010a). With the exception of Long Creek, all bull trout streams in the Klamath originate in the higher elevations of mountains within the wilderness areas of Gearhart and Sky lakes or Crater Lake National Park (ODFW 2016). Rieman and McIntyre (1993) state that bull trout have more specific habitat requirements than other salmonids. They list channel stability, substrate composition, cover, temperature, and migratory corridors as all influencing bull trout distribution and abundance. In general, bull trout are very sensitive to human activities that disturb their stream habitat. As land is cleared, fine sediment runs off slopes and settles in the gravel beds of streams affecting eggs and juvenile bull trout. Additionally, the removal of

trees and shrubs from river edges can result in increased water temperatures. The diversion of water from streams can cause lowered water flow, which restricts bull trout movements.
A key characteristic of streams containing bull trout is cold water (Rieman and McIntyre 1993). Bull trout require highly oxygenated, unpolluted, cold water for persistence, clean gravel and cobble substrate for spawning, and heavy cover for rearing (ODFW 1997). Temperatures in excess of about 15$^{o}$C are thought to limit bull trout distribution, while temperatures colder than 10$^{o}$C are required for successful spawning and early rearing (Rieman and McIntyre 1993; Buchanan and Gregory 1997). Bull trout cannot persist in streams that consistently exceed water temperatures of 18$^{o}$C (Moyle 2002). Many investigations have concluded that water temperatures represent a critical habitat characteristic for bull trout (Buchanan et al. 1997). Bull trout will disappear from streams with degraded water quality even if the streams support other types of trout (Buchanan et al. 1997). During late summer, water temperatures in bull trout streams in the Klamath have been known to exceed water temperatures suitable for bull trout rearing (e.g., Williamson and Sprague creeks, Boyd et al. 2001, as cited in NRC 2004). A recent review of status by ODFW indicated that high water temperatures currently exceeded the temperature preferences of bull trout in most streams in the Klamath Basin (ODFW 2010a). They suggested that insufficient riparian vegetation allows the streams to warm quickly. Bull trout also need well oxygenated, sediment free water for successful egg incubation and emergence (ODFW 1997). Past timber harvests and grazing practices in the upper Klamath Basin have led to reduced cover and increased fine sediment loads (ODFW 1997).

Bull trout numbers will also decline in streams that are invaded by introduced brook trout (*Salvelinus fontenalis*) and other competitors. Hybridization between bull trout and brook trout has been known to occur in some Klamath Basin streams (Markle et al. 1992, as cited in NRC 2004). Brook trout, brown trout (*Salmo trutta*), and non-native strains of rainbow trout (*O. mykiss*) that are common in cold-water streams have replaced bull trout in many areas of the US (NRC 2004). These invasive species represent a continuing threat to bull trout persistence in the Klamath Basin (USFWS 2015a), especially if changes in water quality in the basin promote their further expansion (NRC 2004). Brook trout reproduce earlier and at a higher rate than bull trout so bull trout populations are often supplanted by these non-natives where they overlap (USFWS 2017, webpage). ODFW (2010a) identified the occurrence of brook trout as the biggest limiting factor to bull trout in the Klamath Basin, and a major risk to the long-term survival of bull trout there (through hybridization as well as competition for food and space). Efforts have been made by agencies in the basin to eradicate brook trout and install passage barriers to prevent brook trout from re-invading areas with known bull trout populations (e.g. Buktenica 2000; Buktenica 2013). ODFW (1997) suggest that hybridization with brook trout has been the primary cause of depleted bull trout populations in Sun, Threemile, Cherry, Long, and Coyote creeks, and in upper Sycan River. Brook trout were stocked in those streams as early as 1925 (ODFW 1997). Competition with brown trout is considered to be the primary cause of bull trout declines in Brownsworth, Leonard, Boulder, and Dixon creeks (ODFW 1997).

Other general limiting factors for Klamath bull trout include poor water quality, unscreened irrigation diversions, water withdrawals, and fragmentation of populations (ODFW 2010a). Physical barriers on Sun, Deming and Threemile creeks were also specifically identified as preventing connection for bull trout to other larger stream or river systems (ODFW 2010a). Earlier bull trout assessments (Buchanan et al. 1997) identified channelization, water withdrawals, and removal of stream side vegetation as factors limiting bull trout in the Klamath Basin. USFWS (2015) suggested that threats to Klamath bull trout populations were generally similar throughout the basin and included non-native salmonids (i.e., brook trout and, in some instances, brown trout), small population size, degraded instream and riparian habitat, and impaired connectivity. Low numbers of local populations with the bull trout core areas place these populations at increased risk from genetic and demographic threats (USFWS 2015a).

Bull trout in the Klamath Basin developed originally in the presence of anadromous fish. Marine nutrients from decaying salmon carcasses were important for increasing the primary productivity of bull trout streams, and salmon eggs and fry provided supplemental food for piscivorous bull trout juveniles (ODFW 2010). Loss of anadromous fish fry production has likely had impacts on bull trout growth, survival and productivity (ODFW 2010). Prior to the extirpation of anadromous fish from the Klamath Basin, bull trout were more widely distributed and attained larger sizes than at present. A 330 mm specimen was collected in 1876 from Fort Creek (Buchanan et al. 1997, as cited in ODFW 2010).

Bull trout are aggressive by nature and readily take lures or bait, making them very susceptible to angling pressure (Buchanan et al. 1997). Oregon angling regulations, however, prohibit the take of bull trout in the Klamath Basin (ODFW 2010), and have for some time (ODFW 1997), so overfishing should not currently be a limiting factor. Poaching, however, is an often unquantified threat to bull trout populations throughout Oregon (USFWS 2017, webpage).

### 4.7.5 Management and Recovery Plans

Angling is closed for bull trout. Recovery of ESA-listed bull trout populations in the basin is guided by a Revised Draft Recovery Plan for the Coterminous United States Population of Bull Trout (*Salvelinus confluentus*), with Klamath populations of bull trout addressed explicitly as a distinct Recovery Unit (USFWS 2014). The overarching goal of the recovery plan is bull trout delisting, with underlying objectives focused on ensuring stable, geographically widespread bull trout populations, maintaining genetic and life history diversity, and conserving the connectivity of essential cold-water habitats. Additionally, ODFW and project partners continue to work on a Bull Trout Reintroduction Plan and recently, brook trout have been removed from bull trout streams in Sun Creek, Threemile Creek and the Rock Creek system (Buktenica et al. 2013; ODFW 2016). Reintroduction of bull trout into historic habitats is being planned and prioritized.

### 4.7.6 Conceptual and quantitative models

While bull trout face a range of threats, water temperature may represent the most critical habitat characteristic for predicting bull trout distribution and persistence over the long term. Species with a narrow thermal ''niche'' (Magnuson et al. 1979) such as bull trout are most likely to be affected by alterations in water temperature regimes. In particular, species that are tied to cold-water habitats may be especially vulnerable to the increases in temperature that commonly result from human activities. Dunham et al. (2003) recently analyzed the entire current range of bull trout in the United States, examining the associations between the distribution of bull trout and environmental variables, including temperature, instream cover, channel form, substrate, and the abundance of native and non-native salmonid fishes. They found that only water temperature was strongly associated with the distribution of bull trout. They concluded (based on both their work and related studies) that conservation efforts for bull trout would be most effective by focusing on maintaining and restoring large and interconnected cold-water habitats. We are not aware of any conceptual or quantitative models for bull trout in the Klamath Basin that explicitly link temperature changes (or other basin impacts) to bull trout responses. However, Buchanan and Gregory (1997) summarized water temperature requirements for each bull trout life history stage from assembled field observations and laboratory studies. They identified a range of temperature requirements for: (1) adult and juvenile summer rearing; (2) adult fall spawning; (3) fall, winter, and spring egg incubation; and (4) spring fry growth. Their summary (Figure 4-12) provides a framework for evaluating how stream temperatures are currently affecting different life history stages of bull trout within the Klamath Basin.

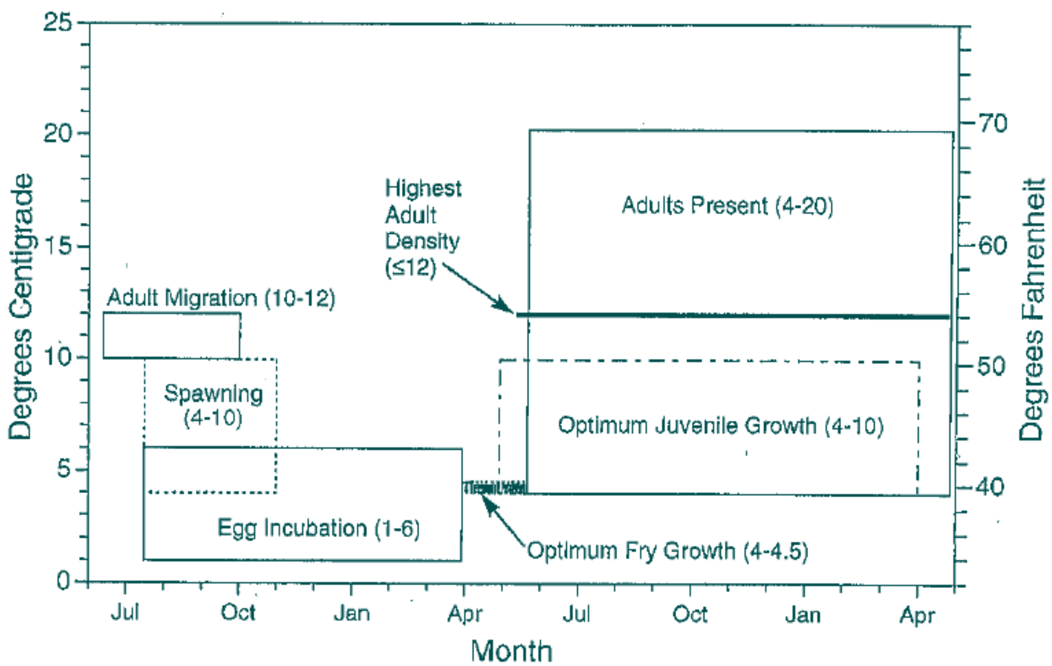



Figure 4-12: Bull trout temperature requirements for each life history stage and time period, as reported in the general literature. Figure from Buchanan and Gregory 1997.

Recently, Benjamin et al. (2016) modeled the interaction of stream temperature and invasive brook trout as primary factors driving current bull trout distribution in the upper Klamath Basin. Benjamin's (2016) model focused on June degree-days as a temperature metric that could be used to effectively describe the overall thermal regime experienced by fish in a stream. Based on their model, they found that the presence of brook trout restricts the thermal regime available to bull trout, with bull trout occupying warmer sites if brook trout are present compared to the sites they occupy if brook trout are absent (Figure 4-13). Comparable modeling has not yet been undertaken to examine the combined effects of thermal regimes and interactions between bull trout and brown trout (Benjamin et al. 2016).

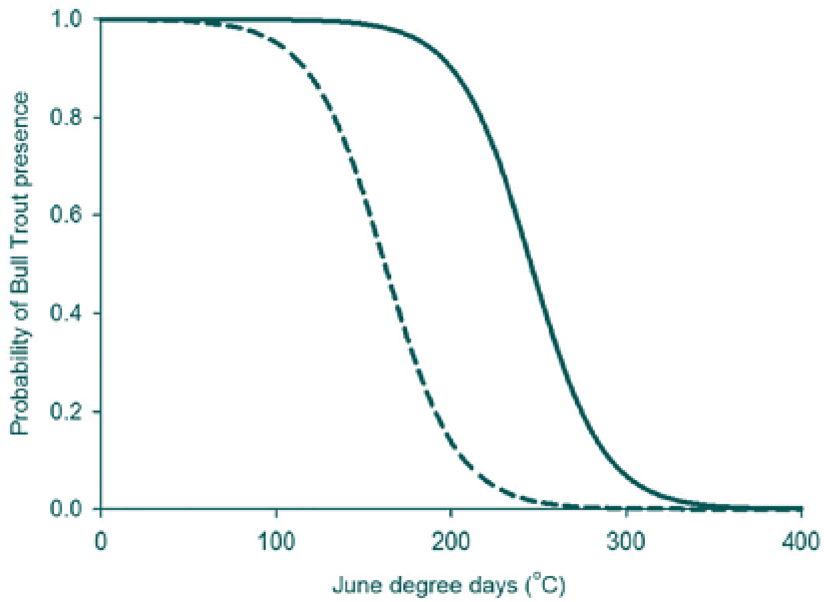



Figure 4-13: Probability of bull trout occurrence at sites in the upper Klamath Basin as a function of June degree-days (°C) and the presence (solid line) or absence (dashed line) of non-native brook trout. Figure from Benjamin et al. 2016.

ODFW (2016) briefly discusses future use of a decision support tool being developed by Oregon State University (OSU) that could be applied to explore alternative decisions around bull trout management in the Klamath and other basins. Presumably a broad conceptual framing of bull trout life-history requirements and sensitivities was developed as part of this decision support model, but to date we have been unable to acquire more detailed information.

### 4.7.7 Critical uncertainties & hypotheses

A natural focus of ongoing and future work on bull trout in the Klamath Basin will be evaluating their predicted and actual responses to restoration actions, in the context of both their habitat needs and their interactions with other species. Key uncertainties include:

- Can habitat complexity be manipulated to significantly improve conditions for bull trout and mediate competition and/or genetic interactions between bull trout and non-native trout species (i.e., brook trout, brown trout, non-native rainbow trout (Thorsteinson et al. 2011))?
- Can water temperatures be reduced in Klamath streams (through riparian planting, reduced water withdrawals, dike removals, etc.) to give native bull trout a competitive advantage over non-native fish species that are less tolerant of cold water (ODFW 2010a)?
- Can intensive control methods like chemical treatment be effective in successfully removing non-native trout species and restoring native fish assemblages to bull trout streams (ODFW 2010a)?

- Can flow augmentation and/or removal of barriers to passage at irrigation diversions reconnect fragmented bull trout populations in the upper basin and increase genetic exchange/heterozygosity (ODFW 2010a)?
- Will removal of Klamath dams result in the return of sufficient numbers of salmon to enhance the productivity of bull trout streams and improve the survival of juvenile bull trout (ODFW 2010a)? Note that bull trout streams that would be considered oligotrophic and that could therefore benefit from marine nutrient additions from returning salmon may be higher in the system than salmon can migrate to (M. Skinner, pers. comm.).

### 4.7.8 Candidate research and assessment priorities

Priorities for bull trout research and assessment in the Klamath Basin that have been suggested include:

- Understand the benefits of controlling bull trout competitors (e.g., brook trout, brown trout, rainbow trout) (Thorsteinson et al. 2011; ODFW 2016).
- Determine the current and ongoing viability of all remaining populations. Oregon's Wild Fish Management Policy [OAR 635-07-527(6) (a)] sets a minimum of 300 breeding fish as necessary to maintain genetically viable populations. Protection and restoration strategies should be meeting or exceeding this standard (Buchanan et al. 1997b).
- Determine the benefit of ongoing and proposed conservation and restoration efforts in reducing limiting factors to bull trout distribution and abundance (i.e., loss of shade and increased water temperatures, loss of instream flows, loss of habitat, passage barriers, siltation of gravels, streambank and riparian degradation, loss of large wood recruitment, loss of stream structure favorable to bull trout, overharvest, competition with introduced non-native species, and hybridization with introduced brook trout and other non-native trout species (Buchanan et al. 1997b).
- Determine the viability of re-introducing bull trout into streams within their historic range where suitable habitat still exists or could be established (Buchanan et al. 1997b; ODFW 2016), provided that the risks to bull trout and existing fauna are evaluated in accordance with appropriate policies and protocols (e.g., ODFW's Wild Fish Management Policy; the Klamath River Basin Fish Management Plan).
- Complete and apply the Oregon State University (OSU) decision support model to Klamath bull trout. This model could be used for evaluating the relative benefits of different management strategies for bull trout (e.g., isolating bull trout populations with barriers and removing brook trout from streams versus managing bull trout populations as they are with brook trout present) (ODFW 2016).
- Evaluate the effects of existing or emerging diseases and parasites on bull trout (USFWS 2015a).
- Develop and implement a statistically rigorous monitoring program to evaluate the effectiveness of recovery efforts through assessment of demographic responses by bull trout (USFSW 2015a).

As noted for other species, the above list of potential research activities needs to be further prioritized and sequenced. That effort should focus on those gaps in understanding and data which will most help to reduce critical uncertainties that significantly affect the choices between alternative management decisions on restoration actions and fish management, and/or improve the ability to evaluate the effectiveness of those decisions.

## 4.8 Redband trout

The native freshwater *Oncorhynchus mykiss* populations occurring east of the Cascade Crest are often referred to as redband trout (IRCT 2016). Studies have shown genetic differences between coastal and interior *O. mykiss*, and in many cases interior populations are managed separately from coastal *O. mykiss*. Three nominal subspecies of interior *O. mykiss* exist: Columbia River redband (*O. mykiss gairdneri*), Sacramento redband (*O. mykiss stonei*), and northern Great Basin and Klamath redband (*O. mykiss newberrii*) (Behnke 1992, as cited in IRCT 2016). Klamath redband trout (Figure 4-14) derive from a unique stock of rainbow trout indigenous to the river and its tributaries (ODFW 1997). Klamath redband trout are state listed as a Vulnerable species in Oregon (ODFW 2016). Federal agencies recognize Klamath redband trout as a Species of Concern (USFWS 2009, webpage).

Figure 4-14: Rock Creek redband trout. Photo from ODF 2016.

### 4.8.1 Population trends

Many populations of redband trout have declined in occurrence and abundance throughout the Pacific Northwest (Thurow et al. 1997), due largely to hybridization and competition with non-native salmonids, and to land use that has resulted in habitat fragmentation, flow alteration, and degraded stream and riparian habitat (IRCT 2016). Consistent data describing the constituent redband trout populations of the upper Klamath Basin over the past 30 years do not exist (ODFW 2005b), so that evaluation of historical population trends is not possible. However, redband trout numbers are high in both lakes and rivers of the upper Klamath Basin above Iron Gate Dam, and these trout currently support a strong summer recreational fishery (NCRWQCB 2010a-c) and a Tribal subsistence fishery (Thomson 2012). The redband trout population in the J.C. Boyle peaking reach (J.C. Boyle Damto Copco 1 reservoir) supports a high quality recreational fishery and has been described by the National Park Service as highly productive and self-sustaining (NCRWQCB 2010a-c). In 1984 the adult population in the upper six miles of the reach was estimated as 890 fish per mile, and in the five miles below this area (near the Oregon-California border) the population was estimated to be 1,911 fish per mile (NCRWQCB 2010a-c).

### 4.8.2 Historic versus current distribution

The redband trout is a resident rainbow trout whose ancestors entered the upper Klamath Basin when it was connected to the Columbia Basin via the Snake River (Behnke 1992, as cited in NRC 2004). An indigenous complex of resident redband trout is now found throughout the upper Klamath Basin above Upper Klamath Lake (ODFW 1997; NRC 2004). These redband trout evolved in historic isolation within the basin and have remained isolated in headwater streams of the Williamson and Sprague River drainages, Jenny Creek, upper portions of the Wood River and its tributaries and in the "Westside tributaries (e.g. Sevenmile Creek) (M. Skinner, pers. comm). Invading coastal stocks of rainbow and steelhead, introgressed with historic populations of Klamath redbands, have resulted in the modern day redband trout stocks of the upper Klamath River, Upper Klamath and Agency lakes and in the lower reaches of their tributaries. redband trout in Fall Creek appear to have been introgressed with hatchery rainbow trout (ODFW 1997). Analyses by Currens et al. (2009) confirmed that redband trout in upper basin headwater streams were genetically different from redband trout in Upper Klamath Lake and the upper Klamath River. Analyses by Pearse et al. (2011) further suggest that multiple lineages of *O. mykiss* are present in the upper basin.

Redband trout have persisted in the upper Klamath over time because of their ability to thrive in lake and stream conditions that would be lethal to most salmonids (NRC 2004). Redband trout, are considered highly plastic in general in response to habitat conditions (e.g., Cassinelli and Moffitt 2010) and Klamath redband trout have developed behavioral and life history characteristics that enable them to inhabit the warmer and highly eutrophic waters of the upper Klamath Basin (Messmer and Smith 2007). Redband trout occupy most accessible waterbodies in the upper Klamath. Recently, however, they are being displaced by non-native brook trout, brown trout, and non-native strains of rainbow trout in streams that lack fish passage or where fish passage and screening is limited (NCRWQCB 2010a-c; ODFW 2016). Current redband trout distribution has been much reduced compared to historical (see Figure 4-15) due to fish passage barriers, lack of instream flow and the dominance of brook trout, and occasionally brown trout, in headwater and cold streams (IRCT 2016). Range-wide, redband trout across the US are estimated to occur in about only 42% of their historical range (Muhlfeld et al. 2015). Thurow et al. (2007) suggested a similar value for the Klamath Basin itself, estimating (through a different methodology) that about 40% of redband trout's historical distribution in the Klamath is currently occupied. Assessments undertaken by the Interior Redband Conservation Team determined that 1,062 km of stream habitat and 36,544 ha of lake habitat were considered currently occupied by redband trout in the Klamath Basin (of which 940 km of stream and 84 ha of lake were used by conservation populations) (IRCT 2016). The term "conservation population" here being defined as a naturally reproducing population of native redband trout that is managed to preserve the historical genome and/or unique genetic, ecological, and/or behavioral characteristics (Muhlfeld et al. 2015; IRCT 2016). The Interior Redband Conservation Team (ICRT), comprised of representatives from federal, state, and tribal agencies as well as Trout Unlimited identified fourteen conservation populations of redband trout in the Klamath Basin (ICRT 2016). The Sprague sub-basin has six conservation populations, Williamson and

Upper Klamath Lake sub-basins each have three conservation populations, and the Upper Klamath Lake and Lost River sub-basins each have one conservation population.

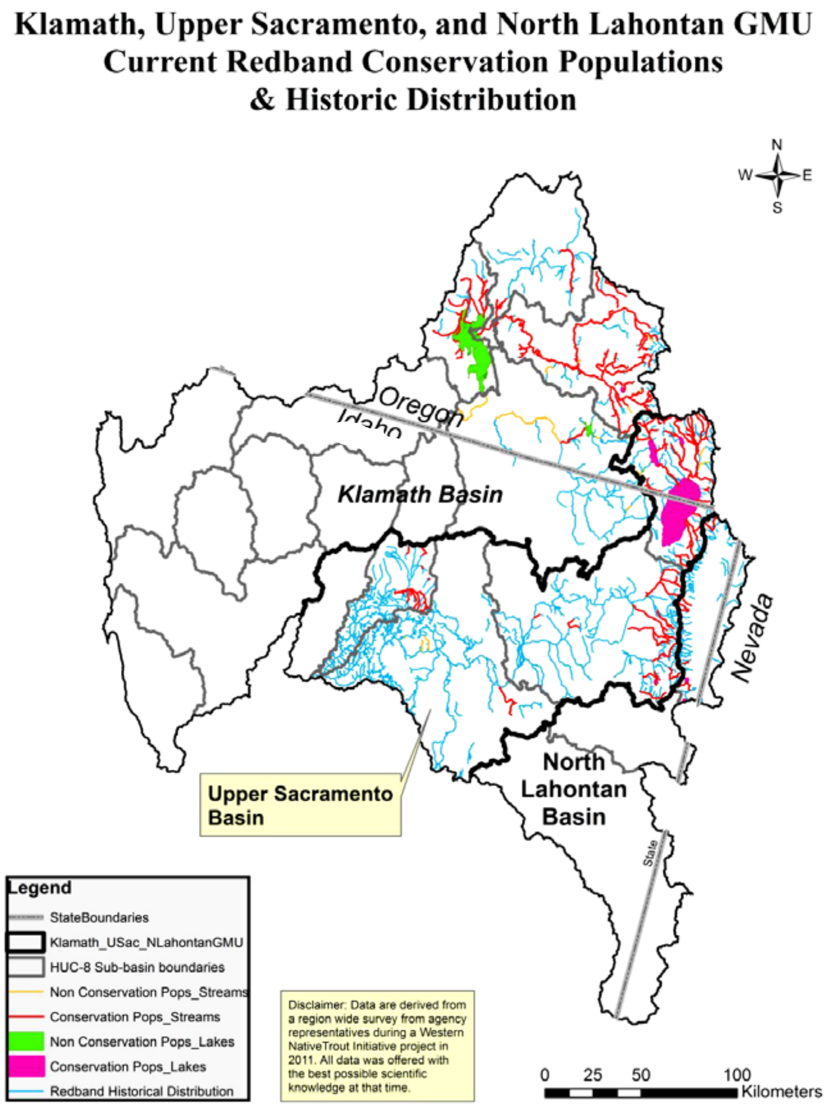



Figure 4-15: Distribution of interior redband trout in the Klamath, Upper Sacramento, and North Lahontan Geographic Management Unit (GMU). Figure from IRCT 2016. Map shows the current redband trout distribution (dark red and yellow lines) overlaid on estimated historical redband trout distribution (light blue lines).

### 4.8.3 General ecology, life history and periodicity

Redband trout populations exhibit broad phenotypic diversity, including variable age-at-maturity, frequency and timing of spawning, seasonal timing and patterns of migration, longevity, habitat selection, temperature tolerance, and a host of other characteristics (Thurow et al. 2007). Life history traits of redband are variable. At least three basic life history strategies have been described, based on how redband use their available hydrologic network during their life cycle.

Redband can rear in lakes and migrate to tributaries for spawning (adfluvial strategy), rear in relatively larger streams or rivers and migrate to tributaries for spawning (fluvial strategy), or display more restricted movements within natal stream networks (resident strategy) (IRCT 2016). Movement among habitats and populations may be an important mechanism for maintenance of genetic variability in populations, and for persistence in variable environments (Rieman and Dunham 2000). The Upper Klamath Lake population of redband trout is adfluvial and it migrates up into the Wood, Williamson, and Sprague rivers for spawning during spring (NRC 2004). These rivers also support resident populations of redband trout, as does the river below Upper Klamath Lake, mostly above Boyle Dam. Isolated stream resident populations, which are genetically distinct from the Klamath Lake and river populations, exist in the upper Williamson and Sprague rivers and in Jenny Creek, which flows into Iron Gate Reservoir (Bowers et al. 1999, as cited in NRC 2004).

Redband trout that rear in Klamath and Agency lakes and in upper Klamath River migrate to tributaries to spawn while redbands in the headwaters spawn in their natal streams. Most redband trout in the Klamath Basin typically spawn in the spring. The redband trout population in upper Williamson River has an additional fall spawning component (Personal Communications, Craig Bienz, The Klamath Tribes, January 1997, as cited in ODFW 1997). Redband trout that rear in spring-fed streams near Klamath and Agency lakes may spawn in the fall, winter, spring or even summer (ODFW 1997). They all spawn in good quality flowing water, with appropriate depth and velocity, over a gravel substrate in which they dig their redds and deposit their eggs (ODFW 1997).

After hatching and emergence from the gravel, redbands in headwaters disperse and rear to maturity in their natal streams (stream resident behaviour). Young migratory redband trout may stay in their natal tributary for more than a year before emigrating down to the lake (adfluvial behaviour) or mainstem river (fluvial behaviour) where they rear to maturity. Anadromous forms of redband trout that may have existed historically in the Klamath Basin have been extirpated (ODFW 2016). Redbands that remain in headwater streams typically mature and spawn at age 3+ years, then die. Redbands in upper Williamson River spawn multiple times (ODFW 1997). Fluvial and adfluvial redbands also mature at age 3+ but often survive to spawn several times in their natal streams – a behavior that maintains the integrity of separate stocks within the migratory redband trout group (ODFW 1997).

Life history stage periodicity of redband trout in the Klamath River is presented in Figure 4-16.

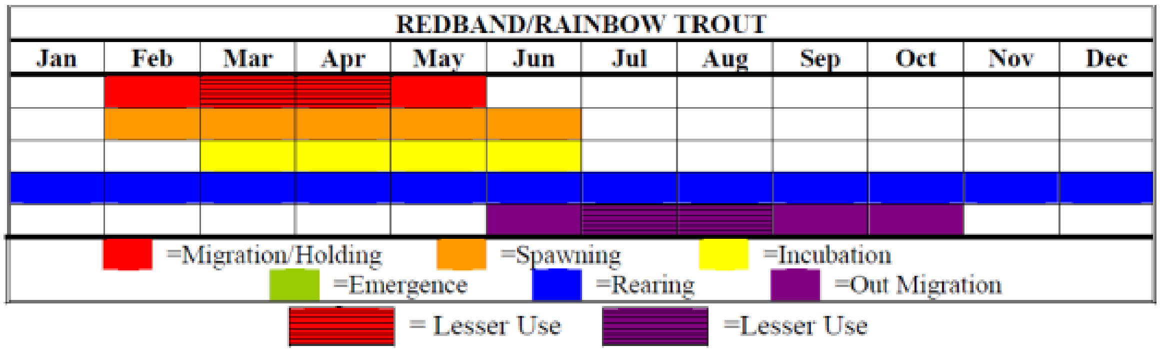



Figure 4-16: Redband/rainbow trout life history stage periodicity for the Klamath River in Oregon. From FISHPRO 2000 as reproduced in NCRWQCB 2010a-c.

## 4.8.4 Habitat requirements and known limiting factors

Numerous studies (as cited in IRCT 2016) have been conducted at several spatial scales on the habitat preferences of redband in streams. In vegetated montane streams, the presence of redband has been positively related to the abundance of pools and negatively related to stream gradient (Muhlfeld et al. 2001). In hotter lowland desert streams, redband presence has been associated more closely with shaded reaches of stream that block solar radiation and contain cooler stream temperatures (Li et al. 1994; Zoellick 1999).

Factors affecting redband trout survival are unique to specific reaches of streams, rivers or lakes (ODFW 2016). Many irrigation diversions remain unscreened and divert a majority of stream or river flow (ODFW 2016). Juvenile rearing habitat, water quality in Upper Klamath-Agency lakes and Sprague River, fish passage, brown and brook trout interactions, warm water species interactions (yellow perch (*Perca flavescens*), brown bullhead (*Ameiurus nebulosus*), largemouth bass), and lack of spawning habitat and thermal refuge are all major limiting factors to redband trout (ODFW 2016). Generally, redband trout respond very positively to good water years suggesting instream flow is an important limiting factor for redband trout populations (ODFW 2016).

Indigenous redband trout that live in waters with *C. shasta* are considered resistant (but not immune) to that disease (ODFW 2010b). Redband stocks that have remained isolated above the influence of coastal rainbow stocks are more susceptible to *C. shasta* and die when exposed to it (ODFW 1997). Behnke (1992) suggests that disease-resistance to C. Shasta may have played a role in originally structuring the Upper Klamath River and Upper Klamath Lake *O. mykiss* complex. It appears from *C. shasta*'s distribution in the Upper Klamath River that it was not able to invade into all waters and susceptible redband trout may persist in these isolated reaches. The existence of a stock with intermediate disease resistance in at least one tributary of the Sprague River suggests that regions of overlap may exist between reaches with different disease-tolerance, which may also delineate divergent lineages of *O. mykiss* (PacifiCorp 2004b).

Populations of redband trout in small streams are likely vulnerable to habitat degradation by roads, grazing, and other activities (NRC 2004). Spawning streams of fluvial and adfluvial populations will be sensitive to the same stresses; redband rearing habitats will need protection from adverse water quality that may affect them directly or promote further expansion of non-native species (NRC 2004). These populations would also benefit from improved habitat in the rivers and improved access to upstream habitat (Bowers et al. 1999, as cited in NRC 2004).

As with other interior salmonid species, the distribution and abundance of redband trout across its range has declined due to anthropogenic influences (IRCT 2016). The introduction of non-native strains of rainbow trout, as well as other non-native trout and non-salmonids has led to competition, hybridization, disease, and predation, and these are considered to be contributing factors in declines of native redband trout. Additionally, redband trout habitat has been lost, degraded and fragmented within a significant portion of its historical range. Causes include land and water use practices (e.g., agricultural and grazing practices, dam construction, water diversions, logging, road building, etc.). Non-point source pollution, sediment and runoff associated from urban development, reduced stream flows, altered thermal regimes due to drought/climate change, and habitat disturbance due to uncharacteristically large forest fires are growing concerns (IRCT 2016).

The establishment of impoundments and operations associated with hydroelectric production and irrigation have modified the environment of native redband trout in the upper Klamath River (IMST 2003; PacifiCorp 2004a). These modifications include fragmentation of habitats, obstruction of upstream and downstream passage, alteration of stream flow and water quality, and increased competition from introduced species associated with habitat changes (Jacobs et al. 2007). Consistent with these identified land use changes, the Interior Redband Recovery Team identified the primary factors affecting redband trout within the Klamath Basin as connectivity to historical habitats, fish passage/screening at diversions, degraded habitats, poor water quality, low stream flows, and the presence of non-native species (IRCT 2016). The Klamath Dam Removal Overview Report for the Secretary of the Interior (USDI, USDC, NMFS 2013) identified hydropower peaking operations as having negative impacts on redband trout.

### 4.8.5 Management and Recovery Plans

Conservative angling regulations on redband trout are implemented, including catch and release, to provide optimal fishing opportunities under the Wild Trout Management Option and the Trophy Redband Trout Management Option under the Klamath Basin Fish Management Plan (1997, OAR 635-500-3600, 635-500-3885, 635-500-3890). Trophy redband trout populations are extensively monitored by bi-monthly spawning surveys throughout spawning timing.

Recovery of redband trout populations in the basin is guided by a Conservation Strategy for Interior Redband Trout (*Oncorhynchus mykiss subsp.*) in the States of California, Idaho, Montana, Nevada, Oregon and Washington. This strategy was released in 2016 by the ICRT . In the context of this report, the plan applies to extant populations of redband trout in the upper Klamath Basin, which once had a much larger historical distribution. The primary goal of this plan is delisting, with a number of supporting objectives specific to the Klamath Basin. These objectives include identifying core conservation populations, maintaining and enhancing the abundance and distribution throughout their historical range through instream and riparian habitat restoration, improving habitat connectivity, improving land-use practices, managing the impacts of angling, minimizing the impacts of non-native species, and establishing new populations through reintroduction of wild or hatchery fish.

### 4.8.6 Conceptual and quantitative models

Muhfeld et al. (2015) have developed a conservation population vulnerability index (CPVI) to assess the status and threats to persistence of individual redband trout conservation populations. Risks within this model are classified as biotic, demographic, or abiotic using nine factors known to influence population viability, habitat quality, and future resilience. Relative importance weights are applied to the different factors, and the results across the factors are then combined to generate a composite risk score (with a total value range from 3-12; very good to very bad) for a redband trout conservation population. The nine measured factors within the CPVI are: (1) Biotic Risk – genetics, introduced species, and disease; (2) Demographic Risk – connectivity, population extent, and life history diversity; and (3) Abiotic Risk – habitat quality, land use practices, and land ownership. Figure 4-17 provides a schematic from Muhlfeld et al. (2015) that illustrates the CPVI structure and the weightings used for each of the nine model variables. The approach is intended to provide a flexible structure with which to evaluate the relative vulnerability of redband trout populations at any spatial scale of interest (Muhlfeld et al. 2015). Table 4-20 provides details of the CPVI criteria used by Muhlfeld et al. (2015) for scoring risks to redband trout conservation populations.

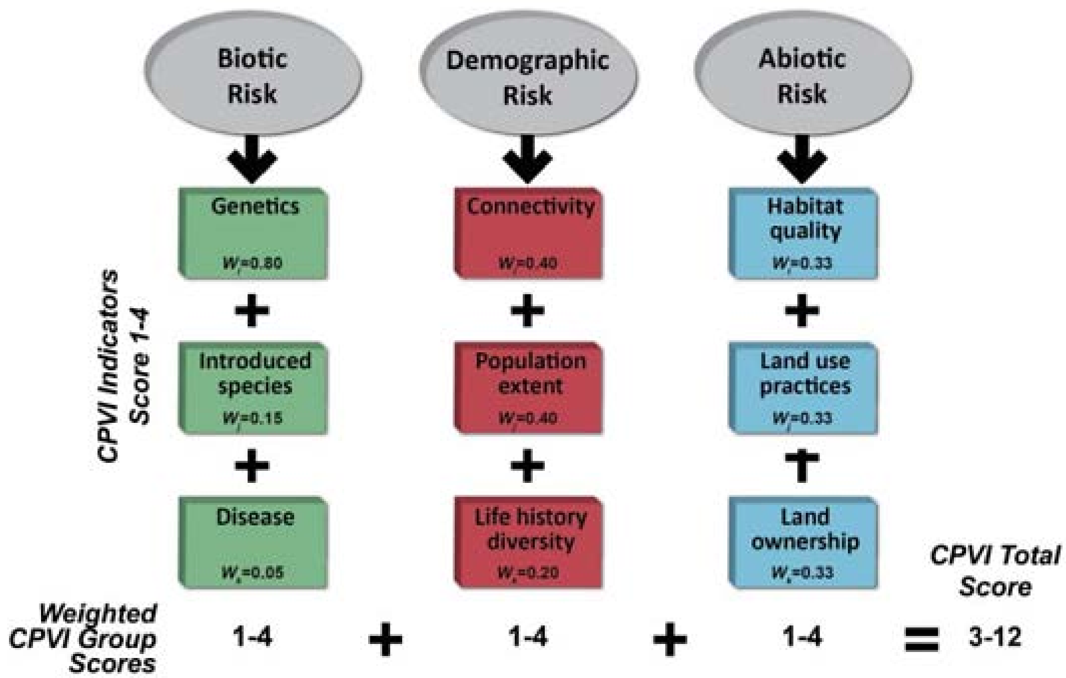



Figure 4-17: Schematic of the conservation population viability index (CPVI) developed for assessment of risk to redband trout conservation populations. Figure from Muhlfeld et al. 2015. The CPVI uses nine factors, which are divided into three general categories (biotic, demographic, and abiotic risks). Each factor is scored from 1 (very good) to 4 (poor), for a total of 12 possible points.

Table 4-20: Risks assigned to redband trout conservation populations based on criteria used in the Conservation Population Viability Index (CPVI) model proposed by Muhlfeld et al. (2015).

| Risk Category | Degree of Risk | Risk Attribute | Conservation Significance |
|---|---|---|---|
| Biotic Risks | | | |
| Genetics (hybridization) | Low | Hybridizing species cannot interact with existing redband trout population because a complete passage barrier is in place or hybridizing fish are not present in the same or any adjacent drainages | Hybridization and introgression with non-native salmonids are among the leading factors in declines of native resident redband trout |
| | Medium-low | Hybridizing species are in the same stream, a drainage farther than 10 km from redband trout population, or both, but not in same stream segment as redband trout or within 10 km where a barrier currently exists (though that barrier may be at risk of failure) | |
| | Medium-high | Hybridizing species are in the same stream or a drainage within 10 km of the redband trout population and no barrier exists, or both; however, hybridizing species are not yet found in the same stream segment as the redband trout population | |
| | High | Hybridizing fish are sympatric with the redband trout population | |
| Introduced Species | Low | Threats minor (0 non-native species) | Introduced species negatively impact native populations through predation, competition, hybridization, disease, and parasites |
| | Medium-low | Non-natives present in watershed, but the chance of spreading is low (1 non-native species) | |
| | Medium-high | Non-natives present in watershed, and the chance of spreading is moderate (2 non-native species) | |
| | High | Non-natives present in watershed, and the chance of spreading is high (>2 non-native species) | |
| Disease | Low | Significant diseases and the pathogens that cause them have very limited opportunity to interact with an existing redband trout population. Significant diseases and pathogens are not known to exist in stream or watershed | Non-native pathogens and parasites can infect redband trout and reduce their populations |
| | Medium-low | Significant diseases, pathogens, or both have been introduced, identified, or both in the stream, a drainage farther than 10 km from the redband trout population, or both but not in same stream segment as the redband trout or within 10 km where barriers exist (though the barriers may be at risk of failure) | |
| | Medium-high | Significant diseases, pathogens, or both have been introduced, identified, or both, in the same stream, a drainage within 10 km of the redband trout population, or both, and no barriers exist | |
| | High | Significant disease, pathogens, or both and disease-carrying species are sympatric with redband trout in the same stream segment | |

| Risk Category | Degree of Risk | Risk Attribute | Conservation Significance |
|---|---|---|---|
| **Demographic Risks** | | | |
| Population Connectivity | Low | Occupied habitat consists of numerous (>5) individual streams and potential subpopulations are strongly networked | Hydrologic connectivity provides more available habitat and facilitates expression of multiple life histories and genetic exchange, which increases the likelihood of persistence |
| | Medium-low | Occupied habitat consists of a few (4–5) streams and potential subpopulations are moderately networked | |
| | Medium-high | Occupied habitat consists of 2–3 streams and potential subpopulations are weakly networked | |
| | High | Population isolated to a single stream or segment of stream, usually due to a barrier | |
| Population Extent | Low | At least 75 km of connected habitats; good connectivity | Small populations are more susceptible to stochastic events, thereby increasing their vulnerability to extirpation |
| | Medium-low | ≥25 and <75 km of connected habitats | |
| | Medium-high | ≥10 and <25 km of connected habitats | |
| | High | <10 km of connected habitats; poor connectivity | |
| Life History Diversity | Low | All four life history forms (resident, fluvial, adfluvial, and lacustrine–adfluvial) present | Loss of life history forms, particularly migratory forms, increases the risk of extirpation and loss of genetic diversity |
| | Medium-low | Three life history forms present | |
| | Medium-high | Two life history forms present | |
| | High | Only one life history present | |
| **Abiotic Risks** | | | |
| Habitat Quality | Low | Stream habitat has the majority of attributes reflecting optimal conditions | Habitat conditions are a primary determinant of population persistence |
| | Medium-low | Stream habitat has a few attributes that are slightly less than ideal | |
| | Medium-high | Stream habitat has more attributes that are less than ideal | |
| | High | Most stream habitat attributes reflect inferior conditions | |
| Land Use | Low | No land use | Increased land use (e.g., timber harvest, grazing, mining, dams, etc.) reduces habitat quality quantity |
| | Medium-low | 1–2 types of land use | |
| | Medium-high | 3–4 types of land use | |
| | High | >4 types of land use | |
| Land Ownership | Low | ≥30% of watershed in protected status | Watersheds with higher proportions of protected lands support higher quality habitat than do other lands |
| | Medium-low | ≥15% and <30% protected | |
| | Medium-high | ≥1% and <15% protected | |
| | High | <1% protected | |

CPVI assessments for redband trout completed by Muhlfeld et al. (21015) calculated a current average CPVI value of 6.37 (1.3) for the fourteen Klamath Basin redband trout conservation populations (940 total stream kms). This was among the lower CPVI risk values determined across the full distribution of US river basins in which redband trout are present. CPVI disaggregated scores for the Klamath Basin redband trout conservation populations were Biotic Risk = 1.37 (0.4), Demographic Risk = 2.1 (0.9), and Abiotic Risk = 2.9 (0.3) (lower value = lower risk, higher value = higher risk).

### 4.8.7 Critical uncertainties & hypotheses

Uncertainties for redband trout relate to the potential benefits of removal of Klamath dams (if that should occur). Dam removal is anticipated to increase free-flowing redband trout habitat downstream of Keno Dam by restoring river channel habitat inundated by reservoirs, eliminating extreme daily flow and water temperature fluctuations in the J.C. Boyle Peaking Reach, and increasing flows in the J.C. Boyle Bypass Reach (USDI, USDC, NMFS 2013). This is predicted to expand the distribution and increase abundance of redband trout significantly from downstream of Keno Dam to the Iron Gate Reach (Buchanan et al. 2011, as cited in USDI, USDC, NMFS 2013).

Operations for peaking power within the reach between J.C. Boyle Powerhouse and Copco 1 Reservoir currently cause chronic stress to redband trout and result in mortality, stranding and turbine entrainment of fry, juvenile, and adult redband trout (Buchanan et al. 2011, as cited in USDI, USDC, NMFS 2013). Removing the dams would be expected to eliminate the effects of power peaking and restore more natural water temperature, flow, and sediment transport regimes, which are anticipated to reverse declines in abundance and size of adult redband trout that utilize habitats downstream of J.C. Boyle Dam. It could also restore life history strategies conducive to maintaining the viability of redband trout populations over the long term (USDI, USDC, NMFS 2013).

There is a risk that if dams were removed redband trout could be affected by increased predation from reintroduced salmonids, but the expectation is that this loss would likely be offset by an increase in available food sources (e.g., eggs, fry, and juveniles of reintroduced salmonids) (Hamilton et al. 2011, as cited in USDI, USDC, NMFS 2013). Existing redband trout and colonizing anadromous steelhead would be expected to co-exist if dam removal should occur, as they do in other watersheds, although there may be shifts in redband trout abundance related to competition for space and food (USDI, USDC, NMFS 2013).

Hodge et al. (2016) suggests that steelhead and rainbow trout can give rise to progeny of the alternate form and thus potentially interbreed, suggesting that dam removal might lead both to a facultatively anadromous *O. mykiss* population in the upper Klamath Basin and to the co-occurrence of, and reproductive exchange between, coastal steelhead–rainbow trout (*O. mykiss irideus*) and inland redband trout (*O. mykiss newberrii*).

### 4.8.8 Candidate research and assessment priorities

The Interior Redband Conservation Team has been applying a 3R analytical framework developed by Haak and Williams (2012) that can be used to inform the development of a rangewide conservation strategy for redband trout. This framework seeks to quantify the 3Rs (Representation, Resiliency, and Redundancy) in a spatially explicit manner in order to support comparisons of population diversity over space and time. Initial application of the Interior Redband Conservation Team's 3R modeling approach concluded that upper Klamath redband trout populations are generally well-connected, with migratory populations that are genetically unaltered (IRCT 2016). Protection of genetics and migratory life history strategies was identified as high priority. Specific priorities for redband trout research and assessment identified in the upper Klamath by the Interior Redband Conservation Team (IRCT 2016) included:

- Obtain more detailed information on the life histories of redband trout in Annie Creek and Sun Creek.
- Evaluate genetic integrity of the redband trout in Paradise Creek (SFK Sprague), as it is currently unknown. Implement biological and/or eDNA sampling to collect genetic material.
- Conduct a thorough genetic analysis of redband trout in Jenny Creek and all tributaries.
- Determine current status of known redband trout populations in headwater streams in California (e.g., North Fork Willow, Boles, Rock, and Fletcher creeks). The current status of these populations is unknown (last surveyed by the California Department of Fish and Wildlife (CDFW) in the 1980s), as is their relationship to hatchery trout that may have been planted in several stock ponds and small reservoirs in the drainage.
- For the California portion of the sub-basin, conduct reconnaissance surveys of headwaters to locate remaining redband trout populations and determine status. California Department of Fish and Wildlife (CDFW) to collect genetic samples from any redband trout populations encountered.
- Determine the status of remaining redband trout populations (if any) in the Oregon portion of the sub-basin. Continue to sample streams for the presence of redband in the sub-basin. ODFW (2016) believes that the known redband population for this sub-basin in Oregon (i.e., Miller Creek) is likely extirpated.
- Research the interactions between redband trout and yellow perch in Lower Crystal Creek.
- All appropriate upper Klamath sub-basins: identify and prioritize areas for reduction and/or removal of non-native fish species, and re-introduction of redband trout.

As noted for other species, the above list of potential research activities needs to be further prioritized and sequenced. That effort should focus on those gaps in understanding and data which will most help to reduce critical uncertainties that significantly affect the choices between alternative management decisions on restoration actions and fish management, and/or improve the ability to evaluate the effectiveness of those decisions.

## 4.9 Pacific lamprey

Lamprey are a primitive group of fish with a very ancient lineage (having remained largely unaltered for 360 million years) that are eel-like in form but lack the jaws and paired fins of true fishes (Gess et al. 2006; Streif 2008). The Pacific lamprey (*Lampetra tridentata)* (Figure 4-18), the most common lamprey in the Klamath Basin, is a Tribal Trust species and significant to Native American tribes. Pacific lamprey play a vital role in the ecosystem: cycling marine nutrients, passing primary production up the food chain as filter feeding larvae, promoting bioturbation in sediments, and serving as food for many mammals, fishes and birds (Goodman and Reid 2015). Tribal fisheries (eelers) in the Klamath target fresh adults of Pacific lamprey for subsistence and cultural purposes.

Figure 4-18: Adult Pacific lamprey (*Lampetra tridentata*). Photo from USFWS – Pacific Region.

Like salmon, adult Pacific Lamprey return from the ocean to spawn in the Klamath Basin, but their ammocoetes spend up to seven years in the freshwater environment before migrating back out to the ocean. Pacific lamprey remain in the ocean and live as predators for several years (Streif 2008).

Seven additional non-anadromous lamprey species are also present in the Klamath Basin (Kostow 2002). These includes the Klamath River lamprey (*L. similes*), the River lamprey (*L. ayresi*), Miller Lake lamprey (*E. minimus*), Klamath Lake lamprey (*E. sp*.), Pit-Klamath brook lamprey (*E. lethophagus*), Modoc Brook lamprey (*E. folletti),* and the Western brook lamprey (*L. richardsoni)* (Kostow 2002; Close et al. 2010). Lamprey taxonomy and field identification is difficult and scientists can be challenged to identify different species (Kostow 2002). This might be particularly difficult in the Klamath Basin, where multiple species of lamprey co-exist with different abundances and distributions.

- Klamath River lamprey are found in the Klamath Basin upstream and downstream of Iron Gate Dam as well as in the Trinity River Basin, including upstream of Lewiston and Trinity reservoirs; they can also persist in lakes and reservoirs in the Klamath Basin (Close et al. 2010).
- Scientists are unsure if the River lamprey is still present in Oregon (Kostow 2002). Not only is the species rare, but it is difficult to find in freshwater (Kostow 2002). For most of their life cycle, they are indistinguishable from the Western brook lamprey (Kostow 2002).
- Miller Lake lamprey are found in the upper Klamath Basin and were historically found in Miller Lake, located in the upper Williamson River. They have also been observed in Miller Creek, Jack Creek and the Sycan River (Lorion et al. 2000, as cited by Close et al. 2010). Miller Lake Lamprey, or a similar species, have also been observed in the Scott and Shasta rivers (Close et al. 2010).

- Klamath Lake lamprey is an undescribed taxon believed to be derived from the landlocked Pacific Lamprey, although they are now genetically distinct (Lorion et al. 2000, as cited by Close et al. 2010). They live in Upper Klamath Lake and migrate upstream to spawn in the Sprague River (Close et al. 2010).
- Pit-Klamath brook lamprey are found upstream of Keno Dam in mid-elevation streams of the upper Klamath Basin such as the Willison and Sprague rivers, and in spring-fed tributaries (Lorion et al. 2000, as cited by Close et al. 2010).
- The systemic status of the Modoc Brook lamprey is uncertain. They have been observed in the Clear Lake Basin, a tributary to the Lost River and potentially may exist in Fall Creek, a tributary to Copco Reservoir (Close et al. 2010).
- The Western brook lamprey is non-parasitic and is the second most widely distributed lamprey in Oregon (Kostow 2002). Within the Klamath Basin, they have been observed only in Hunter and McGarvey creeks, tributaries to the mainstem Klamath River near its estuary (Close et al. 2010). Western brook lamprey move little during their lives; most populations are in complete isolation (Kostow 2002).

### 4.9.1 Population trends

There are currently no status assessments for Pacific lamprey or any other Klamath Basin lamprey species (Close et al. 2010). Spawning and rearing estimates have not been conducted within the basin (Close et al. 2010). Pacific lamprey have been extirpated above Iron Gate Dam in the Klamath River and above Lewiston Dam in the Trinity River, unable to overcome the passage barriers (Close et al. 2010).

Pacific lamprey have been harvested for millennia by Klamath Basin Tribes. Traditional ecological knowledge provides the best existing account of Klamath River lamprey populations. Accounts gathered from traditional Yurok and Karuk Pacific lamprey eelers indicate that their populations have been in decline for 40 years and average annual harvests have dropped from 1,000 adults to 15 (Petersen Lewis 2009). Peterson Lewis (2009) reported that tribal members also observed a steep decline in the number of lamprey ammocoetes observed moving freely in the water column, compared to the situation three decades ago. He recorded tribal members noting that 30 years ago, hundreds of ammocoetes could easily be pulled up from the sand with bare hands; this is no longer the case. Tribal elders remember when Pacific lampreys were so thick in the Klamath River they could literally hear them, and bountiful harvests occurred (Petersen Lewis 2009). Pacific lamprey populations began to notably decline in the 1960s. By the 1980s, an eeler was fortunate to catch 50-100 Pacific lamprey. By the 1990s, an eeler was lucky to catch any fish at all (Petersen Lewis 2009).

Goodman et al. (2015) notes that the few long-term counts of Pacific lamprey available across their full US distribution indicate that large reductions in population size have occurred over the last few decades and earlier (Close et al. 2002). Columbia River populations have been observed in decline; in the Snake River basin, only 200 Pacific lamprey adults have been detected passing the dams annually (Kostow 2002). Pacific Lamprey have also declined in the lower Columbia basin and Oregon Coast (Kostow 2002).

## 4.9.2 Historic versus current distribution

Pacific lamprey were historically widely distributed across the west coast, where they ranged from Baja Mexico north along the Canadian coast and Alaska (Figure 4-19), making them one of the most widespread freshwater species in western North American (Reid and Goodman 2016). They border the Pacific Rim and have been found in Hokkaido Island, Japan (Streif 2008). Historically, Pacific lamprey were observed more than 850 miles inland and at elevations up to nearly 6,900 ft (Everman and Meek 1896, as cited by Kostow 2002). Over the past twenty years, the range of Pacific lamprey has contracted northward, with the southernmost population detected near Big Sur, California (Reid and Goodman 2016).

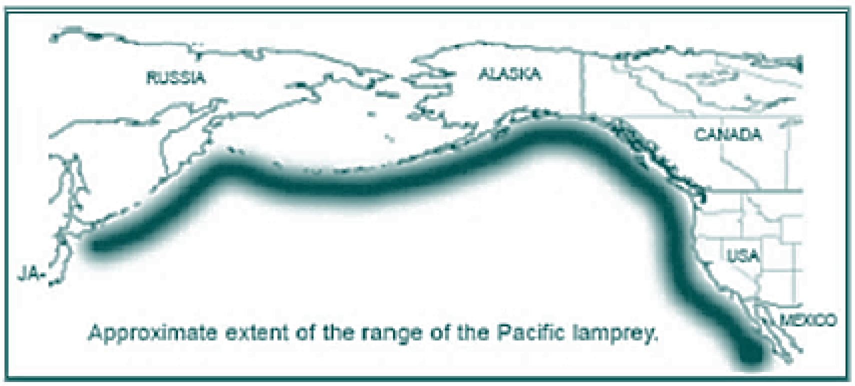



Figure 4-19: Historical distribution of Pacific lamprey. Figure from Streif 2008.

Recent data indicate that Pacific lamprey distribution has declined in many river drainages within their range (Strief 2008). Pacific lamprey are assumed to have been widely distributed and abundant historically in California's north coast, based on current distribution, available habitat and tribal knowledge of fisheries (Goodman and Reid 2015). Dams and other barriers have impeded their migration and reduced their distribution. A principal uncertainty is how far Pacific lamprey extended into the upper Klamath Lake Basin (Goodman and Reid 2015). Pacific lamprey were however considered to be present in the upper Klamath Basin prior to the construction of the dams (Thorsteinson et al. 2011). Subsequent construction of Iron Gate Dam prevented Pacific lamprey from reaching the upstream reaches of the Klamath Basin. Hamilton et al. (2005) found two documents that provided evidence of Pacific lamprey above the current site of Iron Gate Dam, specifically documenting their historic use as far upstream as Upper Klamath Lake as well as Fall Creek, in particular.

## 4.9.3 General ecology, life history and periodicity

Pacific lamprey do not home to their natal streams (Goodman et al. 2008; Spice et al. 2012). They instead use cues from flow patterns and ammocoete pheromones in the offshore river plume to identify suitable rivers for spawning and rearing (Moser et al. 2015). See Figure 4-20 for a general overview of the life cycle of Pacific lamprey. Because of this unique homing characteristic, Pacific lamprey are a nearly homogenous population and returning adults may arrive at a stream that is characteristically different than their natal home (Goodman et al. 2015).

As a result, juveniles have developed generalized adaptive strategies suitable to a broad range of environmental conditions across a very broad historic range (Goodman et al. 2015).

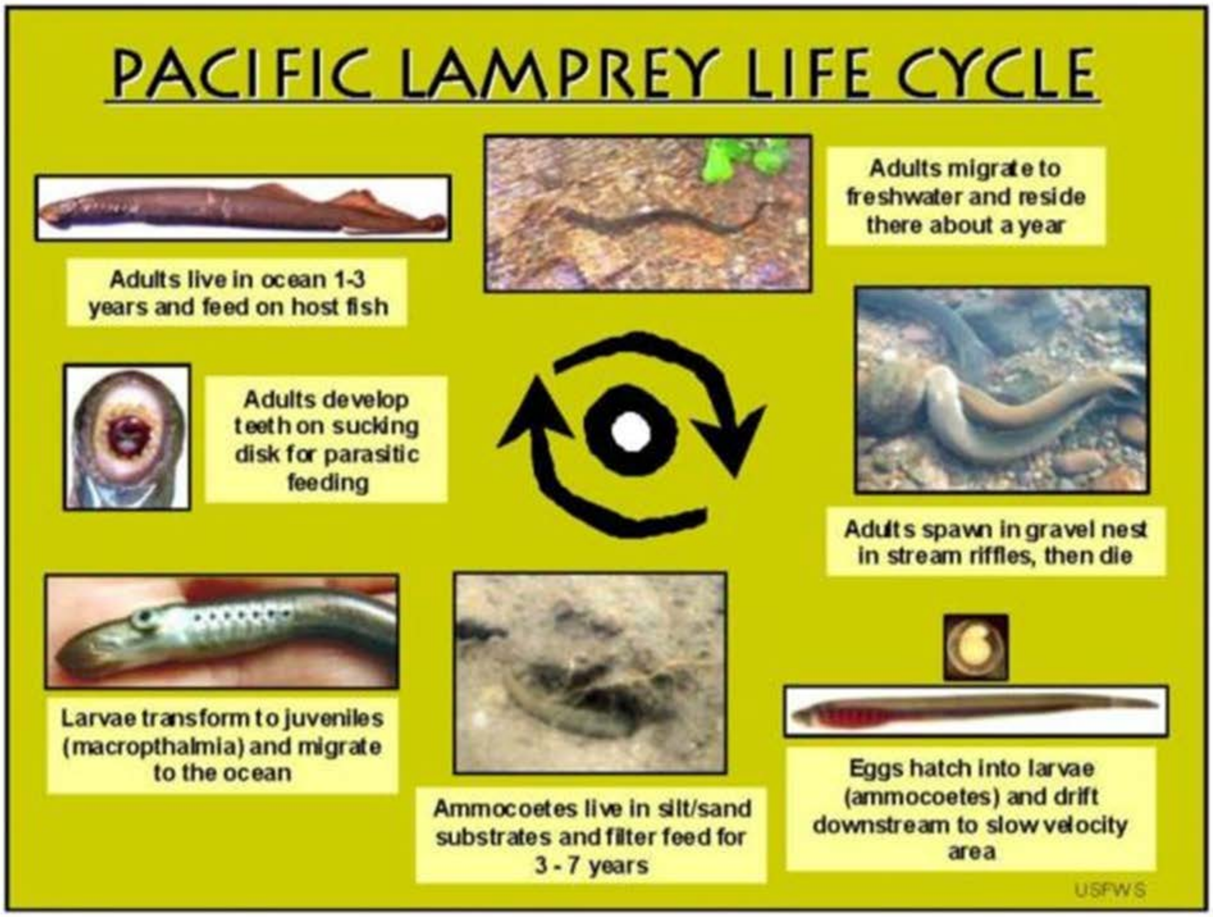



Figure 4-20: Overview of the Pacific lamprey life cycle. Figure from Streif (2008).

As adults living in the ocean, Pacific lamprey are parasitic and feed on various species including salmon, flatfish, rockfish and pollock (Streif 2008). They have been caught in depths ranging from 300 to 2,600 feet and have been caught offshore as far as 62 miles (Strief 2008). Once they have lived in the ocean between one to three years, they migrate to the Klamath River between February and June. This migration occurs largely at night (Robinson and Bayer 2005, cited by Close et al. 2010).

Scientists believe adult lamprey likely overwinter in the Klamath Basin and its tributaries for roughly one year prior to spawning (Streif 2008). During this year, they do not feed; instead, they subsist using stored reserves (Read 1968, as cited in Close et al. 2010) resulting in a reduction in body size (Beamish 1980 as cited by Close et al. 2010).

Pacific lamprey spawn in gravel bottom substrate at the end of riffles, similar to salmon. Spawning occurs beween March and July, depending on location (Streif 2008). Adult lampreys detect pheromones in areas seeded with ammocoetes, then spawn, and typically die three to 36 days after spawning (Streif 2008).

Embryos hatch 19 days after spawning at 59°F, after which ammocoetes will drift downstream to low velocity habitat with sandy substrates (Streif 2008). Ammocoetes spend the next three to seven years buried in fine sediments, filter feeding on diatoms and algae. They drift downstream during high flow events (Streif 2008).

Ammoceotes transition to macropthalmia (juveniles) over several months, during which time they develop eyes and teeth and enter the water column. This typically occurs during summer months (Streif 2008). Emigration to the ocean occurs between late fall and spring (Streif 2008).

Life-history timing of Pacific lamprey in the Klamath Basin downstream of Iron Gate Dam is shown in Figure 4-21.

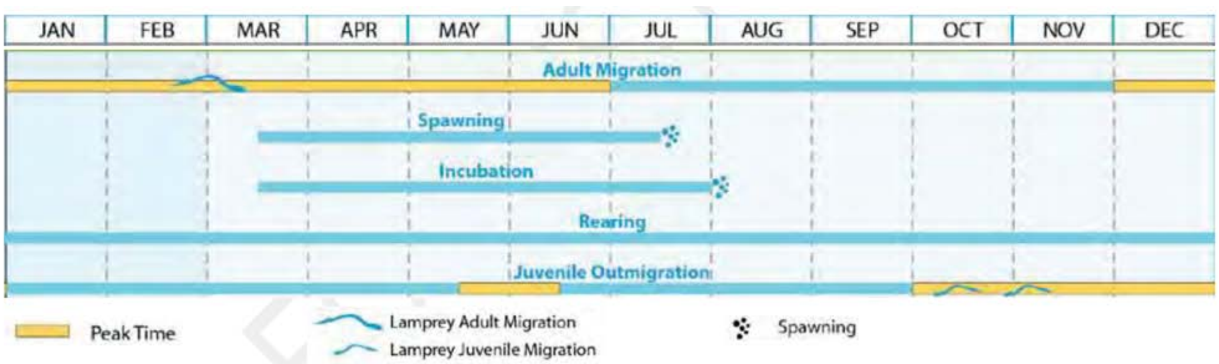



Figure 4-21: Timeline of Pacific lamprey life history stage periodicity in the mainstem of the Klamath River. Figure derived from USDI, USDC, NMFS 2013.

## 4.9.4 Habitat requirements and known limiting factors

Spawning habitat of Pacific lamprey is generally characterized as gravel-bottomed substrate, at the upstream edges of riffles (Scott and Crossman 1973, as cited by Close et al. 2010). Rearing habitat consists of fine sediments or sand deposits along the channel margins. After emergence from spawning gravels, ammocoetes drift downstream to nearby pockets of fine sediments (sand deposits). There they burrow and grow into juveniles.

A number of factors have been identified that limit the distribution and abundance of Pacific lamprey. These factors include: passage limitations caused by dams, culverts, and water diversions; poisoning from accidental spills and chemical treatments; mining and associated suction dredging (which impacts ammocoetes in particular) (Close et al. 2010). Dewatering caused by flow management results in sudden changes in instream flows and may desiccate ammocoete habitat, resulting in a significant impact on local lamprey populations (Streif 2008). Habitat conditions in the Klamath River mainstem reach from Iron Gate Dam to the Scott River (47 mi), has been found to represent a "dead zone" for Pacific lamprey, containing few ammocoetes, presumably due to flow management, poor water quality, lack of sandy fines and high deposition rates of organic material (Goodman and Reid 2015). Habitat degradation and channel simplification, including the loss and reduction of riffle and side channel habitats, has also reduced the amount of spawning and rearing habitat available to Pacific lamprey (Close et al. 2010). Non-native fish species such as bass and walleye prey on Pacific lamprey (Close et al. 2010). In the lower Klamath River, seals and sea lions feed on migrating runs of adult lamprey near the mouth, and this pressure has increased as pinniped populations increase, although their actual impact on the Pacific lamprey population has not been quantified (Goodman and Reid 2015).

Ocean conditions can also be a significant limiting factor for Pacific lamprey, especially when combined with climate change. Reduced abundances of salmon, hake, and other lamprey hosts in the ocean, combined with changing water temperatures resulting from climate change, may affect lamprey survival and growth (Strief 2008; Close et al. 2010). The already documented northward shift of Pacific lamprey distribution due to changes in ocean conditions, inland droughts, and shifts in drainage sizes preferred by the species may be an indicator of potential future impacts of climate change (Reid and Goodman 2016). Additionally, anticipated increases in drought frequency and duration may increase habitat desiccation, preventing or eliminating access to potential freshwater spawning and rearing habitats used by lamprey (Reid and Goodman 2016).

### 4.9.5 Management and Recovery Plans

Recovery of Pacific lamprey is mandated under the Conservation Agreement for Pacific Lamprey (*Entosphenus tridentatus*) released by the U.S. Fish and Wildlife Service in collaboration with state and Tribal agencies in 2012 (USFWS 2012a). The overarching goal of this plan is to achieve long-term persistence of Pacific lamprey and support traditional tribal cultural throughout their historic range. Because Pacific lamprey biology is not yet well understood, many of the supporting objectives of this plan focus on research and coordination, but the plan also includes objectives for enhancing watershed conditions and restoring Pacific lamprey populations within specific regional management units (RMUs). The agreement is backed by a number of Regional Implementation Plans, including an implementation plan for the California – North Coast RMU residing in the Klamath Basin (Goodman and Reid 2015). This latter plan includes objectives more specific to the Klamath Basin such as flow needs assessments, improvement in land use and irrigation practices, reducing the impacts of invasive brown trout and, most notably, restoration of fish passage to historical habitats in the upper Klamath Basin through removal of major dams. While there remains some uncertainty about the historical extent of Pacific lamprey in the upper Klamath Basin, the Implementation Plan concludes that removal of the dams and restoration of natural hydrologic flow regimes to the Klamath River would have a great positive influence on Pacific lamprey in the upper Klamath River drainage (Goodman and Reid 2015). The analysis in the Klamath Facilities Removal EIS/R indicated that the effect of opening significant portions of the Klamath River to anadromous fish species such as Pacific lamprey would be beneficial.

Additionally, a specific conservation plan was written in 2005 for management of lamprey in Miller Lake, near the northern boundary of the Klamath Basin, in the Miller Lake Lamprey

Conservation Plan (ODFW 2005c, OAR 635-500-3885). Reintroduction of Miller Lake lamprey is currently occurring in historic habitats of Miller Lake and tributaries.

### 4.9.6 Conceptual and quantitative models

We are not aware of any conceptual or quantitative models for Pacific lamprey in the Klamath Basin that explicitly link environmental changes and basin impacts to lamprey responses. However, the remainder of this section describes linkages between Pacific lamprey life history characteristics and the key factors that may impact them.

Pacific lamprey differ from other anadromous focal species in the Klamath Basin in that they do not home. Pacific lamprey born in the Klamath River or its tributaries may never again return to their natal river during their lifetime. Though declines in tribal harvest (Petersen Lewis 2009) and greatly reduced spatial distributions (Close et al. 2010) clearly indicate significant impacts, the causes of these impacts are not limited to the Klamath Basin. Rather, the abundance of Pacific lamprey in the Klamath Basin is affected by factors across its entire range, which is extraordinarily broad, including ocean conditions. On the plus side, future restoration actions targeted to benefit Pacific lamprey will have potential benefits for the entire species distribution, not just for those Pacific lamprey spawning or rearing in the Klamath Basin. However, an increase in the production of ammocoetes and outmigrants in the Klamath Basin will not necessarily result in a proportional increase in returning adults (Close et al. 2010).

At an ecosystem function level, ammocoetes can represent a large portion of the biomass in streams where they are abundant, thus making them a potentially important component along with aquatic insects in processing nutrients, nutrient storage, and nutrient cycling (Kan 1975, as cited in Close et al. 2010). As such, future large-scale recovery of Pacific lamprey in the Klamath Basin would likely offer a compounding benefit to other focal anadromous fish species.

In their freshwater environment, Pacific lamprey depend on riffle habitat for spawning and sandy substrate for rearing. Management actions that increase habitat complexity and diversity will, in turn, increase the amount of spawning and rearing habitat available. Similarly, management actions that remove passage barriers (culverts, roads, diversion infrastructure, dams, etc.) will also increase the amount of habitat available. Lamprey are able to use their mouths to cling to and climb over boulders and are thus able to make surprising headway when migrating upstream in tributary environments that may offer temperature refugia.

Flow management can play a vital role in Pacific lamprey recovery. Goodman et al. (2015) emphasized the importance of natural stream hydrology; they recommended synchronizing dam releases with winter and spring high flow storms to reduce ammocoete outmigration time. Longer periods of migration reduce their fitness and health (Goodman et al. 2015). In the Sacramento River Basin, recent research by Goodman et al. (2015) found Pacific lamprey emigration to be associated with rainfall events and high streamflows in the winter and spring, and potentially with temperature. Higher streamflows also decrease potential predation by increasing turbidity and reducing the ability of predators to visually attack (Goodman et al. 2015).

Ammocoetes are also vulnerable to desiccation in fine sediments from dewatering events (Strief 2008). Extreme fluctuations in flow releases that quickly reduce water surface elevations can cause ammocoete mortality. If the Klamath River dams were removed, then the timing of upper basin irrigation diversions will become a key issue, ideally timed to avoid entrainment during emigration. Ammocoetes are small and poor swimmers, causing them to be particularly vulnerable to entrainment, even when diversions are screened (Dauble et al. 2006).

Pacific lamprey prefer large basins (Reid and Goodman 2016), likely because they cue into ammocoete pheromones released into river plumes. Larger basins with larger populations result in more strongly scented plumes. Future enlargement of the Klamath Basin through dam removal may increase their preference for the Klamath River as the pheromone signal from the basin may strengthen and attract larger returns each year. Whether or not such larger returns would actually occur would depend partially on ocean conditions.

## 4.9.7 Critical uncertainties & hypotheses

Of the critical uncertainties facing Pacific lamprey in the Klamath Basin, dam removal is perhaps the most significant. Removal of the Klamath dams would open approximately 420 miles of potential functional spawning and rearing habitat for Pacific lamprey and other anadromous species (Hetrick et al. 2009, as cited by Close et al. 2010). Dam removal would also increase the potential for additional thermal refugia from large springs that would be newly accessible to lamprey (Close et al. 2010). There is, however, no certainty that the upper basin habitat would again be utilized and likewise no ability to predict the resulting abundance of Pacific lamprey.

Pacific lamprey have been observed to successfully colonize new habitats in British Columbia and also in Oregon's Upper Umatilla River after extirpation (Close et al. 2009, as cited in Close et al. 2010). By extension, Pacific lamprey are also expected to recolonize the Klamath River Basin after dam removal, although passive recolonization may occur slowly (Close et al. 2010).

The quality of new habitat for Pacific lamprey upstream of Iron Gate Dam would be variable.
Predictions regarding the amount of sediment that will accumulate indicate that most of the Klamath River mainstem reach above Iron Gate Dam will not constitute high-quality larval lamprey habitat,, but tributaries such as Shovel, Spencer, Fall, and Jenny creeks were likely historically used by Pacific lamprey and offer valuable thermal refugia (Hamilton et al. 2010; Close et al. 2010). Close et al. (2010) noted that the reach between J.C. Boyle Powerhouse and the Caldera rapids, as well as the reach currently under Copco Reservoir, may offer the highest quality of potential new mainstem habitat for Pacific lamprey.

Dam removal and proposed gravel augmentation would be expected to improve natural routing of gravel, expand gravel bars and increase spawning habitat. Flow management would also improve, as dam removal would halt the rapid fluctuations currently observed on the Klamath for power peaking; these flow fluctuations cause rapid channel dewatering that can result in ammocoete desiccation (Close et al. 2010). Pacific lamprey larval rearing capacity downstream of Iron Gate Dam would be increased during the short-term after dam removal because of the added fine sediment loading following dam removal (Close et al. 2010). This new burrowing habitat for ammocoetes would be likely decrease through time after an immediate pulse of fine sediment resulting from dam removal, as these fine sediments should be gradually flushed from the system. However, it is anticipated that more rearing habitat than is presently available would likely remain after dam removal (Close et al. 2010).

Climate change is expected to increase air and water temperatures, which could increase water quality stresses (Close et al. 2010). During the Secretarial Determination process, the U.S. Bureau of Reclamation modeled climate change scenarios. The Expert Review Panel on Lamprey (Close et al. 2010) concluded that dam removal conditions under the Climate Change model showed a slight positive effect on lamprey habitat and distribution downstream of Keno Dam. They further noted the benefit of access to new tributaries and thermal refugia (Close et al. 2010). Climate change will also affect ocean conditions, including the abundance of salmon and other host species. Climate change will likely affect adult Pacific lamprey abundance to the extent that it alters habitat conditions in freshwater and food availability in the ocean (Close et al. 2010).

### 4.9.8 Candidate research and assessment priorities

Little information exists regarding the status, distribution, and general biology of all lamprey species in the Klamath Basin, including the Pacific lamprey (Close et al. 2010). In their Expert Review Assessment for the Secretarial Determination, Close et al. (2010) identified the following critical information needs:

- determine the current distribution of Pacific lamprey ammocoetes within the lower Klamath Basin in relationship to habitat characteristics;
- identify spawning and overwintering locations for Pacific lamprey with respect to timing and water temperature;
- develop population estimates, including emigration, immigration and density and age composition estimates for ammocoetes;
- estimate current harvest rates; and
- obtain a better understanding of possible interactions between anadromous Pacific lamprey and the resident Klamath River lamprey.

Goodman and Reid (2015) identified general research needs to improve understanding of Pacific lamprey conservation needs north coast region-wide. These include:

- **Passage:** Investigate and develop designs or management approaches for lamprey passage at culverts, low-head dams or weirs, and fish ladders. It will also be useful to investigate entrainment risk from small-scale (< 4") unscreened pumping stations and develop downstream passage/screening criteria for ammocoetes and emigrating juveniles.
- **Ammocoete habitat:** Investigate sediment habitat needs of lamprey ammocoetes, the role of temperature and dissolved oxygen levels in sediment habitat quality, the impact of eutrophication and associated algal blooms on sediment conditions, and mitigation measures for use during in-channel projects to reduce mortality of ammocoetes.
- **Adult holding habitat:** Determine thermal and dissolved oxygen tolerances for adult lamprey during the summer holding period.

- **Distribution:** Due to our currently limited understanding of the specific distribution and population dynamics of Pacific lamprey, distributional surveys of ammocoetes, spawning areas and over-wintering habitat, as well as adult population censusing and emigrant monitoring, are recommended.

Such foundational information is necessary prior to developing future models for the species. As noted for other species, the above list of potential research and assessment activities needs to be further prioritized and sequenced. That effort should focus on those gaps in understanding and data which will most help to reduce critical uncertainties that significantly affect the choices between alternative management decisions on restoration actions and fish management, and/or improve the ability to evaluate the effectiveness of those decisions.

## 4.10 Lost River and shortnose suckers

Lost River (*Deltistes luxatus)* and shortnose (*Chasmistes brevirostris*) suckers are large, long-lived, lake-dwelling species endemic to the upper Klamath Basin (NRC 2004). Both species are currently on the federal, Oregon, and California endangered species lists (NCRWQCB 2010a-c; USFWS 2012b). Lost River suckers (Figure 4-22) have elongated bodies, sub-terminal mouths and a notched lower lip; they grow up to 38 inches (Moyle 2002, as cited by Buchanan et al. 2011). Shortnose suckers (Figure 4-23) can be identified by their large heads, oblique terminal mouths, and thin lips; they grow up to 23.6 inches (Moyle 2002, as cited by Buchanan et al. 2011).

Figure 4-22: Adult Lost River sucker (*Deltistes luxatus*). Photo by Josh Rasmussen, USFWS.

Figure 4-23: Adult shortnose sucker (*Chasmistes brevirostris*) Photo by Josh Rasmussen, USFWS.

### 4.10.1 Population trends

Early accounts note that populations of both Lost River and shortnose suckers were robust and an important food resource for Native Americans (Speir 1930, as cited by USFWS 2012b). Both species ascended the Williamson River in the thousands and were "taken and dried in great numbers by native peoples" (Cope 1879, as cited by USFWS 2012b). Bendire 1889 (as cited by USFWS 2012b) described a similar spawning run up the Lost River from Tule Lake. The Klamath Tribes historically harvested tens of thousands of pounds of shortnose and Lost River suckers (NCRWQCB 2010a-c). However, at the time of listing, both species had declined dramatically, reducing spawning runs to a fraction of historical levels (USFWS 2012b).

In their 2012 report, the USFWS indicated that declines of Klamath sucker populations relative to historic levels were most likely the result of habitat loss, which had curtailed up to 75% of their historic range at that time (USFWS 2012b). Declines are continuing, however, with abundances of male and female Lost River suckers estimated to have decreased by 55% and 42% respectively between 2001 and 2013, while abundances of male and female shortnose suckers are estimated to have declined by 77% and 73% respectively over the same time period (Hewitt et al. 2015). The 2014 status and trend assessment of endangered suckers in Upper Klamath Lake noted both species have suffered from substantial decreases of spawning adults, likely because new recruitment has been insufficient to offset mortalities (Hewitt et al. 2015; Burdick et al. 2016). The endangered sucker population in Upper Klamath Lake remains imperilled (Hewitt et al. 2015). The contemporary sucker population is probably a tenth of what it was a decade ago (Hewitt et al. 2014, as cited by Burdick et al. 2015a).

### 4.10.2 Historic versus current distribution

The historic distribution of Lost River and shortnose sucker is believed to be extensive (Buchanan et al. 2011). Both species are native to the Klamath and Lost River watersheds of the Upper Klamath Basin in Oregon as well as California (Buchanan et al. 2011). The species are most abundant in Upper Klamath lakes with spawning populations extending upstream to tributaries such as the Williamson and Sprague rivers. Populations also exist elsewhere in the basin, including Clear Lake, with smaller numbers of individual observed in J.C. Boyle Reservoir, Tule Lake, and Copco Reservoir (Buchanan et al. 2011). Some historical spawning areas in Upper Klamath Lake and its tributaries are no longer used for no apparent physical reason (e.g., Harriman Springs, Barkley Springs, and several tributaries in the Wood River Valley) (USFWS 2008a). Current lack of use of these historical spawning sites likely reflects the effects of past over-harvest and other mortality factors affecting adults, and continued low recruitment of young (E. Janney, pers. comm.). There is also some thought that lack of use of historical spawning sites may have a social element; that is, that fish learn about spawning sites by following or observing other fish (NRC 2004). If so, use of these spawning sites may be renewed if adult populations become substantially more abundant (Buchanan et al. 2011).

### 4.10.3 General ecology, life history and periodicity

Both Lost River and shortnose suckers are large, long-lived and late to mature (Buchanan et al. 2011). Unlike other sucker species, lake suckers have mouths that open more forward than down to better consume zooplankton from the water column instead of feeding from the substrate below (Scoppettone and Vinyard 1991; Moyle 2002, as cited by Buchanan et al. 2011). Suckers grow quickly during the first five to six years. Shortnose suckers reach sexual maturity within four to six years; Lost River suckers reach their sexual maturity within four to nine years (Perkins et al. 2000b, as cited by Buchanan et al. 2011). Lost River suckers have been documented to live as long as 57 years (Terwilliger et al. 2010, as cited by Buchanan et al. 2011), while shortnose suckers have been aged to 33 years (Scoppettone and Vinyard 1991, as cited by Buchanan et al. 2011).

***Spawning*.** The timing of spawning migration varies from year to year and is dependent on age, species, location within the Klamath Basin, and environmental conditions. Spawning generally ranges from March through May (Buchanan et al. 2011; Hewitt et al. 2015). Lost River suckers arrive at shoreline spawning areas each year when lake water temperature reaches approximately 6$^{o}$C (Hewitt et al. 2012, as cited in Burdick et al. 2015b). Lost River sucker spawning has been observed to peak in April when water temperatures were greater than 10°C (Hewitt et al. 2015). The spawning migration window for shortnose suckers has been observed to occur from early April to late April/early May when water temperatures were ≥12°C (Hewitt et al. 2015).

Lost River and shortnose suckers generally migrate approximately 7 to 12 miles from a lake to spawn (J. Rasmussen, pers. comm.). Lost River suckers will also spawn at shoreline springs along lake margins in Upper Klamath Lake and similar water bodies within their range (Buchanan et al. 2011). Spawning occurs at water temperatures between 5°C and 20°C (Perkins and Scoppettone 1996; Moyle 2002; Buettner and Scoppettone 1990, as cited by Buchanan et al. 2010), although peak migration is associated with water temperatures between 10°C and 15°C (Perkins et al. 2000b, as cited by Buchanan et al. 2011). Both species spawn in riffles or runs with a preference for gravel substrate. Spawning has been observed in habitat with depths generally less than 70 cm and velocities between 0.01 and 0.085 m/s for Lost River suckers and 0.7 – 1.2 m/s for shortnose suckers (Scoppettone and Vinyard 1991; Perkins and Scoppettone 1996; Buettner and Scoppettone 1990, as cited by Buchanan et al. 2011). Lost River suckers spawning at shoreline springs in Upper Klamath Lake target depths less than 110 cm (Reiser et al. 2001, as cited by Buchanan et al. 2011). Lost River and shortnose suckers do not die after spawning and can spawn many times during their lifetime (Buchanan et al. 2011). Individuals of both species commonly spawn in consecutive years (Buchanan et al. 2011).

Sucker spawning habitat in Upper Klamath Lake is affected by low lake elevations (Burdick et al. 2015b). Given the imperiled status of the species and the declining abundance of the population in Upper Klamath Lake, any reduction in spawning success and egg production could negatively impact recovery efforts. Current lake elevations in Upper Klamath Lake are regulated through the 2013 joint NMFS and USFWS Biological Opinion for USBR's Klamath Project (NMFS and USFWS 2013) to ensure endangered suckers are not further imperilled by low lake elevations, especially in consecutive years. Burdick et al. (2015b) found that Upper Klamath Lake elevations greater than 1,262.3 – 1,262.5 m (4141'4.85" – 4142'0.72'' would be unlikely to limit the number of spawning suckers and overall egg production. USBR modeling suggests that the near-term (to 2023) operation plan of the Klamath Project should maintain lake surface elevations during the sucker spawning season above 1,262.3 m in more than 90% of years provided weather predictions are accurate (USBR 2012a,b). Severe drought conditions (as occurred in 2012 – 2013), could occasionally bring lake surface elevation below these levels during spring spawning periods (Burdick et al. 2015b). However, it is considered that the current U.S. Bureau of Reclamation operational plan should make it unlikely that low lake surface elevation will impair Lost River Sucker spawning (Burdick et al. 2015b).

***Emergence and larvae*.** Lost River sucker eggs hatch after nine to 19 days, while shortnose sucker eggs hatch after six to 16 days at water temperatures of 14 – 15 °C (Perkins and Scoppettone 1996, as cited by Buchanan et al. 2011). After hatching, larval suckers quickly drift downstream to lakes (Cooperman and Markle 2004; Ellsworth et al. 2007, as cited by Buchanan et al. 2011), although exceptions have been observed where larvae remain in rivers for an extended period (timescale of months). This is hypothesized to be related to flow and habitat conditions (Murphy and Parish 2008, as cited by Buchanan et al. 2011). Larval suckers begin to appear in Upper Klamath Lake in early April with peak catches most often recorded in June. Larval densities decline by mid-July (Cooperman and Markle 2000, as cited by Buchanan et al. 2011). Once in Upper Klamath Lake, most larvae swim near the surface (Figure 4-24).

Figure 4-24: Sucker larvae. Photo from Ron Larson, USFWS.

***Juveniles*.** Juvenile suckers range from 25 – 100 mm total length and occur in Upper Klamath Lake and similar habitats from July through the following winter (Buchanan et al. 2011). Juveniles utilize both near-shore and off-shore habitats and transition to bottom dwellers (Buchanan et al. 2011). Juveniles migrate down the lake to Link River or are entrained into Keno Reservoir during summer months (USFWS 2008a).

***Sub-adults and adults*.** Suckers are considered sub-adults for the first three to eight years, after which time they become adults (Buchanan et al. 2011). Both life stages utilize similar offshore, open water habitats (Scoppettone et al. 1995; Piaskowski and Buettner 2003; USBR 1994, as cited by Buchanan et al. 2011). The juvenile and sub-adult life stages have been observed to be the most limiting for both sucker species, with low survival rates for these life-stages (Burdick et al. 2016). Recovery of Lost River and shortnose sucker populations will require increasing the number of suckers surviving to maturity (Burdick et al. 2016).

Life history stage periodicity of Lost River and shortnose suckers in the Klamath River Basin is shown in Figure 4-25.

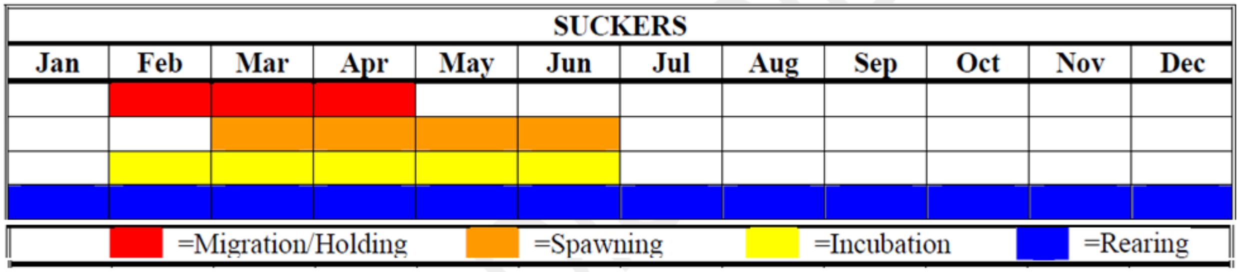



Figure 4-25: Sucker (Lost River and shortnose) history stage periodicity for the Klamath River in Oregon. From FISHPRO 2000 as reproduced in NCRWQCB 2010a-c.

## 4.10.4 Habitat requirements and known limiting factors

***Spawning habitat.*** Both species of suckers target riverine spawning habitat in riffles and runs with gravel substrate. Lost River suckers spawn in shallower water (< 27 in), while shortnose suckers will spawn in water up to 43 inches deep (Buettner and Scoppettone 1990; Scoppettone and Vinyard 1991; Perkins and Scoppettone 1996; Reiser et al. 2001, as cited by Buchanan et al. 2011). Two distinct sub-populations of Lost River suckers will also spawn along shoreline margins, targeting springs in Upper Klamath Lake (Buchanan et al. 2011; USFWS 2012b; Hewitt et al. 2015). Hewitt et al. (2015) examined capture-recapture data to show a high degree of spawning site fidelity between the two sub-populations of shoreline spawners, indicating little reproductive mixing.

***Larval rearing habitat*. .** Larval rearing habitat is found along the shoreline of Upper Klamath Lake and similar habitat in shallow water (4 – 20 inches). Rearing larvae tend to be found in habitats with the following attributes: emergent aquatic vegetation to provide cover (Buettner and Scoppettone 1990; Cooperman and Markle 2004, as cited by Buchanan et al. 2011); food sources (Erdman and Hendrixson 2009, as cited by Buchanan et al. 2011); and warmer water temperatures (Crandall 2004, as cited by Buchanan et al. 2011). Larval and small juvenile (<40 mm standard length (SL) shortnose suckers are slightly more likely to be found in nearshore habitats than Lost River suckers in Upper Klamath Lake (Burdick and Hewitt 2012; Simon et al. 2013, as cited in Burdick et al. 2016). However, there is no difference in the distribution of the two taxa of age-0 suckers larger than about 40 mm standard length (SL) relative to distance from shore from mid-July to September (Hendrixson et al. 2004, as cited in Burdick et al. 2016).

***Juvenile rearing habitat.*** Young-of-year juvenile suckers, as defined by age and morphological development, are found in all accessible habitats with water 0.5 to 4.0 m deep between the last week of July and the first week of September within Upper Klamath Lake (Burdick and Brown 2010; Burdick and Hewitt 2012, as cited in Burdick et al. 2016). However, age-1 suckers are more likely to be found in shallow near-shore habitats in the spring and deep water in the summer (Bottcher and Burdick 2010, Burdick and Hewitt 2012, as cited in Burdick et al. 2016). Spatial patterns among age classes of suckers have not been identified in Clear Lake Reservoir, which has more homogeneous habitat (Burdick and Rasmussen 2013, as cited in Burdick et al. 2016).

***Sub-adult and adult habitat**.* Sub-adult and adult suckers can be found in water depths between 5 and 11 feet deep, which includes most of Upper Klamath Lake (Bottorff 1989, USFWS 2012b). They are widely distributed in Upper Klamath Lake during the fall and winter (USFWS 2012b). They have been observed favoring areas with higher water quality, including suitable pH and dissolved oxygen levels (Banish et al. 2009; USFWS 2012b).

***Limiting factors.*** The inability of juvenile suckers to survive to maturity is the primary limiting factor for both species (Burdick et al. 2015a, 2015b, and 2016). Additionally, the USFWS (2012b) found the loss of spawning, rearing, and adult habitat quantity also contribute to population declines for both species. Only 25% of original sucker habitat remains (USFWS 2012b). This loss is exacerbated by deteriorating habitat quality, water quality impairments, diversion structures, and a lack of habitat connectivity (USFWS 2012b). While little is known about the effects of invasive fish species such as the fathead minnow and yellow perch on suckers, they may have a potentially significant impact through predation on and competition with juveniles (USFWS 2012b; Hereford et al. 2016). Downstream water releases to the lower Klamath Basin also affect lake elevations and can be a limiting constraint to sucker spawning habitat availability (Burdick et al. 2015b).

### 4.10.5 Management and Recovery Plans

The Recovery Plan for the Lost River sucker and shortnose sucker was initially released in 1993 and revised in 2012 (USFWS 2012b). The overarching goal of this plan is delisting, with underlying objectives including improving water quality and fish passage, reducing entrainment, restoring spawning and rearing habitat, and an artificial propagation program to replenish depleted populations. The plan mandates the establishment of a formal Klamath Sucker Recovery Program to achieve these objectives. In addition to the formal recovery plan, PacifiCorp has established its own Klamath Hydroelectric Project Interim Operations Habitat Conservation Plan for Lost River and Shortnose Suckers (PacifiCorp 2013) in the upper basin. This plan focuses primarily on reducing entrainment by limiting dam operations when suckers are present and contributing to habitat enhancement projects in the area through the creation of a Sucker Conservation Fund, where projects to be funded are assessed by the Klamath Sucker Recovery Program, and funding towards riparian and wetland planting through the Williamson River Delta Restoration Project administered by The Nature Conservancy (PacifiCorp 2013). The Habitat Conservation Plan also includes the non-operation of Eastside and Westside projects, both of which have the highest proportional level of take of all PacifiCorp facilities on the Klamath River (D. Ebert, pers. comm.).

The USFWS has also developed a Sucker Assisted Rearing Program (SARP) with the objective of rearing Lost River and shortnose suckers for reintroduction into the Upper Klamath Lake system. This rearing program fulfils the recommendation for “captive propagation” laid out in the NMFS and USFWS 2013 Biological Opinion (Day et al. 2016a,b). Additionally, a reintroduction plan to return suckers to historically occupied habitats has been developed collaboratively by USFWS, USBR, ODFW, and the Klamath Tribes. Finalization of the sucker reintroduction plan is part of the current NEPA process (Day et al. 2016a,b).

### 4.10.6 Conceptual model

We are not aware of any conceptual or quantitative models for endangered suckers in the Klamath Basin that explicitly link environmental changes and basin impacts to sucker responses. However, the remainder of this section describes linkages between life history characteristics of endangered sucker species and the key factors that may impact them.

Both Lost River and shortnose suckers are in peril. Observed mortalities within the juvenile life stage, especially on Upper Klamath Lake where juvenile suckers struggle to survive beyond their first year, is a significant constraint for the species (Burdick et al. 2016). The persistence of Upper Klamath Lake sucker populations is threatened by a prolonged lack of recruitment into adult spawning aggregations (NRC 2004; USFWS 2013). Managers are working to better understand how juvenile survival can be improved. Sucker recovery hinges on increasing the number of suckers that are able to reach maturity (Burdick et al. 2016). Additionally, increasing spawning and rearing habitat, reducing entrainment, and improving water quality will help recover healthy, self-sustaining sucker populations (USFWS 2012b). The USFWS (2012b) estimates recovery of these species will take another 10 to 30 years at a total cost of $135 million.

The upper Klamath Basin historically contained more than 350,000 acres of wetlands and floodplains. These wetlands were subsequently impacted by agricultural and land use development in the basin (USFWS 2010). In Upper Klamath Lake, approximately 70 percent of the original wetlands, including the Wood River Valley, were diked, drained, or significantly altered between 1889 and 1971 (Bottorff 1989, Gearhart et al. 1995, as cited by USFWS 2012b). Some of these historic wetlands likely functioned as crucial habitat for larval and juvenile suckers, while other wetlands may have been fundamental to maintaining the quality and quantity of water (USFWS 2012b). Slightly more than 25,000 acres of wetlands remain connected to Upper Klamath Lake. These remaining wetlands have suffered habitat alterations that have affected their function as rearing habitat for larvae and juveniles, partly because they have lost connectivity with current spawning areas (USFWS 2012b). Pilot sucker habitat restoration projects (see Section 6.5.4) seeking to re-establish connection through levee breaching and hydrological reconnection have been successful in restoring access for suckers to shallow water rearing habitats (Erdman et al. 2011; Erdman and Hendrixson 2012).

Wetland degradation and changing land use in the upper Klamath Basin has resulted in a loss of ecosystem function, alteration of physical habitat, and reduction of habitat connectivity (USFWS 2012b). Habitat that would otherwise be suitable for both sucker species has been converted to agricultural and other uses, and it has been impacted by irrigation. Impacts were further compounded by the construction of hydroelectric infrastructure, which drained lakes and wetlands, created barriers, and increased entrainment risk to fish (USFWS 2012b). Hydrology, both natural and altered, has also impacted these species. The interactions between climate change (less natural inflow) and irrigation diversions (concurrent increased demand for additional water withdrawals) has limited the hydrologic connectivity between spawning habitat in rivers and rearing habitats in lakes (USFWS 2012b). Under drought conditions, the survival of suckers is affected by the cumulative impacts of lower inflows to lake habitats, irrigation demands for water and the shallow bathymetry of habitats such as Clear Lake (USFWS 2012b).

Most water bodies currently occupied by both species do not meet water quality standards for nutrients, dissolved oxygen, temperature, and pH set by the States of Oregon and California (Boyd et al. 2001,2002; Kirk et al. 2010 as cited by USFWS 2012b). In the summer, these conditions have caused several incidents of mass adult mortality, most likely related to a lack of dissolved oxygen. The increasing dominance of *Aphanizomenon flos-aquae (AFA)* (a species of blue-green algae) in the upper Klamath may have led to extreme die-off events and oxygen declines (NRC 2004, as cited by USFWS 2012b). At the present time, high nutrient loads that fuel AFA bloom and crash cycles are the primary factor causing serious declines in dissolved oxygen (USFWS 2012b), as summarized in Section 3.2.3 of this report.

The USFWS also notes that both species were impacted by harvest (prior to listing) and are now currently impacted by disease, predation, and entrainment in the infrastructure used for diverting water (USFWS 2012b). Recovery of Lost River and shortnose suckers hinges on comprehensively addressing a wide range of limiting factors (i.e., hydrology, habitat, water quality, and infrastructure).

### 4.10.7 Critical uncertainties & hypotheses

The recovery of Lost River and shortnose suckers faces numerous challenges, including the degree to which the USFWS's Recovery Strategy can be successfully implemented. The strategy aims to restore natural populations in the upper Klamath Basin. The USFWS seeks to prevent extinction by establishing viable auxiliary populations, reducing existing threats through restoration, and promoting growth of the contemporary population (USFWS 2012b).

Most habitats utilized by endangered suckers fail to meet fundamental water quality standards (Buchanan et al. 2011). High pH, un-ionized ammonia, hypoxic conditions, and microcystin are all water quality concerns with the potential to impact suckers (Burdick et al. 2015a). To recover suckers, improvements are required in nutrient loading, dissolved oxygen, water temperature, and pH. Such improvements require large-scale shifts in landscape-level ecosystem function, significant gains in the area and connectivity of wetland habitats, and alterations to land and irrigation management throughout the basin. These advances would require strong cooperation among private and public parties, including multiple State, Federal, and Tribal agencies.

Currently, elevations in Upper Klamath Lake are established in the Biological Opinion for the U.S. Bureau of Reclamation's Klamath Project (NMFS and USFWS 2013). High lake elevations can benefit emergent vegetation, increase the quality and availability of sucker rearing habitat, and expand the area of offshore adult habitat. In turn, this can increase survival rates and adult recruitment (Buchanan et al. 2011).

Climate change remains a significant uncertainty in sucker recovery. For example, modeled climate change scenarios in the upper Klamath Basin predict an increase in Sprague River winter flows and a decrease in flows during periods of spawning (Markstrom et al. 2012, Risley et al. 2012, as cited by USFWS 2012b). This pattern will likely occur throughout the upper Klamath Basin (USFWS 2012b). Suckers may be impacted by increases in drought frequency and intensity as well as shifts in snowmelt runoff timing (USFWS 2012b).

## 4.10.8 Candidate research and assessment priorities

The USFWS's Recovery Plan (2012b) for shortnose and Lost River suckers identifies priority recovery actions that include a wide variety of potential investigations, some of which are listed below:

- Restore or enhance spawning and nursery habitats, including research on how to manage lake levels to protect spawning habitat and shoreline spring spawning production.
- Improve water quality, including connectivity to refugial areas, applied research into the effects of algal cycles, and determining the effects of microcystin on suckers.
- Research and reduce the effects of invasive species, including the flathead minnow and yellow perch.
- Monitor, assess, and improve juvenile and sub-adult vital rates, demography (USFWS 2012b), and species composition (Burdick et al. 2016).
- Develop approaches for reducing the losses resulting from entrainment.
- Determine relationships between water quality (especially as a result of algal population cycles) and sucker mortality or susceptibility to disease and parasites.
- Undertake investigations to support efforts to increase juvenile survival to adulthood.
- Determine the importance of instream rearing habitats for larvae and juveniles in the Sprague River.
- Identify approaches for recovering the Tule Lake population.
- Determine the status of shortnose suckers in Gerber Reservoir.
- Identify and assess the feasibility of potential habitat improvements for suckers in Lake Ewauna/Keno Reservoir.
- Determine the benefits of actions for conserving and restoring riparian and wetland areas for promoting healthier water quality for suckers.
- Establish a redundancy and resiliency program.

The USFWS (2012b) also recommends developing a Genetics Assessment and Management Plan, emergency response protocols, auxiliary populations, and a program for controlled propagation.

As noted for other species, the above list of potential research activities needs to be further prioritized and sequenced. That effort should focus on those gaps in understanding and data which will most help to reduce critical uncertainties that significantly affect the choices between alternative management decisions on restoration actions and fish management, and/or improve the ability to evaluate the effectiveness of those decisions.

## 4.11 Green sturgeon

The North American green sturgeon (*Acipenser medirostus*) (Figure 4-26) is a large anadromous species with a long life (up to 70 years), that spends most of its life in marine environments, often migrating thousands of miles along the west coasts of Mexico, the United States and Canada (NOAAF 2017, web page). Spawning is only known to occur in the Rogue, Sacramento, and Klamath rivers (Moser et al. 2016). The skeletons of sturgeons are composed of cartilage (like sharks) and they are characterized by a series of external bony plates, called scutes, along their backs and sides. Sturgeons are highly adapted for preying on bottom animals, which they detect with a row of sensitive barbels on the underside of their snouts. Sturgeon do not have teeth, but instead use their long, flexible "lips" to suck up food (summary from NOAAF 2017, webpage). Green sturgeon that spawn in the Klamath River belong to the Northern Distinct Population Segment (nDPS) and are listed by NOAA Fisheries as a Species of Concern, due to impacts from fisheries harvest, alterations to freshwater habitat, and the lack of population data (Doukakis 2014). Green sturgeon is a Tribal Trust species and a tribal fishery exists for green sturgeon in the Lower Klamath Basin. White sturgeon (*Acipenser transmontanus*) are also occasionally caught in the Klamath River, and historically may once have spawned in the basin in low numbers (USFWS 2013, web page).

Figure 4-26: Green sturgeon (*Acipenser medirostrus*). Photo from Scott Macleod.

### 4.11.1 Population trends

Green sturgeon populations successfully persisted throughout North America for two-hundred million years. It is believed that they have declined considerably from their historical abundances (NOAAF 2017, webpage), although documentation of this decrease is poor (NRC 2004). Historically, the Klamath Basin is thought to have supported large numbers of green sturgeon (VanderKooi 2011). Probably 70–80% of all green sturgeon are currently produced in the Lower Klamath River and Trinity River, where several hundred have been harvested annually in the tribal fishery (NRC 2004). To the Yurok Tribe, green sturgeon are considered sacred and these large fish are an extremely valuable source of food (Stanford et al. 2011). The actual number of green sturgeon spawners returning to the Klamath River annually in recent times is, however, largely unknown (USDI, USDC, NMFS 2013). Van Eenennaam et al. (2005) suggested that the Klamath River has a potentially stable spawning population but that flow, temperature and other necessary habitat factors need to be characterized and protected. To date, though, little reliable population-level data have been collected for any population of green sturgeon. Published abundance estimates for this species in the Klamath River are based primarily on counts of spawners made using dual frequency identification SONAR (DIDSON) and mark recapture methods (Mora et al. 2015). Limited historical abundance data preclude any rigorous population trend analyses (Moser et al. 2016). Adams et al. (2007) reported fairly stable adult abundance in the Klamath River based on annual tribal harvest of a few hundred spawning adults. However, no effort data were available, so the value of these fishery-dependent trend data is limited (Moser et al. 2016). Recent studies and monitoring in the Klamath River are providing the first data upon which trends in abundance can be reliably evaluated (Doukakis 2014).

## 4.11.2 Historic vs. current distribution

Green sturgeon occur in the coastal ocean from 200 km south of Ensenada, Mexico north to the Bering Sea (Moser et al. 2016) (Figure 4-27). Adults and sub-adults move among coastal estuaries and regularly aggregate in estuarine areas for extended periods. While green sturgeon range over an extensive area off the North American Pacific coast, they are known to spawn regularly in only three West Coast river systems: the Sacramento and Klamath in California, and the Rogue in Oregon. Larvae and YOY (2–150 cm FL) of green sturgeon are typically found only in rivers where spawning occurs. Green sturgeon appear to have experienced a contraction in their historical spawning range, particularly in California and southern Oregon (Mora et al. 2009 as cited in Moser et al. 2016). The limited historic range of green sturgeon in freshwater likely reflects their very specific requirements for spawning and rearing habitat (Moser et al. 2016).


Figure 4-27: Distribution (shaded green areas) of green sturgeon in North America Figure from Moser et al. 2016.

Within the Klamath Basin, green sturgeon appear to occupy specific locations or holding areas, with migration and holding patterns influenced by flow and temperature. Green sturgeon occur within the lower 67 miles of the Klamath River, downstream of Ishi Pishi Falls (Hamilton et al. 2005; USDI, USDC, NMFS 2013). While some green sturgeon may presently migrate beyond the confluence of the Salmon and Klamath rivers, they are the exception rather than the rule (Doukakis 2014). Green sturgeon have been observed spawning in the Salmon River and large numbers of juvenile green sturgeon were captured in one recent year in the rotary screw trap operated by the Karuk Tribe on the Salmon River (K. Greenberg pers. comm.). Green sturgeon are found within the Trinity River and are caught regularly by Hupa fishers. They are known to travel upstream in the mainstem Trinity to at least the vicinity of the New River confluence, at which point a series of falls is thought to prohibit further upstream passage (R. Franklin, pers. comm.). In the South Fork Trinity River green sturgeon populations appear to be extirpated (Adams et al. 2007 as cited in Moser et al. 2016) although there is some uncertainty in this regard (R. Franklin, pers. comm.).

### 4.11.3 General ecology, life history and periodicity

The general life cycle for green sturgeon is shown in Figure 4-28. Green sturgeon reach maturity around 15 years of age and can live to be 70 years old. They make extensive coastal migrations in depths <80 m and move between estuaries where they aggregate in summer (Moser et al. 2016). Unlike salmon, they may spawn several times during their long lives, returning to their natal rivers every 1-4 years (Moser et al. 2016). Spawning occurs in cool river sections with deep, turbulent flows, and clean hard substrate. In fall, post-spawn adults move back down the river and re-enter the ocean.

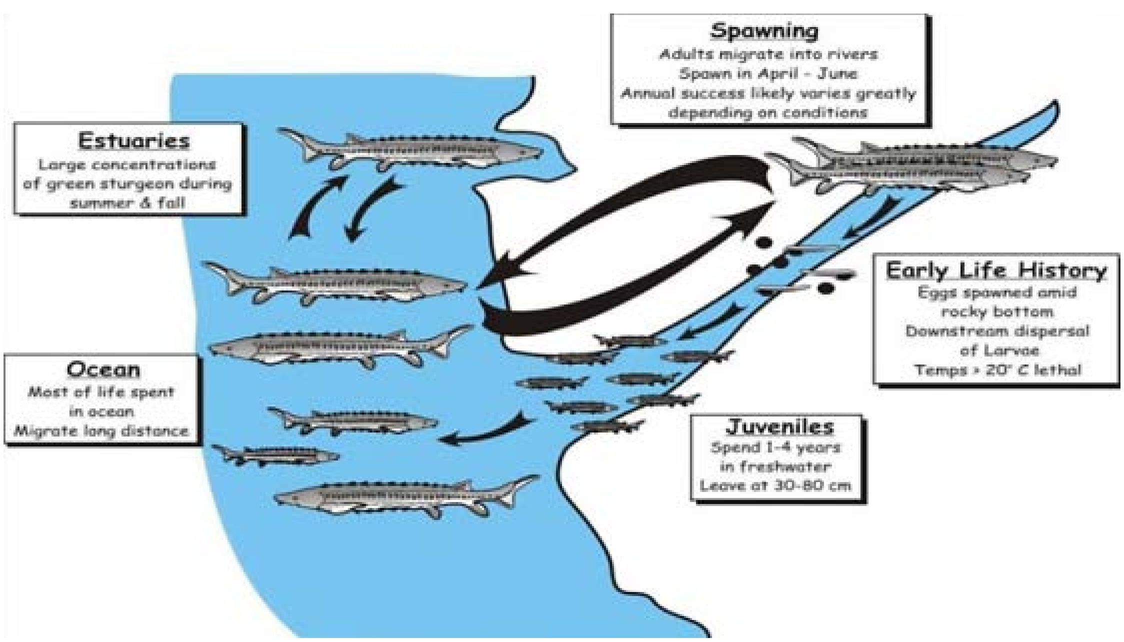



Figure 4-28: General life history cycle of green sturgeon. Figure from NOAAF 2017, webpage.

Green sturgeon eggs, larvae, and YOY typically occur in freshwater portions of the mainstem Klamath River (Moser et al. 2016). Little is known about the specific habitat requirements or behavior of green sturgeon larvae and YOY (Moser et al. 2016). Generally after hatching they will utilize riverine areas to forage and rear until they gain the osmoregulatory capacity to tolerate higher salinity concentrations (Allen and Cech 2007).

Juvenile green sturgeon can spend from 1 to -4 years in freshwater. They are however able to tolerate (and seek out) seawater as early as the end of their first year (Allen et al. 2006). Juveniles appear to move to areas of moderate salinity (e.g., estuaries) between 6 months to 1.5 years of age (Doukakis 2014). Juvenile green sturgeon either remain in or regularly move back into seawater after their initial movement to the seawater environment. The ability to osmoregulate in seawater appears to develop around 1.5 years of age (Allen and Cech 2007). Juveniles will then interchangeably use riverine, subtidal, and intertidal habitats in the Lower Klamath River and estuary (Klimley et al. 2015). Captures in freshwater indicate potential overwintering of more than one age-class in mainstem natal rivers (Brown 2007 as cited in Moser et al. 2016).

Subadult and adult green sturgeon occupy coastal waters for most of their life span, usually migrating north from the natal river (Lindley et al., 2011). As adults, green sturgeon migrate seasonally along the West Coast, congregating in bays and estuaries. Green sturgeon enter estuaries to feed and mature individuals will migrate upriver to spawning habitats in their natal river system. From around April to June, reproductively mature adults enter the Klamath River estuary and migrate up the river (Benson et al. 2007). After spawning, most green sturgeon adults will exit the river during periods of changing flow, usually between October and January. Outmigration during late-fall and early winter corresponds with increased flows and water temperatures dropping to near 10ºC (Doukakis 2014). A smaller proportion will exit in May and June (Benson et al. 2007). In addition to spawning movements, adult and subadult green sturgeon make regular summer (May–October) entries into estuaries to take advantage of warm waters and abundant food resources (Moser et al. 2016).

Figure 4-29 illustrates the periodicity of different life history stages of green sturgeon within the Klamath River.

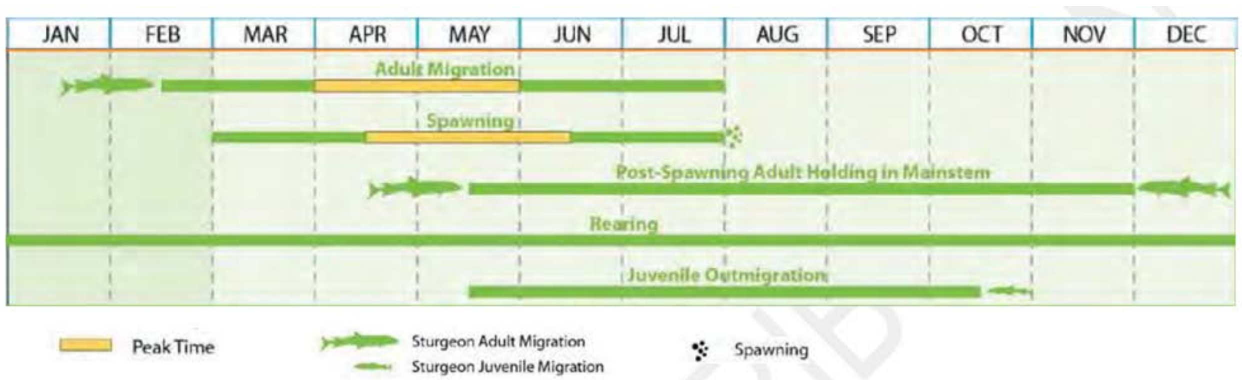



Figure 4-29: Timeline of green sturgeon life history stage periodicity in the mainstem of the Klamath River. Figure derived from USDI, USDC, NMFS 2013.

### 4.11.4 Habitat requirements and known limiting factors

**Adult spawning habitat.** Green sturgeon seem to prefer areas of fast, deep, turbulent water in mainstem channels as spawning habitat (Moyle 2002). They spawn in a wide variety of substrates, from clean sand to bedrock, but they appear to prefer bed surfaces composed of coarse cobble (Moyle 2002). The interstices between the large particles may allow eggs to lodge in the bed surface to provide cover from predators (Moyle 2002).

**Adult rearing habitat.** Green sturgeon prefer to hold in low-velocity, deep water habitats prior to migrating upstream to spawn. The adults move around in the pools, and may stray short distances from a pool, but the scope of their movement is limited. Following spawning, adults migrate downstream to hold in the low-velocity, deep pools through the summer and fall months until emigrating downstream to the estuary or ocean. Water temperatures, rather than changes in flow magnitude, are considered to provide the migratory cue, with timing of adult emigration correlated with water temperatures falling below 10°C (Erickson et al. 2002).

**Larval rearing habitat.** Rearing habitat preferences of green sturgeon larvae and juveniles are poorly understood. Water temperature is considered to be critically important to egg development and larval growth (Moser et al. 2016), and also for recruitment (Doukakis 2014). Eggs do not drift far downstream from the spawning grounds and develop where they are deposited (Moser et al. 2016). Optimal water temperature for egg incubation ranges from 14–17°C and temperatures higher than 20°C can be detrimental to embryos (Van Eenennaam et al. 2005). Environmental temperatures may be sub-optimal in many green sturgeon spawning and rearing habitats in the Klamath River (Moser et al. 2016).

The long marine occupancy of green sturgeon potentially exposes them to mortality from various marine activities such as bottom trawl fishing, dredging, and ocean energy projects (Moser et al. 2016). Historically, overharvest of adult, green sturgeon has likely resulted in direct declines in abundance, while past destruction of spawning and rearing habitats has also led to reduced populations sizes and decreased resilience (Moser et al. 2016). With recent changes in harvest regulations now in effect (Moser et al. 2016) the most significant threats remaining to green sturgeon likely relate to the loss and current inaccessibility of potential spawning habitats (NOAAF 2017, webpage). These threats are driven by competing water resource needs between humans and fish (NOAAF 2017, webpage).

Dams and other water-control structures in the Klamath Basin are a concern for green sturgeon. Dams and reservoirs alter downstream temperatures and flows, and also can block access to upstream habitat. Dams and water removals in the Klamath Basin have altered natural flows and ecosystem processes (e.g., nutrient and sediment transport) which are believed to be necessary to sustain the aquatic habitats, prey bases, and overall biological productivity that support green sturgeon in the lower basin (Thorsteinson et al. 2011).

A 2005 status review (BRT 2005) of the Northern DPS identified the following major threats to green sturgeon: loss of spawning habitat, water diversions and associated impacts of reduced flows, changed flow regimes, increased water temperatures and reduced oxygen concentrations, impacts from land-use changes and increased sedimentation. Harvest was also a concern. New threats to green sturgeon recognized in an updated 2014 status review (Doukakis 2014) included: incidental capture (bycatch) in estuary, coastal, and ocean environments; the impact of post-release mortality; chemical applications in Washington estuaries; climate change and its impact on flow and temperature in spawning rivers; and development of offshore and nearshore kinetic energy projects. However Doukakis (2014) concluded that the general lack of information on population abundance created difficulty in fully assessing the impacts of these threats.

### 4.11.5 Management and Recovery Plans

Only an outline of the federal recovery plan is currently available for the Southern Distinct Population Segment of green sturgeon inhabiting the Klamath Basin (NMFS 2010b); a full recovery plan is currently in development. The interim objectives listed in the outline of the recovery plan focus on restoring access to suitable habitats, as well as research on distribution, abundance, harvest, and contaminant effects. At present, it is unlawful to take sturgeon in any North Coastal River.

### 4.11.6 Conceptual model

We are unaware of a conceptual model developed specifically for green sturgeon in the Klamath Basin. A previously published conceptual model developed for the Sacramento River (Stillwater Sciences 2007) drew principally on research conducted in the Klamath and Rogue rivers. The Stillwater Sciences model could therefore be applicable to the Klamath, with some revisions to reflect the timing of life history stages and additional information from Stanford et al. 2011.

Green sturgeon generally begin moving into the Klamath River in March (Stanford et al. 2011), holding in pools as they move gradually upstream. Low early spring flows may delay late migrants from accessing upstream spawning sites, forcing them to spawn downstream or to abandon spawning altogether. Spawning primarily occurs between May and June, in deep water below Ishi Pishi Falls (thought to be the upper boundary for sturgeon migration in the Klamath), and in the lower Salmon River (Stanford et al. 2011). Green sturgeon may suffer increased egg mortality if displaced to low-gradient alluvial fans where bed sediments are generally finer. In the Salmon River, California, researchers found juvenile steelhead in atypical habitats (e.g., deeper, higher velocity) near the location of suspected green sturgeon spawning activity. They hypothesized that the steelhead were feeding on green sturgeon eggs (T. Soto, personal communication, April 13, 2007 as cited in Stillwater Sciences 2007). If green sturgeon are forced to spawn in finer-grained reaches then their eggs may be more susceptible to predation owing to the lack of interstitial space in the channel bed.

After spawning, adults migrate downstream to hold in pools in the middle Klamath River until late fall or early winter storms provide a cue to migrate downstream to the estuary. Green sturgeon larvae begin to emerge and move downstream beginning in April, with peak passage occurring in June and July. Historically, migrating downstream during the snowmelt period may have helped green sturgeon juveniles emigrate quickly to reduce their exposure to predation, and the higher discharge and associated turbidity likely helped juveniles avoid potential predators, especially visual predators. Current water temperature targets in the Klamath designed to protect fall-run Chinook salmon may help to maintain a favorable water temperature regime in the lower Klamath River, allowing green sturgeon larvae to grow quickly into juveniles. As the juveniles move down the river, they continue their quick growth while acclimating to increasing water temperatures and, eventually, the salinities of the estuary.

### 4.11.7 Critical uncertainties & hypotheses

A critical uncertainty for green sturgeon is whether dam removal in the basin would have any significant benefit to sturgeon habitats and increase population productivity and abundance. There is an expectation that dam removal would return the Klamath River to a temperature and flow regime that more closely mimics historical patterns in the lower river habitats used by green sturgeon, with likely benefits for this species (Hamilton et al. 2011). However, these flow and temperature changes may be relatively small in the reach of the river used by green sturgeon (USDI, USDC, NMFS 2013). Dam removal would also ultimately be expected to accelerate TMDL water quality benefits for this species, including the elimination of algal toxins produced in the Hydroelectric Reach reservoirs (USDI, USDC, NMFS 2013). However, the benefit to green sturgeon populations from these water quality improvements is uncertain (USDI, USDC, NMFS 2013).

There is also uncertainty as to the potential near-term negative effects of green sturgeon if the Klamath dams were removed. Dam removal scenarios could release millions of metric tons of fine sediment (sand, silt, and finer) to downstream reaches of the Klamath River where green sturgeon spawn and rear and rely on mainstem habitat on a seasonal basis (Stanford et al. 2011). Modeling by Stanford et al. (2011) suggested that the effects on Klamath fish of high total suspended sediments (TSS) could range from sublethal avoidance behaviour and physiological stress to direct mortality, depending on species, exposure, duration, and concentration. However, complete mortality was not predicted for any species or life stage (Stanford et al. 2011). The primary mitigating factor is that green sturgeon and the other fish species are widely distributed in space and time both within and outside the Klamath River basin, which should maintain survival rates during dam removal, and contribute towards a strong recovery subsequent to dam removal. Variable life history traits are predicted to buffer the short-term (1–2 years) impacts of elevated TSS following dam removal (Stanford et al. 2011).

### 4.11.8 Candidate research and assessment priorities

Scientists need to better understand the life history and ecology of green sturgeon (Thorsteinson et al. 2011). Research efforts by NOAA Fisheries and partners have focused on monitoring early life history stages and estimating adult abundance to better evaluate overall species status. NOAA Fisheries and its partners are currently undertaking various studies of the distribution, migrations, spawning habitat utilization, and population genetics of green sturgeon across their range (NOAAF 2017).

Critical information needs include: accurate annual population size estimates, data on distribution and habitat requirements for larvae and juveniles, and assessment of mortality due to bycatch, poaching and marine mammal predation (Moser et al. 2016). Research should also focus on improving understanding of the impacts of contaminant exposure, ocean energy projects, and predation by native and non-native species on green sturgeon feeding behavior and survival (NOAAF 2017).

It is also essential that future studies generate population-scale information. This will require sampling to develop estimates of total population size, effective population size, age at maturity, frequency of spawning, and mortality rates (Moser et al. 2016). These demographic data can be incorporated into predictive models to estimate minimum viable population size (Moser et al. 2016). This type of research includes conventional mark-recapture investigations for estimates of abundance and mortality. Other methods include tagging green sturgeon with individually-coded passive integrated transponders (PIT-tags), acoustic, and/or satellite transmitters; collection of biological samples to determine population of origin, age, and reproductive condition; and investigations employing DIDSON and sidescan SONAR technologies to enumerate individuals (Moser et al. 2016).

The early life history remains the least investigated, especially for wild fish <75 cm total length (Moser et al. 2016). Natural mortality and larval drift need to be evaluated, as do larval feeding areas during those critical few days after the yolk has been exhausted. Greater emphasis should be placed on studying this life stage in all natal rivers to characterize green sturgeon habitat preferences (Moser et al. 2016). Studies to tag and track subadults would also be helpful to determine whether their distribution and habitat use expose them to the same anthropogenic threats faced by adults (Moser et al. 2016).

As noted for other species, the above list of potential research activities needs to be further prioritized and sequenced. That effort should focus on those gaps in understanding and data which will most help to reduce critical uncertainties that significantly affect the choices between alternative management decisions on restoration actions and fish management, and/or improve the ability to evaluate the effectiveness of those decisions.

## 4.12 Eulachon

Eulachon (*Thaleichthys pacificus*) are an anadromous type of smelt distinguished by large canine teeth on the bone in the roof of their mouth and 18 to 23 rays in their anal fin (NOAAF 2015, webpage). Eulachon predominantly live in the ocean but briefly return to their natal streams to spawn. The southern Distinct Population Segment (DPS) for eulachon were listed as Threatened under the Endangered Species Act in 2010. The Klamath River is a sub-population of eulachon within the southern DPS (NMFS 2016a). Eulachon were of great cultural and subsistence importance to the Yurok Tribe on the lower Klamath River and are a Tribal Trust species (Trihey and Associates 1996 as cited by Gusaftson et al. 2010, NRC 2004).

### 4.12.1 Population trends

There is almost no scientifically obtained abundance data available for eulachon in the Klamath River or any other basin in northern California (Gustafson et al. 2010). Ethnographic studies, pioneer diaries, interviews with local fishers, personal communications from managers, and newspaper accounts are therefore the best information available that provide documentation of historical eulachon occurrence and abundance in the Klamath River and other rivers on the northern California coast (Gustafson et al. 2010).

Eulachon once supported popular recreational fisheries in northern California rivers, but were never commercially important in California (Gustafson et al. 2010). All eulachon spawning runs are considered to have declined in the past 20 years (NOAAF 2015, webpage). Since 1994, the southern DPS of eulachon have experienced a decline in abundance through its range (NMFS 2016a). Recent range-wide monitoring detected a slight improvement that may have been temporary (NMFS 2016a). More abundance monitoring is needed to determine if population recovery will continue (NMFS 2016a).

Undetected local extirpation or near-extirpation of eulachon may have already occurred (NMFS 2016a), particularly in the southern end of the DPS's range which includes the Klamath River (NOAAF 2015, webpage). Petersen (2006, as cited in Gustafson et al. 2010) reported on interviews with Yurok and Karuk tribal fishers on the lower Klamath River that indicated eulachon were abundant in the river as late as the 1960's. Petersen (2006, as cited in Gustafson et al. 2010) stated that "one fisher remembered picking up 75 pounds of fish in one dip" and that another remembered "filling the back of a pickup truck in one hour" with eulachon in 1966. Recent surveys performed by the Yurok Tribal Fisheries Department found only two eulachon in 2011 and forty in 2012 (Yurok Tribal Fisheries Program 2011, 2012 as cited by USFWS/NMFS 2013).

### 4.12.2 Historic vs. current distribution

The eulachon southern Distinct Population Segment (DPS) that includes fish in the Klamath Basin covers a broad distribution extending from south of the Nass River, British Columbia to the Mad River in Northern California (NOAAF 2015, webpage). Eulachon spawning in the Klamath are essentially at the southern limits of eulachon distribution (Figure 4-30). NMFS has developed a formal critical habitat designation for eulachon, which includes the tidally influenced waters of the Klamath River extending upstream to the Omogar Creek confluence at river mile 10.5 (Figure 4-31).

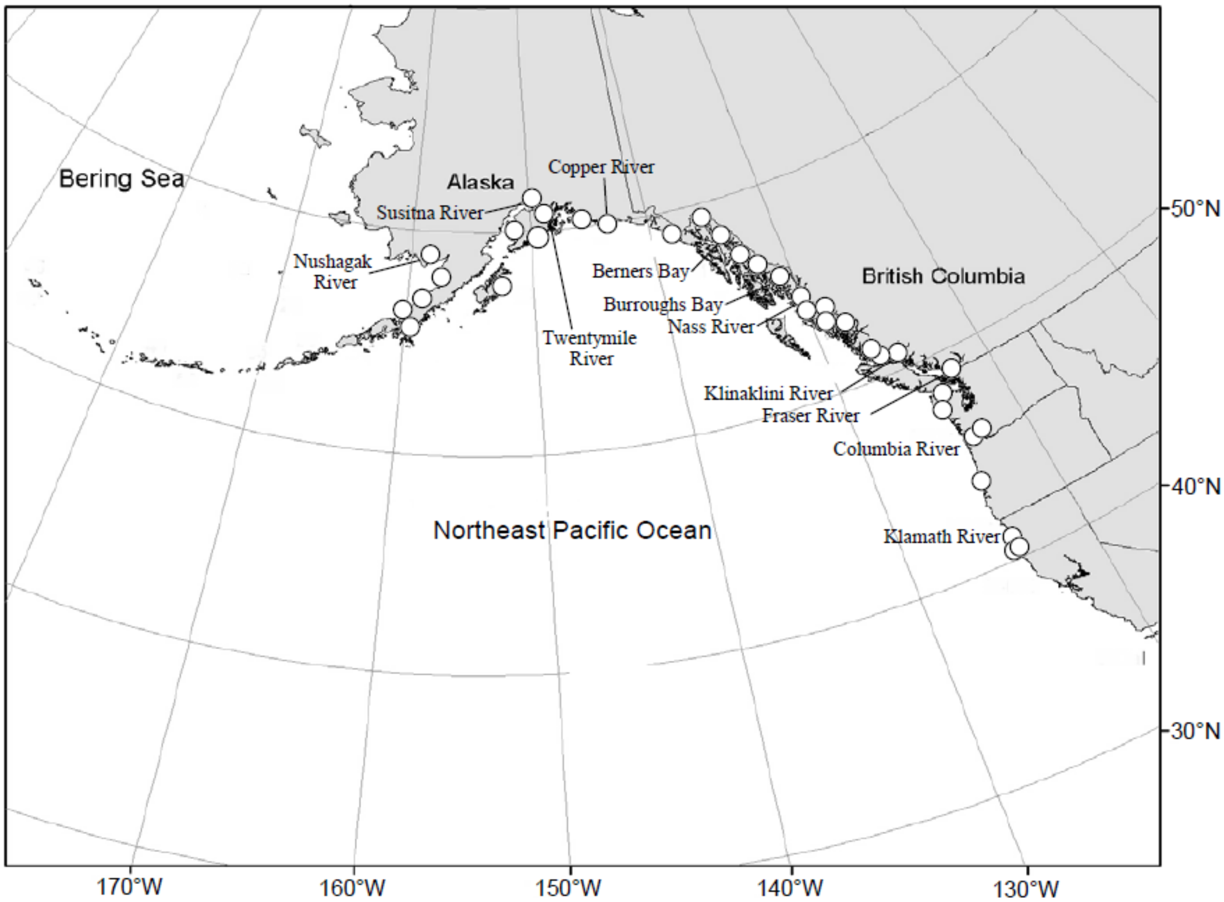



Figure 4-30: Distribution of eulachon spawning rivers (open circles) in the Northeast Pacific Ocean. Figure from Gustafson et al. 2010.


Figure 4-31: Eulachon critical habitat in Northern California. Figure adapted from NMFS 2016a.

### 4.12.3 General ecology, life history and periodicity

Eulachon (Figure 4-32) have slender bodies with an average weight of 40 g. They range from 150 to 200 mm in length (NMFS 2016a). Little is known about eulachon living in the ocean even though they spend 95% to 98% of their lifetime at sea. They often suffer as bycatch of commercial fishing, particularly shrimping (NMFS 2016a). They have been observed at depths ranging from 10 m to 500 m (NMFS 2016a) and are mostly commonly found in nearshore waters at depths up to 300 m (NOAAF 2015, webpage). Eulachon adults feed on zooplankton, chiefly eating crustaceans such as copepods and euphausiids (Hart 1973; Scott and Crossman 1973). Eulachon adults do not feed during spawning.

Figure 4-32: Eulachon (*Thaleichthys pacificus*). Photo from Lewis McLeod.

Spawning occurs from ages 2 – 5, most commonly between age 3 and 4 (Barrett et al. 1984, cited by Willson et al. 2006). The age distribution of spawning eulachon varies by river (NMFS 2016a). Eulachon, like salmon, typically spawn only once before dying, although some individuals have been known to spawn twice (NMFS 2016a). Eulachon prefer to spawn at night (NMFS 2016a). Spawn timing varies by river system but generally occurs during the spring (NMFS 2016a). Entry into the spawning rivers appears to be related to water temperature and the occurrence of high tides (Ricker et al. 1954). Spawning generally occurs in January, February, and March in the Klamath River (Gustafson et al., 2010).

Eulachon eggs are enclosed in a double membrane; after fertilization in the water, the outer membrane breaks and turns inside out, creating a sticky stalk which acts to anchor the eggs to the substrate (Hart and McHugh 1944; Hay and McCarter 2000). Eggs hatch within 20 to 40 days of deposition, with incubation time dependent on water temperature (NOAAF 2015, webpage). Survival of eggs within egg masses on the substrate is low during the first ten days. Comparatively, eggs that drift have much higher survival rates, averaging 69% to 82% and up to 97% (NMFS 2016a).

Eulachon larvae are four to eight mm in length at hatch. Shortly after hatching, the larvae are carried downstream and dispersed by estuarine, tidal, and ocean currents. Larval eulachon may remain in low salinity, surface waters of estuaries for several weeks or longer (Hay and McCarter 2000) before entering the ocean. Similar to salmon, juvenile eulachon are thought to imprint on the chemical signature/smell of their natal river basin. However, juvenile eulachon spend less time in freshwater environments than do juvenile salmon and researchers believe that this may cause returning eulachon to stray between spawning sites at higher rates than salmon (Hay and McCarter, 2000).

Eulachon larvae and juveniles eat a variety of prey items, including phytoplankton, copepods, copepod eggs, mysids, barnacle larvae, and worm larvae (Barraclough 1967; Barraclough and Fulton 1967; Robinson et al., 1968a, 1968b).

Once juvenile eulachon enter the ocean, they move from shallow nearshore areas to deeper areas over the continental shelf. Larvae and young juveniles become widely distributed in coastal waters, where they are typically found near the ocean bottom (Barraclough 1964) at a variety of depths (NMFS 2016a). There is currently little information available about eulachon movements in nearshore marine areas and the open ocean but it is known that they may school with other species of fish such as herring and anchovy (Hay et al. 2002 as cited by NMFS 2016a).

### 4.12.4 Habitat requirements and known limiting factors

Spawning habitat is limited to the reach of river that is tidally influenced (Lewis et al. 2002, cited by Willson et al. 2006). In the Klamath River, they rarely swim more than 8 miles inland (USFWS/NMFS 2013). Entry is believed to be tied to water temperatures between 4°C and 10°C and high tides (Willson et al. 2006 as cited by NMFS 2016a) and possible low river flows (Spangler 2002, cited by Willson et al. 2006 as cited by NMFS 2016a). Spawning habitat ranges in depth and has been observed to occur between 3 in and 25 ft (NMFS 2016a).

Even though eulachon are present in freshwater environments for only several weeks during spawning and do not feed, they can take up pollutants from spawning rivers (NMFS 2016a) and have been known to bioaccumulate detectable levels of metals originating from mine tailings (Futer and Nassichuk 1983, cited by Willson et al. 2006).

Eulachon eggs commonly adhere to sand (Langer et al., 1977) or pea-sized gravel (Smith and Saalfeld, 1955), though eggs have been found on silt, gravel to cobble sized rock, and organic detritus (Smith and Saalfeld, 1955; Langer et al., 1977; Lewis et al. 2002). Eggs found in areas of silt or organic debris reportedly suffer much higher mortality than those found in sand or gravel (Langer et al., 1977). Egg survival is greatly influenced by salinity: exposure to salt water, especially salinity greater than 16 ppt, can be lethal (Farara 1996).

### 4.12.5 Management and Recovery Plans

Recovery of eulachon populations in the basin is guided by the Draft Endangered Species Act Recovery Plan for the Southern Distinct Population Segment of Eulachon (*Thaleichthys pacificus*) (NMFS 2016a). The overarching goal of the eulachon recovery plan is delisting, with a number of supporting objectives including ensuring population viability, conserving spatial structure and distribution, conserving genetic and life-history diversity, and reducing the severity of threats to this species. Threats-oriented objectives include reducing bycatch, implementing TMDL programs to improve water quality, and reducing the impacts of industrial activities such as the influence of dams on estuary plume environments and entrainment through dredging. With regards to the Klamath Basin, this plan highlights the need for a research and monitoring plan to monitor the effects of post-dam removal on recruitment and recovery of downstream eulachon. Because very little is known about the ecology of eulachon in this region, the majority of actions outlined by the plan are oriented towards research and monitoring.

### 4.12.6 Conceptual and quantitative models

We are not aware of any conceptual or quantitative models for eulachon in the Klamath Basin that explicitly link environmental changes and basin impacts to eulachon responses. However, the remainder of this section describe linkages between eulachon life history characteristics and the key factors that may impact them.

While the causes of eulachon decline are essentially unknown, they are most likely linked to changing ocean conditions and degraded freshwater water quality (Moyle 2002 as cited by NRC 2004). The Klamath River population is one of the most southern subpopulations within the DPS and is thus at the highest risk of extirpation (NMFS 2016a). Recovery objectives established by NMFS (2016a) focus on ensuring subpopulation viability, conserving temporal distribution patterns, protecting existing genetic and life history diversity, and eliminating or sufficiently reducing threats.

In their freshwater environment, eulachon are sensitive to water quality and water temperature, both of which can oftentimes be poor in the lower Klamath River. Additionally, spring spawning is likely associated with historic and contemporary peak flow hydrology, which is severely altered in the Klamath Basin because of hydropower operations.

Eulachon spend most of their life cycle in the ocean and are perhaps thus most impacted by changes in ocean conditions, as well as commercial fishing bycatch (NMFS 2016a). While fishing regulators are working to adjust fishing practices and rules to better protect eulachon (NMFS 2016a), changing ocean conditions as a result of global climate change effects will likely continue to impact this imperiled species. Gustafson et al. (2010) suggests that these southerly eulachon populations, already exhibiting dramatic declines and impacted by other threats (e.g., habitat loss and degradation), might be at risk of extirpation if unfavorable marine conditions predominate in the future.

Gustafson et al. (2010) expressed concern that the remaining abundances of eulachon in the Klamath River may be below what would be considered the minimum viable population size for such a highly fecund species.

### 4.12.7 Critical uncertainties & hypotheses

NMFS (2016) identified climate change impacts on ocean conditions as the most serious threat to the Klamath River sub-population of eulachon. Climate change impacts on freshwater habitat and ocean bycatch were also noted as threats to the sub-population. Changing ocean currents and water temperatures will affect food supply resources and survival for eulachon, especially for larvae outmigrating to the ocean (NMFS 2016a). Ocean warming also changes water chemistry and contributes to ocean acidification, which harms eulachon (NMFS 2016a). In freshwater and estuarine rearing environments, climate change will likely contribute to warmer water temperatures, flow-related changes, altered food supplies, and increased sediment deposition (NMFS 2016a).

Dams on the Klamath River were also listed as a significant threat to the sub-population (NMFS 2016a). The six dams on the Klamath and Trinity rivers, combined with associated irrigation withdrawals in the upper Klamath Basin, have shifted spring peak flow timing (NMFS 2016a) and may impact spawning success. Throughout the Klamath Basin, impacts to water quality from irrigation practices, dredging and mining, and hydropower generation also degrade the viability of the sub-population (NMFS 2016a).

Bycatch, disease and predation also threaten the southern DPS of eulachon (NMFS 2016a). Because of these combined threats, eulachon are at moderate risk of extinction throughout their range (Gustafson et al. 2010). NMFS (2016) estimates recovery of the eulachon southern DPS will take 25 to 100 years at a cost of nearly $85 million.

During the biological evaluations of the Secretarial Determination process surrounding dam removal, Hamilton et al. (2011) concluded that, like salmon and steelhead, eulachon would also benefit from dam removal due to accelerated TMDL water quality benefits predicted as a result of dam removal.

### 4.12.8 Candidate research and assessment priorities

Because eulachon are not a commercial species, less research and monitoring has been conducted to better understand and protect the species. The southern DPS Draft Recovery Plan for Eulachon (NMFS 2016a) cites the need to conduct strategic research on eulachon. This includes:

- Performing annual in-river spawning stock biomass surveys to develop long-term estimates for each subpopulation;
- Collecting and analyzing age structure, intrinsic mortality rates, sex ratios, fecundity and other parameters to develop a matrix project model and develop biological viability criteria for each subpopulation;
- Developing a method to assess ocean stock;
- Developing a method to correlate freshwater and marine abundance estimates; and
- Conducting annual in-river presence/absence surveys.

Additional areas of recommended research and assessment focus on:

- Researching tidal freshwater habitats, including shifts in water temperatures and flow resulting from climate change;
- Developing biological viability targets;
- Determining threats to eulachon;
- Assessing regulatory measures; and

- Developing a research, monitoring, evaluation, and adaptive management plan.

NMFS (2016a) also recommends developing a Klamath-specific monitoring plan to assess the effects of post-dam removal (if that should occur) (e.g., changes in water temperature, water quality, and sediment transport) on eulachon.

As noted for other species, the above list of potential research activities needs to be further prioritized and sequenced. That effort should focus on those gaps in understanding and data which will most help to reduce critical uncertainties that significantly affect the choices between alternative management decisions on restoration actions and fish management, and/or improve the ability to evaluate the effectiveness of those decisions.

# 5 Overview of Restoration and Monitoring In the Klamath

This section introduces the historical context for restoration and monitoring in the Klamath Basin, defines the major types of restoration and monitoring considered in this report, and describes the approach to synthesis of the major restoration and monitoring actions carried out across the basin to date.

## 5.1 History of Klamath Basin Restoration and Monitoring

There is a long history of fisheries restoration and monitoring in the Klamath Basin. This history dates back at least to the early 1900s, which saw the earliest attempts at stock supplementation through fish rearing on the upper Klamath River and the beginnings of water quality and flow monitoring (Leitritz 1970, Royer & Stubblefield 2016). Early attempts at restoration were sporadic and focused mainly on fisheries enhancement and harvest controls to stem population decline. However, the effectiveness of these actions was limited by a poor understanding of the underlying limiting factors constraining fish production (KRBFTF 1991). Similarly, initial monitoring projects were relatively fragmented, focused on specific needs at local sites, and were not explicitly oriented towards fish (Royer & Stubblefield 2016). Growing understanding of important limiting factors such as habitat and water quality in the late 1900s spurred a more concerted effort to target monitoring and restoration to better track and address these underlying drivers of fish population decline (KRBFTF 1991, Royer & Stubblefield 2016). This gradual paradigm shift improved the outcomes of some localized restoration initiatives, but failed to produce dramatic improvements in fish populations at the watershed scale due a lack of coordination across efforts (KRBFTF 1991). More recent approaches have increasingly focused on ecosystem-based restoration at the scale of whole watersheds, with the understanding that all of the interconnected parts of the watershed ecosystem must be restored before large-scale benefits will be realized. Recognition of the need for a more concerted and coordinated approach to restoration paved the way for planning efforts at the basin scale, which have included deliberations leading up to the passage of the Klamath Act. This Act established a 14-member Klamath River Basin Fisheries Task Force (KRBFTF) and directed the U.S. Secretary of Interior to collaborate with the Task Force on the creation of the first Long Range Plan for the Klamath River Basin Conservation Area Fishery Restoration Program in 1991 (KRBFTF 1991). Further work building on this foundation culminated in the signing of the KBRA and KHSA in 2010, and the most recent efforts leading up to the creation of an Integrated Fisheries Restoration and Monitoring Plan for the Klamath Basin (detailed further in Section 1). Figure 5-1 provides a timeline of key events that have influenced monitoring and restoration efforts in the Klamath Basin to date. Contemporary approaches to fisheries restoration and monitoring are focused on:

1. Using the best available science, including status and trend monitoring data, to understand limiting factors on fish populations,
2. Applying the most appropriate restoration actions known to mitigate those factors, and
3. Ongoing project effectiveness monitoring to measure performance against objectives.


Sources: (USDI et al. 2013) (NRC 2004) (KTWQC 2016) (Royer & Stubblefield 2016) (PFMC 2007) (CalFish 2004) (NRC 2008) (Water Education Foundation 2016 - http://www.watereducation.org/aquapedia/klamath-river-basin-chronology) (KRBFTF 1991) (TNC n.d.)

Figure 5-1: Timeline of Key Klamath Basin Events Influencing Monitoring & Restoration.

## 5.2 Types of Restoration Actions

The general philosophy underpinning contemporary fisheries restoration efforts is that fish populations will benefit most from the general return of watersheds to more natural conditions (KRBFTF 1991). Progress towards objective more natural state in the Klamath Basin has been incremental, with many localized projects gradually improving local watershed conditions, and occasionally punctuated by major efforts such as large-scale channel rehabilitation. Given the level of disturbance still observed in many Klamath Basin waterways today, restoration will need to continue for many decades, and span multiple human generations. Restoration practitioners draw on a wide range of techniques chosen for their ability to address specific watershed stressors, and often use a range of complementary techniques together to achieve more holistic and resilient recovery of ecosystem function. Moreover, lessons learned from past projects have significantly improved the design criteria for habitat restoration projects over the years. Practitioners now have greater access to guidance on what techniques are most compatible and effective given particular stream characteristics or target species, improving the likelihood of successful implementation (KRBFTF 1991).

The diverse toolbox of potential watershed restoration techniques has been helpfully organized into a typology of restoration actions by the NOAA Pacific Coastal Salmon Recovery Fund (PCSRF) Data Dictionary to facilitate their restoration grant tracking and reporting process (detailed in Appendix J). Although this typology was originally developed to describe restoration actions relevant to anadromous fish, it is broadly applicable to watershed restoration in general. Within this typology, direct watershed restoration actions benefiting fish populations generally fall into one of nine major categories; these categories are further subdivided into specific techniques. Here, we provide a definition and brief summary of current status of each major restoration category. Section 6 provides further exploration of individual techniques, status, and trends.

The major categories of on-the-ground restoration actions considered in this synthesis are:

- **Fish Passage Improvement**

  This category includes actions that improve or provide for fish migration up and down stream, including fish passage at road crossings (bridges or culverts), barriers (dams or log jams), fishways (ladders, chutes or pools), weirs (log, rock). Restoring fish passage in the Klamath Basin is particularly relevant to anadromous fishes, which have lost access to hundreds of miles of historical spawning habitat due to the installation of both small agricultural diversion dams and the large hydroelectric facilities. While collaborative efforts have led to the gradual removal of a great many smaller diversion dams, the most significant development in this category is the prospective decommissioning and removal of the four mainstem Klamath River dams (Iron Gate, Copco I, Copco II and J.C. Boyle).

- **Fish Screening**

  This category includes actions that result in the installation, improvement or maintenance of screening systems that prevent fish (especially juveniles) from entrainment into areas that do not support fish survival; for example, into irrigation diversion channels. Significant effort has gone into installing and upgrading fish screens at agricultural diversions, often in conjunction with the removal of a diversion dam, with substantial screening effort taking place in the Scott and Shasta sub-basins. In addition, recent research by fish and wildlife agencies has led to the development of new screen designs that can effectively exclude sucker and lamprey in addition to salmonids.

- **Hatchery Rearing & Reintroduction**

  This category includes operations that collect and spawn adult fish; incubate eggs; rear and maintain fry/smolt in a hatchery facility or pond; and/or, outplant juveniles to supplement declining natural populations. In the Klamath Basin, reliance on multiple small-scale rearing projects has declined in favor of production at three major hatchery facilities producing coho (*Oncorhynchus kisutch*), Chinook (*Oncorhynchus tshawytscha*), and steelhead (*Oncorhynchus mykiss irideus*) to compensate for loss of spawning habitat above major mainstem dams.

- **Instream Flow Restoration**

  This category includes actions that maintain and/or increase the flow of water to provide needed fish habitat conditions. This can include temporary water rights purchases/leases, permament dedication of instream flows, or irrigation practice improvements including water conservation projects to reduce stream diversions or extractions. Significant work has gone into restoring instream flow in the upper basin by improving the efficiency of irrigation systems via NGO and USDA water conservation programs and through the creation of water transaction programs. The 2000 ROD for Trinity stands as the most substantial example, raising minimum release volumes on a scale seen nowhere else, based on the recommendations of the Trinity River Flow Evaluation Study (USFWS and Hoopa Valley Tribe 1999). Other recent examples in this category include the Scott River Water Trust and the Klamath Basin Rangeland Trust (which merged with Trout Unlimited in early 2016) Water Transactions Program.

- **Instream Habitat Restoration**

  This category includes projects that increase or improve the physical conditions and/or connectivity within the stream environment (below the ordinary high water mark of the stream) to support higher abundances of fish. Many of the earliest projects in this category focused on the placement of instream structures, and this technique continues to be applied across the basin to increase fish habitat complexity. More recent approaches to instream habitat restoration are more complex and include channel reconfiguration, streambank stabilization, and the introduction of beavers or artificial beaver dam analogues to increase stream complexity. Notable recent examples include several large-scale channel rehabilitation and reconnection projects such as those carried out as part of the Trinity River Restoration Program.

- **Riparian Habitat Restoration**

  These projects focus on restoring riparian habitat and vegetation in areas above the ordinary high water mark of the stream, including lakeshores, and within the flood plain to help provide habitat, food, and shade necessary to sustain fish throughout their life cycle. Riparian restoration also increases riparian and floodplain roughness, promoting the deposition of particulate matter in surface runoff and high flow events and thus reducing nutrient and sediment loading. Riparian habitat restoration is one of the most widespread restoration techniques employed throughout the Klamath Basin and typically involves installation of riparian exclusion fencing and grazing management as well as riparian planting to accelerate the recovery of native species on previously grazed streambanks. The success of these projects is also contingent on adequate instream flows. Riparian restoration projects are often carried out in collaboration with private landowners or on federal lands. For example, the Trinity River Restoration Program has restored riparian function and plant communities along many reaches of the Trinity mainstem, largely on federal lands.

- **Upland Habitat and Sediment Management**

  This includes landscape-level actions implemented above the elevation of the riparian zone (above the floodplain) that are intended to benefit fish habitat (for example, reducing/eliminating fine sediment flow from upland areas into streams). The majority of these types of projects in the Klamath Basin fall into two broad categories: (1) rehabilitating or decommissioning logging roads in the lower basin that have historically contributed large amounts of fine sediment to lower basin waterways, and (2) upland vegetation management to reduce the risk of high-severity wildfires that are another significant source of sediment input.

- **Water Quality Restoration**

  This category, as it is defined by the PCSRF, includes actions that aim to dirctly improve instream water quality conditions for fish or reduce impacts of instream point/non-point pollution, including improved water treatment; return flow cooling; or, reduction or treatment of toxins, sewage outfall, agricultural runoff, and/or stormwater. In the Klamath, most pollutants enter waterways through agricultural tailwater runoff which can introduce excessive nutrients, residual herbicides or pesticides, and latent heat. Projects being carried out to manage these pollutants include modifications to manure storage practices, improvements to irrigation systems to reduce runoff, systems to treat runoff before it is released, or systems to capture and recycle polluted runoff rather than returning it to streams. It is important to note that the PCSRF classification of water quality projects is defined primarily by the type of physical work, rather than the stressor being addressed, and that many other types of restoration work described here (e.g., riparian habitat restoration, upland habitat management) also contribute to water quality improvements as shown in Table 5-1.

- **Wetland Restoration**

  This category includes actions designed to improve, restore, or create connected wetland, meadow or floodplain areas that are known to support fish production through their role in providing spawning, nursery, or feeding habitat. Wetland restoration has been a particularly critical objective in the Upper Klamath Basin, where hundreds of thousands of acres of historical wetland has been diked and drained to create new agricultural land during the Klamath Project. Several major contemporary restoration efforts have sought to reverse these actions by breaching dikes, re-flooding and re-planting historical wetland areas such as the Williamson River Delta that are now known to provide crucial fish spawning and rearing habitat, particularly for endangered suckers. In this report, the habitat benefits of wetland restoration are described in Section 6.5.4 on Instream Habitat Restoration, and the water quality benefits of wetland restoration are discussed in Section 6.5.7 on Water Quality Restoration.

Restoration actions within each of these categories are selected for their ability to address one or more specific stressors, as summarized in Table 5-1. As reflected in this table, it is important to stress that many types of restoration actions have broad-ranging benefits, and that projects undertaken for one purpose such as restoring riparian habitat often yield improvements in other stressors such as water quality.

Table 5-1: Crosswalk table mapping restoration categories onto the stressors they are generally best suited to address, although they may also indirectly contribute to improvements in other categories. Adapted from a more detailed version in the NOAA PCSRF Data Dictionary*.

| | Stressor Categories | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Restoration Category | Habitat Quantity | Mortality and Disease | Riparian Conditions | Peripheral Habitats | Channel Structure, Complexity | Sediment Conditions | Water Temperature | Water Quality | Water Quantity |
| Fish Passage Improvement | ■ | | | | | | | | |
| Fish Screening | | ■ | | | | | | | |
| Instream Flow Restoration | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Instream Habitat Restoration | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | |
| Riparian Habitat Restoration | | | ■ | ■ | ■ | ■ | ■ | ■ | |
| Upland Habitat & Sediment | | | ■ | ■ | | ■ | ■ | ■ | |
| Water Quality | | ■ | | | | | ■ | ■ | |
| Wetland | ■ | | | ■ | | | ■ | ■ | |
| Hatchery Rearing & Reintroduction | ■ | | | | | | | | |

* https://www.webapps.nwfsc.noaa.gov/apex/f?p=409:13, see also Appendix J

In the upcoming Section 6, we provide greater context on the specific techniques employed in each category, describe the mechanisms through which they relieve each of these target stressors, and provide real-world examples of their implementation and effectiveness in the Klamath Basin.

## 5.3 Types of Monitoring

Monitoring plays a key role in understanding how various stressors cumulatively affect the overall status and trends of fish populations, and also in gauging how successful management actions are at reducing these stressors and improving fish survival. For the purposes of this report, we delineate two main types of monitoring. These categories are part of a more complex monitoring typology presented in Figure 5-2 that is applicable to fisheries restoration projects.

- **Status and Trend Monitoring**

  Status and Trend Monitoring provides information about changes in anthropogenic and natural stressors, habitat attributes, and fish populations, and can be divided into **Habitat Monitoring** and **Population Monitoring.** The former encompasses monitoring of habitat variables such as flow, temperature and water quality while the latter tracks fish population variables like adult and juvenile abundance, marine and in-river survival, age-structure and population composition (e.g., hatchery vs. wild). Outputs from Status and Trend Monitoring help describe a system and how its habitats and populations are changing over time. These data (particularly when available for a wide range of populations with contrasting habitats) provide a foundation for the analysis of factors and life history stages that are most likely limiting fish populations. Status and trend monitoring is therefore very helpful for determining the structure and locations of restoration plans and projects (top of Figure 5-2).

- **Project Effectiveness Monitoring**

  Project Effectiveness Monitoring tracks how well restoration projects are meeting their desired goals, objectives and outcomes using tools such as Before-After-Control-Impact (BACI) designs to distinguish project effects from the effects of natural forces. One key difference is that Project Effectiveness Monitoring requires an experimental design to isolate the effects of an individual project (or multiple projects of a given type), whereas Status and Trend Monitoring reflects the cumulative effects of multiple projects and natural/human stressors upstream of the sampling location or on the fish life stage being monitored (e.g., egg, alevin, fry, parr, smolt, adult).

  For the purposes of this report we focus on Project Effectiveness Monitoring only at a high level. However, it is useful to note that this type of monitoring can be divided into four sub-types: (1) **Implementation Monitoring**; (2) **Compliance Monitoring**; (3) **Physical Effectiveness Monitoring**; and (4) **Biological Effectiveness Monitoring**. Each of these types examines how effective a restoration project is at meeting its objectives and is described in more detail below.

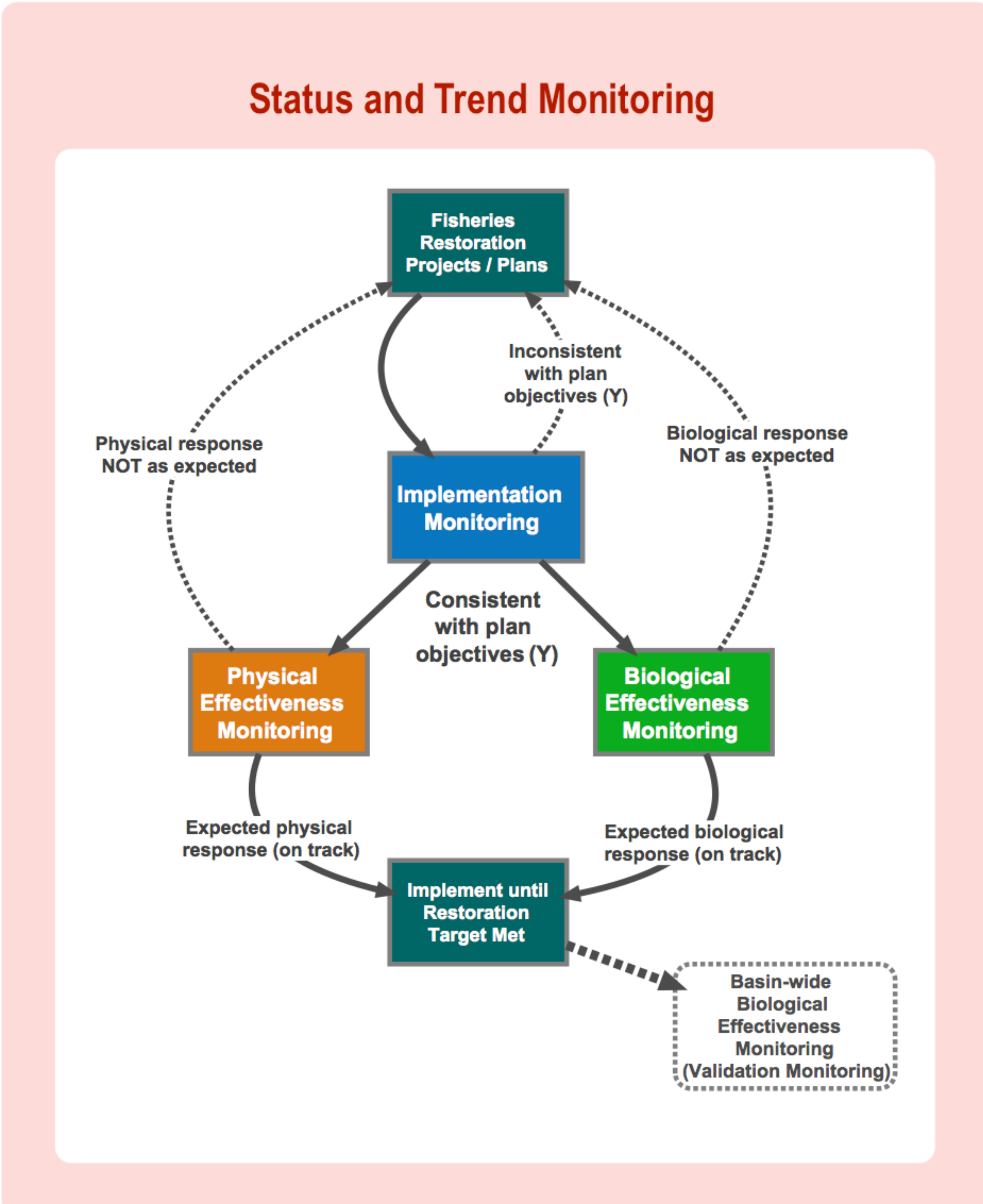



Figure 5-2: Relationships among types of monitoring for a fisheries restoration project.

**Implementation Monitoring** is checking to see if the implementation actions of a fish restoration plan have actually been carried as designed (NMFS 2014a).

**Compliance Monitoring** (not shown in Figure 5-2) is similar to Implementation Monitoring in that it checks if implementation actions are being carried out, with reference to particular compliance criteria. In practice, if actions are not being completed or adhered to it may be time to re-evaluate their feasibility and make adjustments to the original project plan. However, Compliance Monitoring is unique in that it evaluates whether enforcement is required (NCRWQCB 2011). For example, a dam operator may be required by law to maintain a specified minimum instream flow below the dam during warm, dry months and may be monitored to ensure compliance.

The next two monitoring types evaluate responses to fish restoration actions. **Physical Effectiveness Monitoring** checks to see if the expected physical response has occurred and **Biological Effectiveness Monitoring** checks to see if the expected biological response has occurred (USFS 2003a,b; NCRWQCB 2011; Harris 2005). For example, a physical response has occurred if planting of trees to provide shade creates thermal refugia in a stream. If fish begin to use the thermal refugia, that is a biological response.

Finally, **Basin-wide Biological Effectiveness Monitoring**, or **Validation Monitoring**, is important to determine cause-effect relationships between basin-wide restoration actions and changes in fish populations. This type of monitoring relies on the results from multiple projects throughout a river basin and uses these to inform statistical analyses that can determine whether a causal link exists (or can be detected) between actions and population-level responses (Harris 2005). Strong experimental designs are required to elucidate such effects from effectiveness and validation monitoring (Marmorek et al. 2004, Bennett et al. 2016, Bouwes et al. 2016a).

## 5.4 Major Restoration and Monitoring Organizations

Represented here are the major agencies and organizations involved in restoration and monitoring in the Klamath River Basin, with a more complete list provided in Appendix I.

### Federal Agencies

U.S. Bureau of Land Management
U.S. Bureau of Reclamation
U.S. Fish and Wildlife Service
U.S. Forest Service
U.S. Geological Survey
U.S. National Marine Fisheries Service (NOAA)
U.S. Department of Agriculture – Natural Resource Conservation Service

### State Agencies

California Department of Fish and Wildlife
California Conservation Corps
North Coast Regional Water Quality Control Board
Oregon Department of Fish and Wildlife
Oregon Department of Environmental Quality

### Tribal Agencies

Hoopa Tribe

Karuk Tribe
Klamath Tribes
Klamath Tribal Water Quality Consortium
Quartz Valley Indian Reservation
Resighini Rancheria
Yurok Tribe

**NGOs**
National Fish and Wildlife Foundation (NFWF)
Klamath Basin Monitoring Program
The Nature Conservancy
Trout Unlimited
Northern California Resource Center

**Community Organizations**
Mid-Klamath Watershed Council
Salmon River Restoration Council
Scott River Watershed Council
Shasta Valley Resource Conservation District
Siskyou Resource Conservation District

**Universities**
Oregon State University
University of California Davis

**Utility Service Providers**
PacifiCorp
Klamath Water and Power Agency
Irrigation Districts

## 5.5 Approach to Restoration and Monitoring Synthesis

**NOTE ON THE SCOPE OF SYNTHESIS**

*Although it is beyond the scope of this review to conduct an exhaustive analysis of monitoring and restoration efforts to date, we have applied multiple complementary approaches to capture and synthesize information on major restoration and monitoring organizations, programs, and projects across the Klamath Basin at a sufficient level of detail to provide broad insights into the scale, distribution, and nature of these activities.*

To effectively plan the future of restoration and monitoring efforts in the Klamath Basin, we must first understand the history of efforts already undertaken to reduce the impacts of various stressors and to monitor responses to these actions. One of the challenges of creating an adaptive management framework for a watershed of such large size and long history is effectively synthesizing the sheer scale and scope of restoration and monitoring activities to date, particularly given that their documentation may be scattered across numerous reports, offices, and organizations. A further challenge is effectively capturing both the broader programs and projects undertaken internally by Federal and State agencies, which may not produce detailed public documentation, as well as the finer-scale programs and individual projects undertaken externally by Tribes, NGOs, community organizations, and private landowners with support from government, NGO, or private funding programs. Although it is beyond the scope of this review to conduct an exhaustive analysis of monitoring and restoration efforts, we have attempted here to capture and synthesize information on ***major*** restoration and monitoring organizations, programs, and projects across the Klamath Basin at a sufficient level of detail to provide broad insights into the scale, scope, distribution, and nature of these activities. Our approach to synthesis has sought to capture information across these scales as follows:

### 5.5.1 Synthesis of Major Organizations and Programs

This level of synthesis seeks to provide broad narrative summaries of major Federal, State, Tribal, NGO, and Community organizations and programs that have made major contributions to monitoring and restoration across the entire Klamath Basin. Information on major organization and program objectives, accomplishments, and financial investments in Klamath Basin activities was drawn from a combination of organization websites, annual reports, reports to Congress, budgets, and personal communications with agency representatives.

### 5.5.2 Synthesis of Major Grant-Driven Projects

This level of synthesis seeks to assemble finer scale information on the major restoration and monitoring projects that have been carried out in the basin to date. The sheer volume of restoration projects, numbering in the thousands, prohibits timely and efficient synthesis through review of individual project documents. However, because many restoration projects are accomplished with at least some contribution from grant programs, synthesis can be accomplished much more rapidly and efficiently by compiling and summarizing the project information contained in multiple databases that track public grants for restoration. Moreover, exploring the types of projects that are funded through competitive grant programs can provide insights into priority project types, and how the relative emphasis on different techniques or locations receiving funding may change over time.

Thus, we began our project-level synthesis by collecting Klamath-specific project information from a wide range of existing public government, NGO, and academic databases tracking grant-funded watershed restoration projects at the state and national scale (***full list of sources and methods detailed in Appendix H***). Data was acquired through direct download of open databases, through direct requests for data from agencies, and through manual data entry from reports and grant award bulletins such that original data and metadata format did not limit our ability to include data in the database, and all entries were manually coded according to the PCSRF restoration work types for ease of analysis and comparison. Further, all cost figures were adjusted for inflation using year-by-year conversion factors derived from the Consumer Price Index published by the U.S. Bureau of Labour Statistics to facilitate more accurate comparisons of cumulative spending across years. Where projects included more than one type of restoration work, the project data was disaggregated into separate entries for each work type identified in Section 6 to permit analysis at the level of each restoration work type.

In the course of data collection, we also reached out to numerous organizations to request additional information on major restoration efforts not adequately captured by existing restoration tracking databases, although we acknowledge that some may be missing and request further assistance in filling these gaps. Where we have learned of restoration projects or programs that could not be readily integrated into our data collection, we describe them verbally and direct readers the original source for further information.

The resulting collection of grant-driven projects and actions capture a majority of the major restoration programs relevant to both the upper and lower Klamath Basin as described in Section 6.2, and the resulting scope and coverage of data is further described in Section 6.4.

### 5.5.3 A Note of Caution in Interpreting Program and Project Syntheses

This synthesis of major agencies and programs and the complementary collection of major projects, despite the potential gaps, are a useful tool for providing ***reasonably accurate broad insights into the scope, scale, distribution, and nature of restoration and in the basin and how they have changed through time.*** The data on individual restoration project actions in particular also lends itself well to visual summaries of restoration effort through time, using histograms, or through space, using choropleth maps that shade sub-basins according to the cumulative number of restoration projects or spending. However, these summaries and figures must be interpreted in full recognition that some projects may be missing. Thus while absolute numbers of projects may not be exactly right, patterns in the *relative* distribution of projects across types or sub-basins are more likely to reflect real patterns.

Moreover, it is important to remember that these summaries of programs, project status, and project trends are only one component of a broader and more holistic review of restoration and monitoring in the basin. These summaries are further supported by broader discussions of restoration and monitoring techniques, their effectiveness, and case studies of recent projects in the Klamath Basin that provide greater context around how these activities are implemented on the ground.

# 6 Restoration Actions

This section provides an overview of status and trends in restoration actions across the Klamath Basin and, for each category of restoration taking place, provides case studies of representative projects, and reviews the state of knowledge on the mechanism and degree of effectiveness of these interventions in achieving their ecological objectives for species and ecosystem recovery.

## 6.1 Overview of Restoration in the Klamath Basin

"We must quit looking at just a pool, a riffle, or even a reach, but address the problem as it fits into a complete watershed. How often have we visited a good looking K-dam, stream deflector, or rock crib to enhance a small reach, only to look around the watershed and see it crumbling down upon us."

~ W.S. Platts, 1984, quoted in KRBFTF (1991)

There is a very long history of fish and habitat restoration in the Klamath River Basin that must be documented and understood in order to inform future efforts. While earlier restoration work in the basin was more focused on the immediate benefits provided by instream structure restoration, more recent work has sought to address the root causes of watershed impairment. The vast majority of restoration projects in the Klamath Basin are now carried out with the objective of overall watershed improvement, and although some projects aim to provide benefits to one or more particular target species, most aim to provide a general benefit to all aquatic biota. The many decades of restoration efforts in the Klamath Basin have made gradual progress towards restoring watershed function and fish populations in many waterways (Kier Associates 1999), and have set the stage for the substantial work that still lies ahead.

This section begins with an overview of major organizations and programs driving restoration in the Klamath Basin. The remainder of the chapter provides more in-depth profiles of each major class of restoration action defined in Section 5.2. These profiles begin with a brief review of the most widely used work types and techniques within that class and available evidence on their effectiveness in achieving their desired beneficial effects, followed by a discussion of the status and trends of that type of restoration in the Klamath Basin based on summaries of grant-driven restoration, and concludes with a few detailed case studies of representative projects providing greater context for how such projects are implemented.

## 6.2 Major Restoration Organizations and Programs

This section provides a brief overview of major organizations and programs involved in restoration within the Klamath Basin, while acknowledging that many more organizations and individuals also contribute to restoration beyond what can be reviewed in detail in this document. Although we provide overviews only for these major organizations and programs, we have also compiled a more detailed list in Appendix I of organizations that are known to be involved in Klamath Basin Restoration by way of their role as a funding agency, project lead, or partner organization (as described in Section 5.5).

### 6.2.1 Federal Agencies & Programs

#### *National Oceanic and Atmospheric Administration (NOAA)*

NOAA's work in the Klamath Basin relates primarily to restoration benefiting Klamath River Coho (*Oncorhynchus kisutch*) in fulfillment of the recovery plan for this species that was developed in response to the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006. NOAA conducts its own restoration work through the National Marine Fisheries Service (NMFS) and the NOAA Restoration Center, and also supports restoration by external organizations by awarding restoration grants through the competitive Pacific Coastal Salmon Recovery Fund (PCSRF). NOAA's commitments to restoration in the Klamath Basin have been substantial, and the agency has allocated over $61 million in funding across its programs to the restoration of Klamath Basin salmonids between 2000 and 2013 (NMFS 2013, 2015).

#### *U.S. Fish and Wildlife Service (USFWS)*

The USFWS leads and also funds many planning, restoration, and monitoring efforts in the Klamath Basin that are coordinated through three field offices closely tied to the basin – the Arcata and Yreka Fish and Wildlife Offices in California, and the Klamath Falls Fish and Wildlife Offices in Oregon. In addition to planning, assessment, and monitoring (described further in Section 7 – Monitoring Activities), the USFWS also implements restoration projects and administers four key programs (among many others) that fund external efforts and boots-on-the-ground restoration activities in the Klamath and beyond:

- The National Fish Habitat Partnership supports collaborative partnerships that work to restore and enhance fish and aquatic habitats and communities. A notable example relevant to the Klamath is the Pacific Lamprey Partnership.
- The National Fish Passage Program is a voluntary, non-regulatory initiative providing funding and technical assistance to improve fish passage through water ways. Past projects have improved fish passage at culverts, repaired defective screens, and studied remedies to other fish passage problems.
- The Partners for Fish and Wildlife (PFW) Program is a technical and financial assistance program working with private landowners to restore wetlands, streams and river corridors, fish and wildlife habitats.
- The Wildlife and Sport Fish Restoration (WSFR) Program leverages revenue from fishing license and taxes on other fishery-related purchases to provide grant funds to the states, the District of Columbia, and fish and wildlife agencies for projects that will conserve, protect, and enhance fish, wildlife, their habitats, and hunting, sport fishing and recreational boating opportunities.

The USFWS has made substantial investments in the Klamath Basin (USFWS ECOS and USFWS 2008b), committing over $42 million across its programs to Klamath Basin planning, fish and wildlife conservation, habitat and population assessment, fisheries management, and habitat restoration activities between 2007 and 2016 (USFWS ECOS Fisheries Information System), which overlaps with an estimated investment of $16.8 million specifically related to salmonid restoration between 2000 and 2013 (NOAA 2013, 2015).

## *U.S. Forest Service (USFS)*

The Klamath Basin encompasses several large expanses of National Forest, which are operated by the USFS under obligations for the stewardship of federal lands. These forests consist of the Klamath and Six Rivers National Forests in the lower part of the basin and the Fremont, Winema, and Modoc National Forests in the upper part of the basin. The USFS contributes to fish and habitat restoration within these forests according to their Land and Resource Management Plans (LRMPs) and associated Aquatic Conservation Strategy (Reeves et al. 2006), as required under the Northwest Forest Plan (USFS 1989, 1990, 1991, 1995, 2010). These plans feature objectives relevant to fish, including maintaining and restoring the distribution, diversity, and complexity of watershed features, stream systems, riparian areas and wetlands, and improving water quality and instream flows to support aquatic habitats and fisheries. For example, the USFS conducts terrestrial habitat restoration in the Klamath National Forest (KNF) in the form of forest thinning and prescribed burning. This work is designed to reduce the accumulation of small diameter trees and other fuels that have built up over the past 100+ years of fire suppression. These actions may indirectly affect fish and their habitat because the work is aimed at reducing the occurrence of large high severity wildfires that consume riparian habitat and have drastic effects on sediment regimes. A new Northwest Forest Plan and Aquatic Conservation Strategy (encompassing all of the National Forests in the Klamath Basin) is currently under development. This Plan and Strategy will provide guidance on future land use and restoration, based on an updated science synthesis for the region; a draft was released in early 2017[24].

The USFS has committed roughly $40 million to restoration in the Klamath Basin across its programs between 2000 and 2013 (NOAA 2013, 2015).

## *U.S. Department of Agriculture - Natural Resource Conservation Service (NRCS)*

The NRCS provides financial and technical support for farmers and ranchers to voluntarily carry out conservation activities on their lands in ways that benefit both landowners and the environment. This agency also administers three key grant programs created through the 2002 Farm Bill that fund conservation projects on agricultural and ranch lands:

- The Environmental Quality Incentives Program (EQIP) provides financial and technical assistance to agricultural producers in order to address natural resource concerns and deliver environmental benefits such as improved water and air quality, conserved ground and surface water, reduced soil erosion and sedimentation or improved or created wildlife habitat. This program has awarded substantial funding for irrigation

[24] https://www.fs.fed.us/pnw/research/science-synthesis/

improvements and water-control projects to improve instream flows in the Klamath Basin (detailed further in Section 6.5.3).

- The Conservation Stewardship Program (CSP) helps agricultural producers maintain and improve existing conservation systems and adopt additional conservation activities to address priority resources concerns under a payment per performance model.
- The Agricultural Management Assistance Program (AMA) helps agricultural producers use conservation to manage risk and solve natural resource issues through natural resources conservation.

The NRCS has committed roughly $13 million to restoration in the Klamath Basin across its programs between 2000 and 2013 (NOAA 2013, 2015).

## *U.S. Bureau of Reclamation (USBR)*[25]

The USBR, through its Klamath Basin Area Office, works towards long-term, durable solutions to water and power issues in the Klamath Basin and strives to manage available water in the upper Klamath Basin to meet the needs of fish as well as irrigation. Within the Basin, the USBR oversees the Klamath Project for agricultural irrigation, encompassing several major pumping plants, storage reservoirs, and many miles of canals and diversions, and also operates Clear Lake Dam, Gerber Dam, and the Lost River Diversion Dam. Additionally, the USBR is working towards operational compliance with a Total Maximum Daily Load (TMDL) Water Quality Monitoring and Compliance Plan developed to meet the states of Oregon and California TMDL requirements. Given its role in water management, the USBR was a major participant in the Klamath settlement process leading up to the signing of the now-defunct Klamath Basin Restoration Agreement (KBRA), and continues to play a key role in water management for fish and wildlife in the Klamath Basin. In addition to its water management operations, the USBR also supports restoration through funding support to the National Fish and Wildlife Foundation (NFWF) Bureau of Reclamation Klamath Coho Habitat Restoration Program (detailed further in Section 6.2.4).

Overall, the USBR has committed roughly $61 million to restoration in the Klamath Basin across its programs between 2000 and 2013 (NOAA 2013, 2015).

## *Environmental Protection Agency (USEPA)*[26]

The USEPA supports restoration in the Klamath Basin primarily through the 205(j) Water Quality Planning Grant Program and the 319(h) Nonpoint Source Management Grant Program, established under the 1987 amendments to the Clean Water Act (CWA). Under these programs, funds are provided only to designated state and tribal agencies that plan and implement their approved nonpoint source management programs with the overall goal of improving water quality. The USEPA has awarded an estimated $316,000 in 205(j) funds to four water quality planning projects between 1993 and 2002 (UC Davis NRPI Database[27]) and $4.8 million in

[25] https://www.usbr.gov/mp/kbao/index.html
[26] https://www.epa.gov/nps/319-grant-program-states-and-territories
[27] http://www.ice.ucdavis.edu/nrpi/home.aspx

319(h) funds to 15 water quality implementation projects in the Klamath Basin between 2006 and 2015 (EPA GRTS Database[28]). The 305(j) funds have supported water quality studies on agricultural drainage water in the Upper Klamath Basin, sedimentation studies in the Scott sub-basin, and the development of the Shasta River Water Quality Management Plan. The 319(h) funding has supported water quality improvements in the Trinity, Scott, Salmon, and Shasta rivers, and has also been a major source of funding for the basin-wide Klamath Tracking and Accounting Program (KTAP) that links conservation projects to load reductions called for in both California's and Oregon's Klamath River TMDLs (described further in Section 7).

### 6.2.2 State Agencies & Programs

#### *Oregon Department of Fish and Wildlife (ODFW)*

The ODFW carries out its activities in the Klamath Basin primarily through two field offices closely tied to the basin – The Klamath Watershed District Office in Klamath Falls and the Lakeview Field Office. The agency administers a wide range of programs related to fish and habitat restoration, fish passage and screening, hatchery rearing, and water quality and quantity. Among the most important of these programs are:

- The Restoration and Enhancement Program[29], which distributes income from angling license fees to specific ODFW field offices as well as to external collaborators to carry out a variety of restoration work. This program has funded roughly 30 projects in the Klamath Basin from 2005 to 2013 which include fisheries management equipment, angler surveys and outreach, fish disease studies, hatchery operations, instream habitat restoration, riparian fencing and restoration, and fish passage and screening projects.
- The Salmon and Trout Enhancement Program (STEP), created in 1981, recruits volunteers passionate about fish conservation who have donated money, materials, equipment, time and labor to help completed stream habitat restoration work, conducted surveys, delivered education projects, and hatched and reared several million salmon and trout eggs.[30]
- The Fish Passage Program and Fish Screening Program. The latter conducts research into screen designs and effectiveness, operates three “screen shops” across the state that build screens, and provides funds and support to help partners install screens. The screening program has made major investments in the Klamath Basin, including nearly $450,000 for the installation of a major fish screen on the North Fork of the Sprague River in 2013-15 (ODFW 2014).

Through these and other programs, the ODFW has contributed many millions of dollars towards restoration in the Oregon portion of the Klamath River Basin.

[28] https://iaspub.epa.gov/apex/grts/f?p=grts:95
[29] https://nrimp.dfw.state.or.us/re/default.aspx?p=1
[30] http://www.dfw.state.or.us/fish/STEP/

## Oregon Watershed Enhancement Board (OWEB)[31]

OWEB is a state agency that provides grants to support protection and restoration of local streams, rivers, wetlands and natural areas to help achieve the objectives of the Oregon Plan for Salmon and Watersheds (OPSW). The agency is led by a 17 member citizen board drawn from the public at large, tribes, and federal and state natural resource agency boards and commissions, and determines which projects to fund based on internal priority criteria. The OWEB has provided over $9 million in funding to at least 45 restoration projects in the Upper Klamath Basin between 2002 and 2016, with a focus on projects aimed at improving riparian habitat, instream habitat, instream flows, and fish passage and screening (KTAP Database, NOAA PNW Salmon Restoration Database, OWEB 2016 Grant Slate).

## California Department of Fish and Wildlife (CDFW)

The CDFW has field offices in Yreka, Eureka, and Redding California, and contributes directly to fisheries restoration in the Klamath Basin primarily through three of its Fisheries Branch programs:

- The Anadromous Conservation and Management Program is a focus of CDFW efforts and, along with NOAA Fisheries, has been developing a statewide plan to initiate standard monitoring and conduct applied research necessary to implement sound conservation and population recovery measures.
- The Inland Fisheries Conservation and Management consists of multiple programs responsible for conservation, recovery, and management of inland fish species, including the Heritage and Wild Trout Program. These programs involve: developing management plans and recommending and conducting management actions; designing, conducting and overseeing resource assessment, monitoring, and research; conducting fish passage inventories; coordinating habitat enhancement projects; and managing recreational fisheries.
- The Fish Production and Aquatic Pathology Program operates the Trinity River Hatchery and Iron Gate Hatchery to supplement wild populations of salmonids (as detailed in Section 6.5.2)[32].

In addition to agency-led restoration, the CDFW has also administered grant programs through its Watershed Restoration Grants Branch[33] that fund restoration by Tribes and NGOs. The most important of these is the Fisheries Restoration Grant Program (FRGP), established in 1981 in response to rapidly declining populations of wild salmon and steelhead trout (*Oncorhynchus mykiss irideus*) and deteriorating fish habitat in California. This competitive grant program has invested millions of dollars to support projects from sediment reduction to watershed education throughout coastal California. Partners contributing to projects in the form of funding or in-kind donations include federal and local governments, tribes, water districts, fisheries organizations, watershed restoration groups, the California Conservation Corps, AmeriCorps, and private landowners. Other grants administered by this Branch include the Proposition 1 Grant Programs

[31] http://www.oregon.gov/OWEB/pages/index.aspx
[32] https://www.wildlife.ca.gov/Fishing/Hatcheries
[33] https://www.wildlife.ca.gov/Explore/Organization/WRGB

and the Cannabis Restoration Grant Program. The CDFW has also run several shorter grant programs, including a Klamath River Restoration Grant Program in the 2006-2007 fiscal year. Lastly, the CDFW also manages conservation easements in the basin, such as the Noyes Valley Wildlife Area in the Scott watershed.

The CDFW has committed roughly $26 million to restoration in the Klamath Basin across its programs, including the FRGP, between 2000 and 2013 (NOAA 2013, 2015).

## California State Wildlife Conservation Board (WCB)[34]

The WCB is a separate and independent board within the CDFW that selects, authorizes, and allocates funds for land acquisition or easements (Richardson 2010), habitat restoration and development of wildlife oriented public access facilities. The WCB administers a number of programs with specific funding objectives relevant to the Klamath Basin, including programs providing funding for Riparian Restoration, Wetland Restoration, Stream Flow Enhancement, and many others. Notable acquisitions in the Klamath Basin funded through the WCB include the Butte Valley Wildlife Area, Horseshoe Ranch, and Shasta Valley Wildlife Areas, among others. Within the Klamath Basin, the WCB has provided an estimated $55 million in funding primarily for land acquisitions, but also for several restoration projects, in the period spanning 1960 to 2015 (CalFish Database[35]).

## California State and Regional Water Resources Control Boards

The State Water Control Board (SWRCB) plays a role in protecting water quality by setting statewide policy, allocating surface water rights, coordinating and supporting the efforts of regional boards, such as the North Coast Regional Water Quality Control Board (NCRWQCB) in the Klamath basin. Together, the State and Regional Boards are also responsible for implementing and enforcing the federal Clean Water Act in California and for distributing funding through a number of grant programs for water quality improvement projects, including river restoration projects, which will help to achieve this objective (CWB 2013). Key grant programs that have funded restoration in the Klamath Basin include the Clean Water Act Section 319(h), Nonpoint Source (NPS) Grant Program and Agricultural Water Quality Grant Program (AWQGP) PROP 50, among others.[36]

## California State Coastal Conservancy[37]

The Coastal Conservancy is a state agency, established in 1976, to protect and improve natural lands and waterways, to help people get to and enjoy the outdoors, and to sustain local economies along California's coast. The Conservancy is a non-regulatory agency that supports projects to protect coastal resources and increase opportunities for the public to enjoy the coast. The Conservancy implements statewide resource plans through its projects, including the California Water Action Plan, the Wildlife Action Plan, and many others. The Conservancy

[34] https://www.wcb.ca.gov/
[35] http://www.calfish.org/DataandMaps/CalFishDataExplorer.aspx
[36] http://faast.waterboards.ca.gov/Public_Interface/PublicSearch.aspx
[37] http://scc.ca.gov/about/

works along the entire length of California's coast and within the watersheds of rivers and streams that extend inland from the coast. The Conservancy also provides technical assistance and grant funding to local communities, non-profit organizations, other government agencies, businesses, and private landowners to implement multi-benefit projects that protect, restore, and enhance fish and wildlife habitat, improve water quality, and support coastal communities. The Conservancy has funded or collaborated on a number of projects in the Lower Klamath Basin, including land acquisitions, assessment and removal of fish passage barriers, sediment control, instream habitat enhancement, and capacity-building.

The Coastal Conservancy has committed roughly $2.7 million to restoration in the Klamath Basin across its programs between 2000 and 2013 (NOAA 2013, 2015).

#### *California Conservation Corps.*

The California Conservation Corps is a state agency that recruits youth to work on projects improving California's natural resources. The Corps has implemented a number of restoration projects in the Klamath Basin, particularly in the lower reaches, including instream habitat restoration, riparian planting, streambank stabilization, upland erosion and sedimentation control, and removal of fish passage barriers. Between 1986 and 2005, the value of Corps restoration work in the Klamath Bain is estimated to have exceeded $2.5 million (CalFish Database[38], UC Davis NRPI Database[39], NOAA PCSRF Database[40]).

### 6.2.3 Tribal Agencies & Programs

There are six federally recognized Tribes in the Klamath Basin: Yurok Tribe, Resighini Rancheria, Hoopa Valley Tribe, Karuk Tribe, Quartz Valley Indian Community of the Quartz Valley Reservation, and The Klamath Tribes. Tribal culture is tied to the Klamath River. Traditions, ceremonies, and spiritual practices are deeply rooted in the Klamath Basin ecosystem – the river, lakes and tributaries, salmon, suckers, plants and wildlife. The Federal government has the responsibility to uphold tribal trust responsibilities and to safeguard the fishery to ensure that tribes with fishing rights are able to practice those rights (USDI 2012b). When considering the role of Tribes in fisheries management in the Klamath River, it is important to understand the nature of "Indian rights." Pierce, 1998 states that, "*The fact is that these rights, such as Tribal fishing rights and the right to self-governance, are rights that the Indian People as sovereign nations had prior to conquest, and they retained these "Reserved Rights" when they gave up their land by Treaty or Agreement."*

Tribes in both the Upper and Lower basins carry out ecosystem restoration planning and implementation for their individual traditional territories. The Yurok Tribe has been conducting fisheries and watershed assessments to guide development, prioritization, and implementation of stream, riparian, and upslope restoration activities in the Lower Klamath River Sub-basin since the late 1990s. The Yurok Tribe has developed a Lower Klamath Restoration Plan focused first on upslope erosion control and reducing road sediment inputs, followed by

[38] http://www.calfish.org/DataandMaps/CalFishDataExplorer.aspx
[39] http://www.ice.ucdavis.edu/nrpi/home.aspx
[40] https://www.webapps.nwfsc.noaa.gov/apex/f?p=309:13

instream and riparian habitat restoration (Gale and Randolph 2000). Implementation of this plan is the responsibility of the Yurok Tribal Fisheries Program, which focuses on process-based approaches such as riparian planting, instream structure placement, and beaver dam analogs; and its Watershed Restoration Program, which focuses on watershed assessment, road-crossing removals, and road improvement or decommissioning (Gale and Randolph 2000). The Karuk Department of Natural Resources operates under a similar Strategic Plan for Organizational Development which includes goals and objectives for each of its programmatic areas, including Fisheries, Watershed Restoration, and Water Quality (Karuk Department of Natural Resources 2015). At the time of writing, the Klamath Tribes were in the process of developing an aquatic and riparian restoration program that will be structured directly around the provisions and components of the forthcoming Upper Klamath Basin Watershed Action Plan (Klamath Tribes 2016, M. Skinner, pers. comm.) with the overarching goals of restoring wetland function, improving water quality, restoring river structure and function, and improving instream habitat for native aquatic organisms, as well as monitoring and adaptive management for the program.

Moreover, many Tribes collaborate to tackle restoration issues at broader scales. The Klamath, Karuk, Hoopa Valley, and Yurok Tribes collaborate on broader ecosystem restoration initiatives through participation in the Klamath River Inter-Tribal Fish and Water Commission (KRITFWC). Commission Tribes are actively involved in salmon restoration efforts throughout the Klamath River Basin and implement important restoration and recovery activities with financial support through NOAA PCSRF funding. KRIFWC has received a total of over $7.6 million from PCSRF for FY's 2000 – 2008 that has been used by member Tribes to implement 178 restoration projects. Tribes also have unique authority to manage and protect water quality within their Reservations. The Yurok Tribe, Hoopa Valley Tribe, Karuk Tribe, Quartz Valley Indian Reservation, and Resighini Rancheria formed the Klamath Tribal Water Quality Consortium to collaborate on water quality issues including monitoring, assessment, and restoration planning. Each tribe has its own water quality plan, but the Consortium member tribes also jointly produced and are working to implement an Upper Klamath Basin Nonpoint Source Pollution Assessment and Management Program Plan (KTWQC 2016).

### 6.2.4 NGOs

#### ***National Fish and Wildlife Foundation (NFWF)***

NFWF uses federal funding as a springboard to leverage additional contributions from government agencies, industry, foundations, and other sources to fund science-based conservation projects. NFWF administers four important grants that fund restoration work in the Klamath Basin, but does not itself conduct restoration work. These grant programs include the:

- Klamath River Coho Enhancement Fund. This program seeks to fund projects that will restore, enhance, and improve habitat, flows, and fish passage for the Southern Oregon / Northern California Coastal coho salmon in the Klamath River and/or its tributaries downstream of Iron Gate Dam.
- Upper Klamath Basin Initiative. Funded in collaboration with the Oregon Watershed Enhancement Board (OWEB), the U.S. Fish and Wildlife Service, and the U.S. Forest Service, this program funds projects that will restore watershed and water flow

conditions in the Upper Klamath Basin in order to support increased distribution and abundance of federally-listed Lost River sucker (*Deltistes luxatus*) and shortnose sucker (*Chasmistes brevirostris*), as well as state sensitive redband trout (*O. mykiss newberrii*).

- Klamath River Coho Habitat Restoration Program. Funded in collaboration with the Bureau of Reclamation and PacifiCorp, this program seeks applications for funding to implement coho habitat restoration projects within the Klamath River and its tributaries downstream of Iron Gate Dam.
- Bring Back the Natives Program. Funded in collaboration with private donors, the Bureau of Reclamation, the U.S. Fish and Wildlife Service, and the U.S. Forest Service, this program funds conservation activities that restore, protect, and enhance native populations of sensitive or listed fish species across the United States, especially in areas on or adjacent to federal agency lands. Although not specific to the Klamath, this program has funded several restoration projects in the basin.

### *The Nature Conservancy (TNC)*

The Nature Conservancy's mission is to conserve the lands and waters on which all life depends, and this mission has been pursued in the Klamath Basin primarily through implementation of on-the-ground habitat restoration. TNC's Lower Klamath Basin Project worked to obtain a conservation easement on the Big Springs Ranch and has worked in partnership with a number of other organizations to restore critical salmonid spawning and rearing streams and degraded streamside habitat at Shasta River and Big Springs Creek through livestock grazing management, fencing, and riparian planting. In addition, TNC leads the Shasta River Water Transaction Program which plays a role in enhancing flows in the Shasta River. In the upper basin, TNC and its partners are focused on large-scale wetland restoration in the Williamson River Delta and in Sycan Marsh to help restore natural flows and connectivity, improve water quality, restore wetland vegetation, and replenish important habitat for juvenile suckers, bull and redband trout, and other aquatic organisms.

### *Trout Unlimited (TU)*

Trout Unlimited's mission is to conserve, protect and restore North America's cold-water fisheries and their watersheds. To accomplish this mission in the Klamath Basin, TU collaborates with an extensive list of partners including state and federal agencies, tribes, other non-profits, and private landowners. Trout Unlimited's focus in the upper Klamath Basin (tributaries to Upper Klamath Lake) centers on: 1) addressing the over-commitment of water resources by implementing a variety of strategies to reduce water use; 2) encouraging land, water, and cattle grazing management that will improve water quality; and 3) restoring and protecting riverine, riparian, and wetland habitats. Trout Unlimited enables landowner participation in federal and state programs that encourage sustainable land and water management through cooperative partnerships with private property owners and public agencies. Additionally, TU works to increase and protect instream flows through individual water transactions and established programs such as Agricultural Water Enhancement Program. Finally, TU implements restoration and conservation projects such as riparian fencing, stream restoration, fish passage and screening improvements, and diffuse-source treatment wetlands that enhance habitat conditions for native fish and wildlife populations. TU staff also lead and provide technical support for a number partnerships that focus on restoring habitats and recovering native species, including the development of a restoration plan for the upper Klamath Basin, the bull trout working group, Oregon Spotted Frog recovery, and redband trout population monitoring.

Notable projects underway at the time of writing include the Lower Sun Creek Restoration, the Melhase Fish Screen, and the Lower Threemile and Crane Creek Reconnection projects. The Lower Sun Creek Restoration project will enhance bull trout (*Salvelinus confluentus*) populations by reconnecting the historic Sun Creek channel with the Wood River, screening an irrigation diversion, reducing irrigation deliveries through instream transfers, and improving irrigation efficiency through conveyance and on-farm irrigation improvements. The Melhase Fish Screen project will replace a non-functioning fish screen with a new, low-maintenance fish screen at a large irrigation diversion on the Wood River. This is a high priority site because it is immediately downstream of important redband trout spawning habitat and within bull trout critical habitat. Finally, the Lower Threemile and Crane Creek Reconnection project will restore aquatic and riparian habitat by reconnecting the creeks to their historic channels and nearby habitats. This project will enhance bull trout populations by providing connectivity across aquatic habitats. These projects illustrate TU's success in conserving, protecting, and restoring cold-water fisheries and their watersheds in the upper Klamath Basin through collaborative partnerships. These projects all build on prior successful work by TU to implement similar projects of this scope and scale (TU, pers. comm.).

## *California Trout*

California Trout (CalTrout) carries out salmonid protection and restoration programs throughout California, with an area of regional focus in the Shasta-Klamath Region. California Trout's objectives in this region are to protect and restore the spring-fed cold water river systems that, in the face of drought and climate change, sustain native salmonids, support the local economy, supply water to central and southern California, and provide critical habitat for trout, steelhead and salmon. This group has been particularly active in implementing restoration projects along the Shasta and Scott Rivers and is an active participant and coordinator in the proceedings pursuing dam removal.

## *Watershed Councils*

A number of local watershed councils play an important role in local watershed restoration in the Klamath basin and include the Salmon River Restoration Council (SRRC), the Mid-Klamath Watershed Council (MKWC), the Scott River Watershed Council (SRWC). These councils convene, plan, design, and implement a significant portion of the fisheries restoration activities within the basin with the assistance of community partnerships. The councils identified here have led or contributed to several regional restoration plans in the basin (identified in Appendix K). Most recently, The Mid Klamath Watershed Council and the Salmon River Restoration Council have worked with their multitude of governmental, tribal and NGO partners to create a detailed Candidate Action Table for in-stream fisheries restoration in the Mid Klamath and Salmon River subbassins. These efforts have brought together the knowledge of a multitude of partners and experts and gained collaborative agreement on future restoration actions and priorities within these areas. Based on the information available in public grant tracking databases, local watershed councils have directed over $4 million in restoration grant spending on more than 40 diverse restoration projects within the basin between 1994 and 2016.

#### *Other NGOs*

A number of other smaller NGOs have been very active in obtaining grants to fund the implementation of restoration work within their local watersheds. This group includes smaller basin-wide partnerships such as the Klamath Basin Rangeland Trust (which has since merged with Trout Unlimited), as well as smaller environmental NGOs, foundations, land trusts, land trusts, fishermen's associations.

### 6.2.5 Multi-Agency Programs

The most notable example of a multi-agency program in the basin is the Trinity River Restoration Program (TRRP), which is managed by the Trinity Management Council (TMC) whose membership includes the USBR, USFWS, USFS, NOAA Fisheries, Hoopa Valley Tribe, Yurok Tribe, California Resources Agency, and Trinity County. The goal of the TRRP is "to restore and sustain natural production of anadromous fish populations downstream of Lewiston Dam to pre-dam levels, to facilitate dependent tribal, commercial, and sport fisheries' full participation in the benefits of restoration via enhanced harvest opportunities" (TRRP and ESSA 2009). This program carried out extensive annual restoration activities focused on increasing annual flow regimes, fine and coarse sediment management, and large-scale channel rehabilitation projects (TRRP and ESSA 2009). Since the ROD for this program was signed in 2000, the USBR, USFWS, CDFW, and Central Valley Project Improvement Act (CVPIA) Restoration Fund have provided upwards of $8-15 million annually for the TRRP to implement these restoration activities (TRRP 2009b). For more details on the TRRP, see Box 2-2 in Section 2.4 and the adaptive management case study of this program in Section 8.3.1.

### 6.2.6 Other Organizations and Programs

A great many other organizations are also involved in restoration within the Klamath Basin, most often in partnership with one of the larger regional organizations mentioned above. Public interest and support for salmonid restoration have grown rapidly in the last few decades, bringing with it growing engagement of a broader diversity of organizations beyond governments, tribes, and NGOs. Many of these groups have become an integral part of the success of restoration initiatives not only through fundraising, volunteering, or donations, but also through contributing to a grass-roots community-level commitment to fish conservation (KRBFTF 1991). These various organizations may include the following:

- Resource Conservation Districts
- Watershed councils
- Public utilities
- Water users associations
- Research organizations
- Local schools

- Industry partners (e.g., Consulting firms, engineers, dam operators, timber enterprises)
- Sport fishermen's organizations
- Private landowners (e.g., farmers and ranchers)

Specific examples of these types of organizations that are actively participating in restoration within the Klamath Basin are listed in detail in Appendix J.

## 6.3 Common Restoration Goals and Objectives

The Klamath Basin has a long history of restoration plans and programs, laying out a number of goals and objectives at a range of spatial scales, from individual streams to the entire basin (listed by sub-basin in Section 2), and making recommendations for how to achieve them. For many of these plans, the ultimate **goal**, or end towards which efforts are being directed, is identified as *restoring self-sustaining natural production of fish populations to eventually allow for the resumption of Tribal, recreational, and commercial fisheries full participation in the benefits of restoration via enhanced harvest opportunities*, with an emphasis on anadromous fish. Each plan then specifies its own unique set of **objectives**, or specific, measurable, and achievable steps towards achieving the overall goal.

Comparing the goals and objectives outlined in the restoration plans and programs published to date, even if their terms have expired, and tracking those that appear most frequently can yield valuable insights into the relative importance of objectives in this region. Such a comparison also provides a starting point for drafting a unified set of interim restoration goals and objectives to inform future restoration planning. This review has identified *at least 72 publicly available strategic plans* including goals and objectives relevant to fisheries restoration in the Klamath Basin (full list of plans provided in Appendix K). This set of plans spans 1991 to 2017, encompasses 28 federal, state, tribal, and other agencies, and includes a representative mix of plans pertaining to the Lower (32%), Upper (36%), Mid (5%), and whole Klamath Basin (18%) as well as national scale species recovery plans (10%). Plans fall into four categories:

- Species-specific Conservation and Recovery Plans
- Fisheries Restoration Plans
- Watershed and Habitat Restoration Plans
- Water Quality Plans

To explore commonalities in goals and objectives across these restoration and management plans, we selected a *subset of 25 plans* considered to be broadest in scope and representative in their geographic focus, responsible agencies, and planning categories. Commonly occurring goals and objectives across all plans were compiled into a list and overlap between these goals and objectives catalogued in a crosswalk table (Table 6-1). Many common goals are evident in this table, and perhaps the most universal were general goals related to improvements in water quality, fish habitat, and riparian habitat benefiting all anadromous and resident fish species. Species-specific goals and objectives were less common, and largely confined to their respective species conservation and recovery plans. Also common across many plans was a desire to approach restoration using an adaptive management approach. Notably, there was less focus on goals and objectives specifically related to hydrologic processes across plans, particularly for sediment transport. This set of goals and objectives are also well aligned with those cited by interested parties participating in a kickoff workshop informing the development of this Synthesis Report (summarized in Appendix B), the most common of these being the restoration of self-sustaining natural populations of anadromous and resident fish. The common goals and objectives identified in this exercise are clearly important to many restoration practitioners in the basin and provide a reasonable starting point for forming the common set of goals and objectives that will inform future restoration planning.

Table 6-1: Table of Interim Goals and Objectives identified from key recovery and restoration plans relevant to the Klamath Basin. Species codes corresponding to superscripts can be found at the bottom of the table.

## PART I

| Overall Goal or Overarching Objective | Core Objectives (Level 1 Objectives) | Sub-Objectives (Level 2 Objectives) | Conceptual Model Component | Programs | Species Conservation & Recovery Plans: Steelhead Restoration and Management Plan for California (CDFW 1996) | Federal Recovery Outline - North American Green Sturgeon Southern Distinct Population Segment (NMFS 2010) | PacifiCorp Klamath Hydroelectric Project Interim Operations Habitat Conservation Plan for Coho Salmon (PacifiCorp 2012) | Recovery Plan for Southern Oregon/Northern California Coast Coho Salmon (SONCC) (NOAA Fisheries 2014) | Revised Lost River Sucker and Shortnose Sucker Recovery Plan (2012) | Klamath Hydroelectric Project Interim Operations Habitat Conservation Plan for Lost River and Shortnose Suckers (PacifiCorp 2013) | Revised draft recovery plan for the coterminous United States population of bull trout (Salvelinus confluentus) (USFW 2014) | Conservation Strategy for Interior Redband (Oncorhynchus mykiss subsp.) (Upper Klamath Pops) (Interior Redband Conservation Team 2016) | Conservation Agreement for Pacific Lamprey and Regional Implementation Plan for Measures to Conserve Pacific Lamprey - California - North Coast Regional Management Unit (USFWS 2015) | Endangered Species Act Recovery Plan for the Southern Distinct Population Segment of Eulachon (NMFS 2016) | Fisheries Management Plans: Pacific Coast Salmon Fishery Management Plan (PFSMC 2016) | Hatchery and Genetic Management Plan For Iron Gate Hatchery Coho Salmon (USFW 2014) | Klamath Hatchery Program Management Plan (ODFW 2017) | A Plan for Reintroduction of Anadromous Fish in the Upper Klamath Basin (ODFW, Hooton & Smith 2008) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Improve water quality, quantity and ecological flow regimes | Improve instream ecological flow regime | Refine instream flow needs assessments incld. definition of eco-hydraulic functional relationships | F | | | X | | X | | | | X | X | | | | | |
| | | Operate dam releases to produce ecologically beneficial flow regime, satisfying critical functional flow needs over species/time/space | F | | X | | X | | | | X | | X | X | | | | |
| | | Identify and reduce the number of unauthorized diversions, and/or improve irrigation & water conservation practices | F | | X | | | X | | | | | X | | | | | |
| | | Pursue water leasing, sharing and purchase agreements | F | | | | X | | | | | X | | | | | | |
| | Reduce external nutrient and pollutant inputs | Reduce point and non-pint source nutrient loads and pollution, esp. phosphorous runoff via TMDL implementation & other methods | I | | | | | X | X | | | | X | X | | | | |
| | | Create and implement pesticide management plans to reduce pesticide inputs | I | | | X | | X | X | | | | | | | | | |
| | | Remediate mine tailing piles to reduce runoff inputs | I | | | | | | X | | | | | | | | | |
| | | Treatment of irrigation and rangeland tailwater returns | I | | | | | | X | | | | | | | | | |
| | | Restoration of existing wetlands or creation of treatment or "walking" wetlands | I B | | | | | | X | | | | | | | | | |
| | Reduce fine sediment inputs | Improve agricultural and ranch land management practices | I | | X | | | X | X | | | X | X | | | | | |
| | | Improve timber harvesting and forestry management practices to minimize stream inputs | I | | X | | | X | X | | | X | | | | | | |
| | | Improve suction dredge, gravel, lode, and placer mining practices to minimize sediment inputs | I | | | | | | X | | | | | | | | | |
| | | Improve or decommission roads | I | | X | | | X | X | | | | | | | | | |
| | | Stabilize streambank and upland slopes | I | | X | | | X | X | | | | | | | | | |
| | Minimize the impact of harmful algal blooms | Clarify the effects of agal toxins on native fish and implement appropriate management actions | I B | | | | | | X | | | | | | | | | |
| | | Develop and implement system to remove algal biomass at outlet of Upper Klamath Lake | I B | | | | | | | | | | | | | | | |
| | Enhance dissolved oxygen (DO) concentrations | Implement dam turbine venting to aerate releases | I | | | | X | | | | | | | | | | | |
| | | Replace diversion dams with pumps that also aerate water to supply irrigation systems | I | | | | | | | | | | | | | | | |
| Create and maintain spatially connected and diverse channel morphology | Increase physical habitat diversity and availability | Increase size, frequency, and topographic relief of bar/pool sequences | F | | | | | X | | | | X | | | | | | |
| | | Increase channel/thalweg sinuosity | F | | | | | X | | | | | | | | | | |
| | | Increase in-stream habitat connectivity and complexity | H | | | | X | X | | | | X | | | | | | |
| | Increase coarse sediment transport and channel dynamics | Increase and maintain target coarse sediment recruitment and transport rates | F | | | | | | | | | | | | | | | |
| | Replenish and maintain existing coarse sediment storage capacity | Increase bars, side-channels, alcoves, and other complex alluvial features | F | | | | | | | | | | | | | | | |
| Improve freshwater habitat access and the quality and quantity of habitat for freshwater life stages of anadromous fish | Restore fish passage and re-establish channel and other habitat connectivity | Remove or improve barriers to fish passage, including dams | H | | X | X | X | X | X | | X | X | X | | | | | X |
| | | Re-establish channel connectivity | H | | | | X | X | X | | X | X | | | | | | |
| | | Manage lake levels to maintain access to important shoreline habitat | H | | | | | | X | | | | | | | | | |
| | | Implement beaver management or relocation strategies or consider deployment of beaver dam analogues | H | | | | | X | | | | | | | | | | |
| | Reduce fish mortality due to entrainment, scour and stranding | Minimize dam operations that produce scour, stranding, entrainment during periods of high fish occurrence | H | | | | | | | X | | | | | | | | |
| | | Support effective screening of all diversions | H | | | X | | X | X | | X | X | X | | | | | |
| | | Plan and implement fish rescue strategies in the event of stranding by extreme drought conditions | B | | | | | X | X | | | X | | | | | | |
| | | Minimize impact of suction dredge mining on entrainment of juvenile fish | B | | X | X | | X | X | | | | | | | | | |
| | Increase and maintain anadromous and resident habitat availability for all freshwater life stages | Increase/maintain spawning habitat and gravel quantity and quality | H | | X | | X | X | X | | X | X | X | | | | | X |
| | | Increase/maintain larval and juvenile rearing habitat | H | | X | | X | X | X | | X | X | X | | | | | X |
| | | Maintain or increase adult holding habitat from baseline conditions | H | | | | | | | | X | | | | | | | X |
| | Improve water temperatures and thermal conditions for growth and survival of natural anadromous salmonids | Identify, protect, and prioritize restoration at existing or potential cold-water refugia | H | | | | X | X | | | X | | | | | | | |
| | | Assess and obtain water rights at cold-water spring complexes | H | | | | | X | | | | | | | | | | |
| | | Dedicate sources of cold water such as springs to instream flow | H | | | | | X | | | | | | | | | | |
| | | Minimize warm tailwater inputs through reduction or cooling | H | | | | | X | | | | | | | | | | |
| | Enhance or maintain food availability for fry and juvenile salmonids | Restore marine-derived nutrients to streams by way of increased escapement, carcass placement, or pellet dispersal | I | | | | | X | | | | | | | | | | |
| Establish and maintain riparian vegetation that supports fish and wildlife | Promote diverse native riparian vegetation on different geomorphic surfaces that contribute to complex channel morphology and high quality aquatic and terrestrial habitat | Increase species, structural, and age diversity of riparian vegetation to improve and maintain riparian habitat | H | | | | | | | X | X | X | | | | | | |
| | | Encourage establishment of riparian species on surfaces within the future channel migration corridor that will recruit LWD | H | | X | | | X | | X | X | X | | | | | | |
| | | Encourage establishment of vegetation that provides habitat and shading for anadromous fish, aquatic organisms and wildlife | H | | X | | | | X | X | X | X | | | | | | |
| | | Remove or control non-native or weedy riparian vegetation encroaching on fish habitat (e.g., reed canary grass, common reed, Himalayan blackberry, yellow pond lily) | B | | | | | X | | | X | | | | | | | |
| | | Minimize livestock grazing on riparian vegetation through the use of riparian fencing | H | | X | | | X | | | | X | | | | | | |
| Increase naturally produced focal species and where appropriate accelerate range expansion through supplementation [non-habitat actions] to promote long-term resilience and facilitate enhanced harvest opportunities for tribal, commercial, and sport fisheries' | Conduct hatchery supplementation and rearing to meet fish restoration objectives without adverse genetic consequences | Use enhancement programs as a temporary strategy to increase fish population abundance | B | | | | X | X | X | | X | X | X | | X | X | X | X |
| | | Develop and follow hatchery and genetic management plans (HGMPs), pHOS standards, etc. | B | | | | X | X | X | | | | | | X | X | X | X |
| | | Implement small-scale rearing pond programs only as temporary measures associated with habitat restoration projects | B | | | | | X | | | X | | | | X | X | | |
| | | Relocate fish from donor populations to replenish depleted populations, restablish historical populations, or establish new populations | B | | | | | | X | | X | X | X | | X | | | X |
| | Minimize disease-related mortality by reducing vectors & factors known to lead to fish disease outbreaks | Assess all possible means of disrupting *Ceratomyxa shasta* life cycle and develop and implement a disease management plan | B | | | | | X | | | | | | | | X | X | |
| | | Determine the resistance of hatchery broodstock to *Ceratomyxa shasta* and select for resistence | B | | | | | | | | | | | | | | | X |
| | | Fit hatchery operations with water supply filters | B | | | | | | | | | | | | | | | |
| | | Improve scour of polychaete disease host habitat through strategic placement of coarse sediment | B | | | | X | | | | | | | | | | | |
| | Minimize the impact of non-native species on fish | Remove or control non-native fish (e.g., brook trout and brown trout) to reduce competition and predation on native fish or their prey | B | | | X | | X | X | | X | X | X | | | | | |
| | Increase naturally produced individuals of the target restoration species to the extent necessary to meet or exceed escapement objectives and facilitate expanded harvest opportunity (see Species Conservation and Recovery Plans) | If applicable, re-introduce target species into historical habitat in Upper Klamath Lake and tributaries if natural recolonizion is slow or absent following restored fish passage | B | | | | | | | | | | | | | | | $X^{1,2,8}$ |
| | | Ensure populations are widely distributed across ≥ 80% of accessible habitat and that habitats are connected | B | | $X^{3}$ | | | $X^{2}$ | $X^{7}$ | $X^{7}$ | $X^{4}$ | $X^{5}$ | | $X^{6}$ | | | | |
| | | Maintain genetic and life-history diversity through conservation of ESUs, hatchery practices | B | | $X^{3}$ | | | $X^{2}$ | $X^{7}$ | $X^{7}$ | $X^{4}$ | $X^{5}$ | | $X^{6}$ | | | | |
| | | Improve and manage harvest of naturally produced fish such that it does not limit population recovery | B | | $X^{3}$ | $X^{9}$ | $X^{2}$ | $X^{2}$ | $X^{7}$ | $X^{7}$ | $X^{4}$ | $X^{5}$ | $X^{8}$ | $X^{6}$ | $X^{1,2}$ | | | |
| Adaptive Management | Implement an adaptive management program to reduce uncertainty and maximize learning | NA | I F H B | | | | X | X | | X | X | | | X | X | X | | X |

Species Codes: 1 = chinook salmon, 2 =Coho salmon, 3 = steelhead, 4 =bull trout, 5 = redband trout, 6 = eulachon, 7 = sucker, 8= Pacific lamprey, 9 = green sturgeon

## PART 2

| Overall Goal or Overarching Objective | Core Objectives (Level 1 Objectives) | Sub-Objectives (Level 2 Objectives) | Conceptual Model Component | Programs | Fish and Habitat Management Plans | | | | | | | | | | Water Quality Plans | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Long Range Plan For The Klamath River Basin Conservation Area Fishery Restoration Program (KBFRTF 1991) | Salmon River Subbasin Restoration Strategy (Elder, D. et al, 2002, US Forest Service and Salmon River Restoration Council) | Lower Klamath River Sub-basin Watershed Restoration Plan (Gale and Randolph 2000, Yurok Tribal Fisheries Program) | Shasta Watershed Recovery Plan (Shasta River Coordinated Resource Management and Planning Committee 1997) | Initial Phase of the Scott River Watershed Council Strategic Action Plan (SRWC 2005, extensive goals and objectives) | Mid-Klamath Subbasin Fisheries Resource Recovery Plan (USFWS 2008) | Klamath, Six Rivers, Fremont, Winema, and Modoc National Forest Land Resource Management Plans (USFS 1989, 1990, 1991, 1995, 2010) | Klamath Basin Restoration Agreement (KBRA 2010) | Upper Klamath Basin Comprehensive Agreement (2014) | Wetland and Aquatic Resources Program Plan 2015 – 2018 (Klamath Tribes 2014) | Water Quality Restoration Plan - Upper Klamath Basin (USDA FS 2003) | North Coast Regional Water Quality Control Board - Water Quality Control Plan for the North Coast Region (NCRWQCB 2011) | Upper Klamath and Lost River Subbasins Total Maximum Daily Load (TMDL) and Management Plan (WQMP) (ODEQ 2010) | Upper Klamath Basin Nonpoint Source Pollution Assessment (KTWQC 2016) |
| **Improve water quality, quantity and ecological flow regimes** | Improve instream ecological flow regime | Refine instream flow needs assessments incld. definition of eco-hydraulic functional relationships | F | | X | | | X | X | | | | | | | | | |
| | | Operate dam releases to produce ecologically beneficial flow regime, satisfying critical functional flow needs over species/time/space | F | | X | | | X | X | | X | X | X | X | | | | |
| | | Identify and reduce the number of unauthorized diversions, and/or improve irrigation & water conservation practices | F | | X | | | X | X | X | | X | X | | | X | | X |
| | | Pursue water leasing, sharing and purchase agreements | F | | | | | X | | | | X | X | | | | | |
| | Reduce external nutrient and pollutant inputs | Reduce point and non-pint source nutrient loads and pollution, esp. phosphorous runoff via TMDL implementation & other methods | I | | | | | | | | | | | X | X | X | X | X |
| | | Create and implement pesticide management plans to reduce pesticide inputs | I | | | | | | | | | | | | | X | X | |
| | | Remediate mine tailing piles to reduce runoff inputs | I | | | | | | X | X | | | | | | | | |
| | | Treatment of irrigation and rangeland tailwater returns | I | | | | | | | | | | | | | X | X | X |
| | | Restoration of existing wetlands or creation of treatment or "walking" wetlands | I B | | | | | | | | X | X | | X | X | X | X | X |
| | Reduce fine sediment inputs | Improve agricultural and ranch land management practices | I | | X | | | | X | | X | | | | X | X | X | X |
| | | Improve timber harvesting and forestry management practices to minimize stream inputs | I | | X | | | | X | X | X | | | | | X | X | |
| | | Improve suction-dredge, gravel, lode, and placer mining practices to minimize sediment inputs | I | | X | | X | | | | | | | | | X | | |
| | | Improve or decommission roads | I | | X | X | X | | X | X | X | | | | X | X | X | X |
| | | Stabilize streambank and upland slopes | I | | X | | X | | X | X | X | | | | X | X | X | |
| | Minimize the impact of harmful algal blooms | Clarify the effects of agal toxins on native fish and implement appropriate management actions | I B | | | | | | | | | | | | | | | |
| | | Develop and implement system to remove algal biomass at outlet of Upper Klamath Lake | I B | | | | | | | | | | | | | X | | X |
| | Enhance dissolved oxygen (DO) concentrations | Implement dam turbine venting to aerate releases | I | | | | | | | | | | | | | | | |
| | | Replace diversion dams with pumps that also aerate water to supply irrigation systems | I | | | | | X | | | | | | | | | | |
| **Create and maintain spatially connected and diverse channel morphology** | Increase physical habitat diversity and availability | Increase size, frequency, and topographic relief of bar/pool sequences | F | | | | X | | | | X | | | | | | | |
| | | Increase channel/thalweg sinuosity | F | | | | X | | | | X | | | | | | | |
| | | Increase in-stream habitat connectivity and complexity | H | | | | X | | | | X | | | | X | | | |
| | Increase coarse sediment transport and channel dynamics | Increase and maintain target coarse sediment recruitment and transport rates | F | | | | | | X | | X | | | | | | | |
| | Replenish and maintain existing coarse sediment storage capacity | Increase bars, side-channels, alcoves, and other complex alluvial features | F | | | | | | X | | X | | | | | | | |
| **Improve freshwater habitat access and the quality and quantity of <u>habitat for freshwater life stages</u> of anadromous fish** | Restore fish passage and re-establish channel and other habitat connectivity | Remove or improve barriers to fish passage, including dams | H | | X | | X | | X | X | | X | X | X | | | X | X |
| | | Re-establish channel connectivity | H | | | | X | | X | X | | X | X | X | | | X | X |
| | | Manage lake levels to maintain access to important shoreline habitat | H | | X | | | | | | | | | X | | | | |
| | | Implement beaver management or relocation strategies or consider deployment of beaver dam analogues | H | | | | | | X | | | | | | | | | X |
| | Reduce fish mortality due to entrainment, scour and stranding | Minimize dam operations that produce scour, stranding, entrainment during periods of high fish occurrence | H | | | | | | | | | | | | | | | |
| | | Support effective screening of all diversions | H | | | | | X | X | X | | X | X | | | | | |
| | | Plan and implement fish rescue strategies in the event of stranding by extreme drought conditions | B | | X | | | | X | | | | | | | | | |
| | | Minimize impact of suction dredge mining on entrainment of juvenile fish | B | | X | | | | | | | | | | | | | |
| | Increase and maintain anadromous and resident habitat availability for all freshwater life stages | Increase/maintain spawning habitat and gravel quantity and quality | H | | | | X | | | | | | | | | | | |
| | | Increase/maintain larval and juvenile rearing habitat | H | | | | X | | | | | | | | | | | |
| | | Maintain or increase adult holding habitat from baseline conditions | H | | | | | | | | | | | | | | | |
| | Improve water temperatures and thermal conditions for growth and survival of natural anadromous salmonids | Identify, protect, and prioritize restoration at existing or potential cold-water refugia | H | | | | | | X | X | | | | | X | | | |
| | | Assess and obtain water rights at cold-water spring complexes | H | | | | | | | | | | | | | | | |
| | | Dedicate sources of cold water such as springs to instream flow | H | | | | | | | | | | | | | | | |
| | | Minimize warm tailwater inputs through reduction or cooling | H | | | | | | X | | | | | | | | | |
| | Enhance or maintain food availability for fry and juvenile salmonids | Restore marine-derived nutrients to streams by way of increased escapement, carcass placement, or pellet dispersal | I | | | | | | | | | | | | | | | |
| **Establish and maintain riparian vegetation that supports fish and wildlife** | Promote diverse native riparian vegetation on different geomorphic surfaces that contribute to complex channel morphology and high quality aquatic and terrestrial habitat | Increase species, structural, and age diversity of riparian vegetation to improve and maintain riparian habitat | H | | X | | X | X | X | X | X | | X | | X | | X | X |
| | | Encourage establishment of riparian species on surfaces within the future channel migration corridor that will recruit LWD | H | | X | | X | X | X | X | X | | X | | X | | X | X |
| | | Encourage establishment of vegetation that provides habitat and shading for anadromous fish, aquatic organisms and wildlife | H | | X | | X | X | X | X | X | | X | | X | | X | X |
| | | Remove or control non-native or weedy riparian vegetation encroaching on fish habitat (e.g., reed canary grass, common reed, Himalayan blackberry, yellow pond lily) | B | | | | | | X | | | | | | X | | | |
| | | Minimize livestock grazing on riparian vegetation through the use of riparian fencing | H | | X | | X | X | | X | | | X | | X | | X | X |
| **Increase naturally produced focal species and where appropriate accelerate range expansion through supplementation [non-habitat actions] to promote long-term resilience and facilitate enhanced harvest opportunities for tribal, commercial, and sport fisheries'** | Conduct hatchery supplementation and rearing to meet fish restoration objectives without adverse genetic consequences | Use enhancement programs as a temporary strategy to increase fish population abundance | B | | X | | X | | | | | X | | X | | | | |
| | | Develop and follow hatchery and genetic management plans (HGMPs), pHOS standards, etc. | B | | X | | | | | | | X | | | | | | |
| | | Implement small-scale rearing pond programs only as temporary measures associated with habitat restoration projects | B | | X | | | | | | | | | X | | | | |
| | | Relocate fish from donor populations to replenish depleted populations, restablish historical populations, or establish new populations | B | | | | | | X | | | X | | X | | | | |
| | Minimize disease-related mortality by reducing vectors & factors known to lead to fish disease outbreaks | Assess all possible means of disrupting *Ceratomyxa shasta* life cycle and develop and implement a disease management plan | B | | X | | | | | | | X | | | | | | |
| | | Determine the resistance of hatchery broodstock to *Ceratomyxa shasta* and select for resistence | B | | X | | | | | | | X | | | | | | |
| | | Fit hatchery operations with water supply filters | B | | X | | | | | | | | | | | | | |
| | | Improve scour of polychaete disease host habitat through strategic placement of coarse sediment | B | | | | | | | | | | | | | | | |
| | Minimize the impact of non-native species on fish | Remove or control non-native fish (e.g., brook trout and brown trout) to reduce competition and predation on native fish or their prey | B | | | X | | | X | | | | | | | | | |
| | Increase naturally produced individuals of the target restoration species to the extent necessary to meet or exceed escapement objectives and facilitate expanded harvest opportunity (see Species Conservation and Recovery Plans) | If applicable, re-introduce target species into historical habitat in Upper Klamath Lake and tributaries if natural recoloniztion is slow or absent following restored fish passage | B | | $X^{1}$ | | | | | | | $X^{1,2,8}$ | | | | | | |
| | | Ensure populations are widely distributed across ≥ 80% of accessible habitat and that habitats are connected | B | | $X^{2,3,6}$ | | | | | | | | | | | | | |
| | | Maintain genetic and life-history diversity through conservation of ESUs, hatchery practices | B | | $X^{2,3,6}$ | | | | | | | | | | | | | |
| | | Improve and manage harvest of naturally produced fish such that it does not limit population recovery | B | | $X^{1\text{-}3,6,8,9}$ | | | | | | | | | | | | | |
| **Adaptive Management** | Implement an adaptive management program to reduce uncertainty and maximize learning | NA | I F H B | | X | X | X | | X | | X | X | X | X | X | X | X | |

Species Codes: 1 = chinook salmon, 2 =Coho salmon, 3 = steelhead, 4 =bull trout, 5 = redband trout, 6 = eulachon, 7 = sucker, 8= Pacific lamprey, 9 = green sturgeon

## 6.4 Status and Trends of Restoration in the Klamath Basin

Trends in restoration activity over time have closely followed important events in Klamath Basin history. Project records show a sharp rise in restoration action and spending in 2002 and 2003, particularly on projects intended to reduce watershed sediment inputs (Figure 6-2 and Figure **6-3**). This rise coincides with the declaration of a drought state of emergency and the release of the NMFS and FWS Biological Opinions for Klamath coho and suckers in 2001, followed by a significant fish kill at the mouth of the Klamath River in 2002 due to a combination of low flows, high water temperatures, disease, and other unknown factors (NRC 2004, 2008). Although the number of projects has declined slightly from this record high in more recent years, total spending adjusted for inflation to 2017 dollars demonstrates that investments in Klamath Basin restoration have been sustained since their initial rise, suggesting a shift towards fewer but more intensive restoration actions.

A large share of these projects has been led by a few core federal, state, and county agencies (Figure 6-1). Those agencies responsible for the largest share of projects and spending include the U.S. Fish and Wildlife Service, the Bureau of Land Management (BLM), the U.S. Forest Service, the Siskiyou and Trinity County Resource Conservation Districts, and the California Department of Fish and Wildlife. The remaining projects are spread across a large group of smaller organizations carrying out fewer restoration projects on more local scales. There are over 200 interested parties involved in restoration within the Klamath Basin, including representation from individual landowners, Tribes, NGOs, industry (defined here as for-profit businesses other than farms, ranches, or utilities), academic institutions, and government, including specific divisions within larger agencies (Figure 6-4). The full list of the parties represented as funders, leads, or partners on grant-driven restoration projects is available in Appendix I.

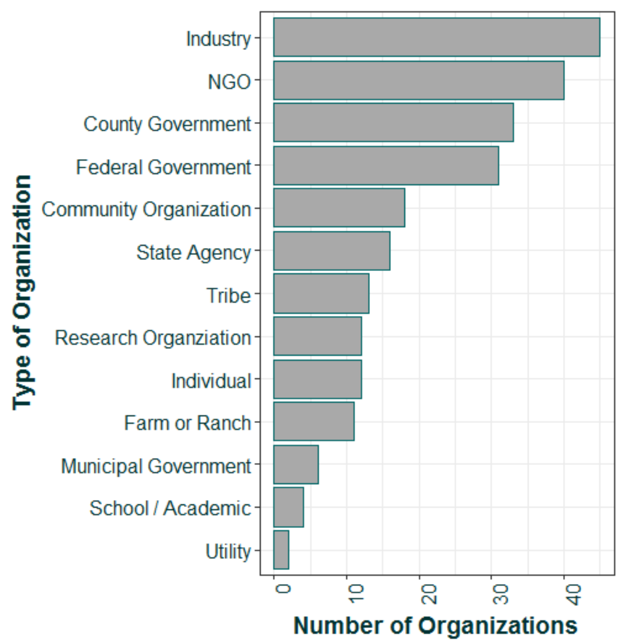



Figure 6-1: Types of agencies involved in restoration in the Klamath Basin. Sources of data and methods described in Appendix H.

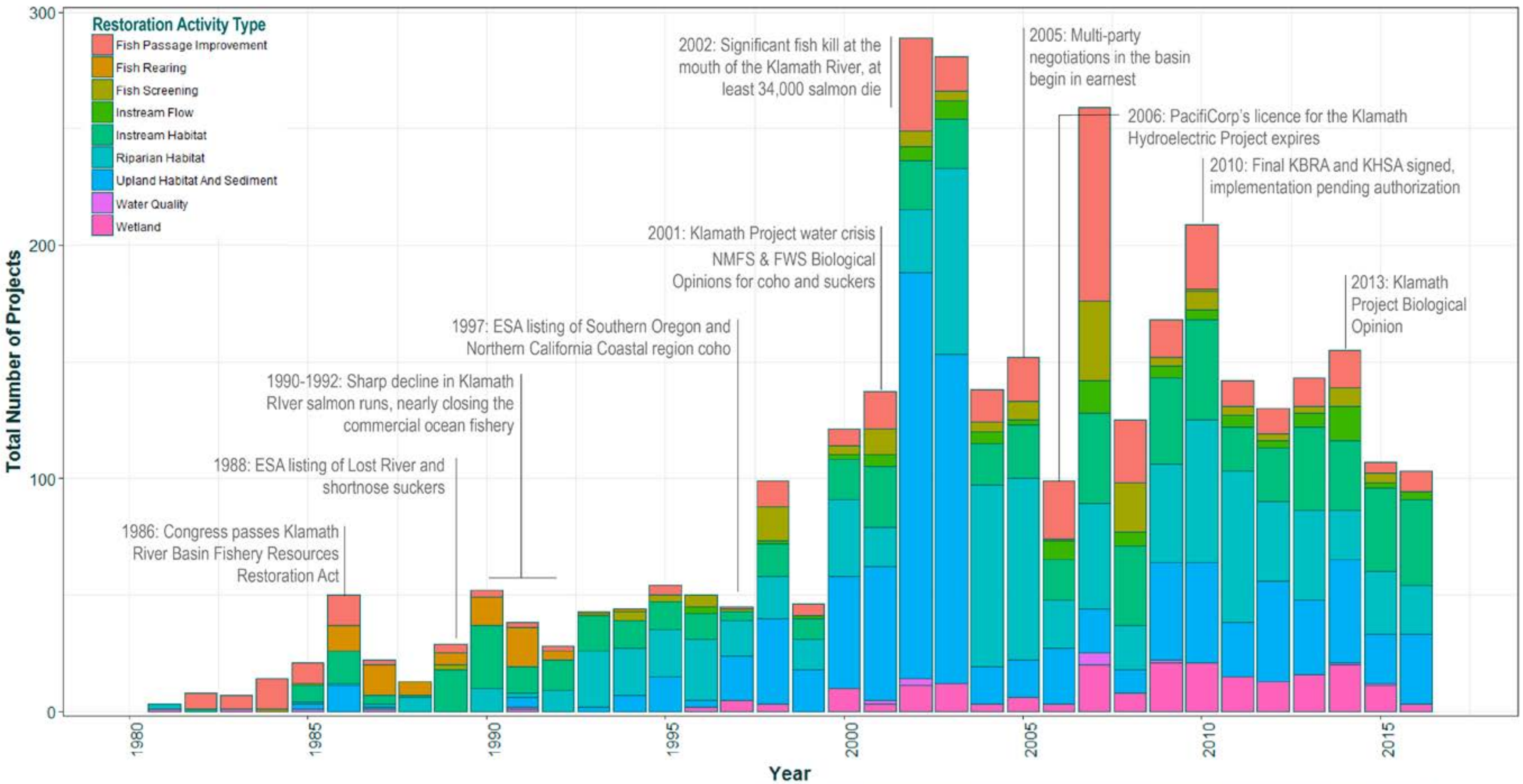



Figure 6-2: Timeline of the total number of grant-driven restoration project actions classified by activity type. Overlays show notable events in the history of Klamath Basin that have had an influence on restoration activities (NRC 2008)[41]. Sources of data and methods described in Appendix H.

[41] http://www.watereducation.org/aquapedia/klamath-river-basin-chronology

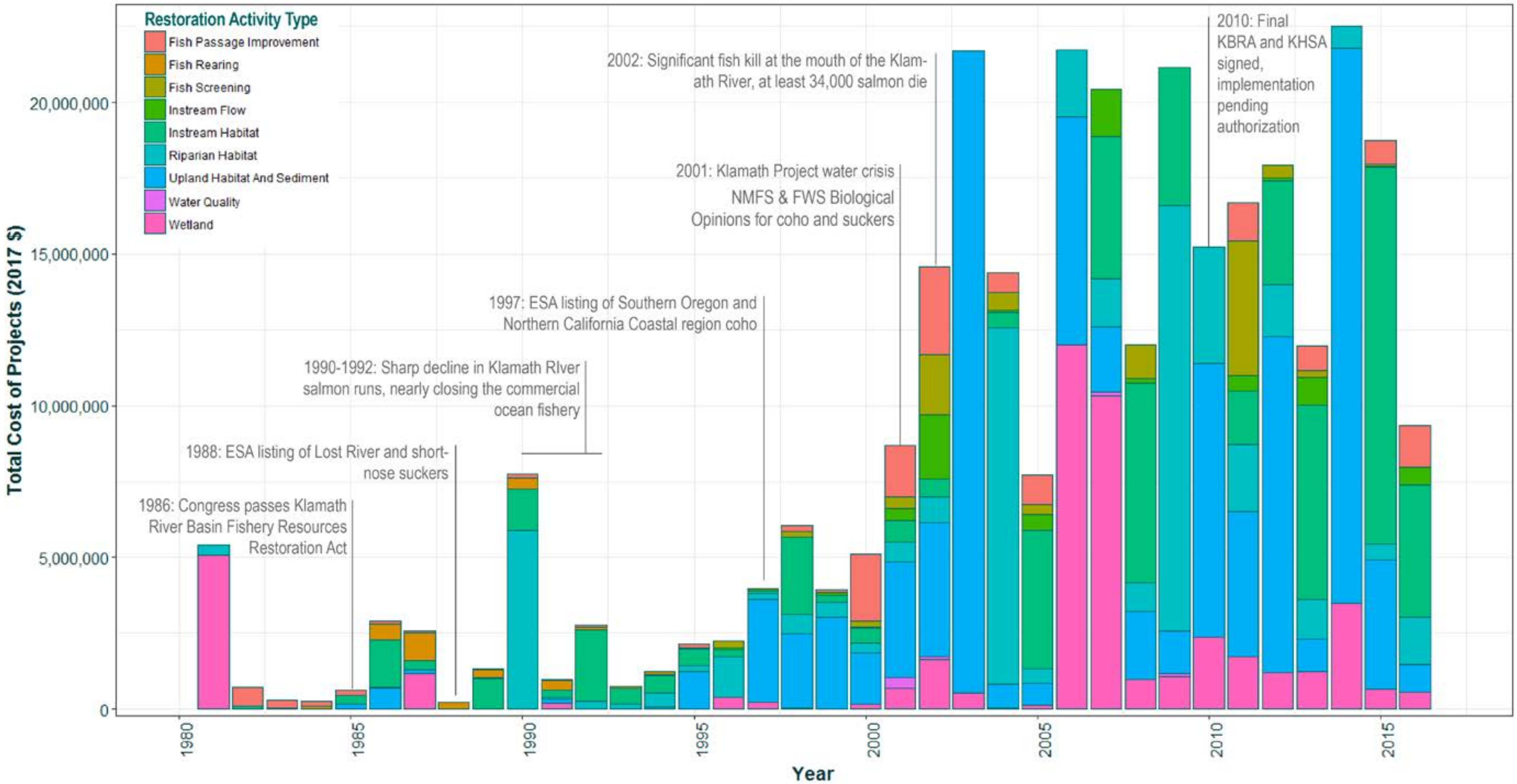



Figure 6-3: Timeline of the total cost (adjusted for inflation to 2017 $) of grant-driven restoration project actions classified by activity type. Overlays show notable events in the history of Klamath Basin that have had an influence on restoration activities (NRC 2008). Surges in spending in specific categories often coincide with major works, such as the peak in spending on wetland restoration associated with the restoration of the Williamson River Wetland in 2006/7, or an accumulation of many small coordinated projects, such as the peak in upland habitat and sediment spending in 2003 associated with a large number of upland thinning and road decommissioning projects carried out by various agencies under the umbrella of the former Regional Ecosystem Office. Sources of data and methods described in Appendix H.


Figure 6-4: The top 30 organizations responsible for the greatest number (A) and total cumulative cost (adjusted for inflation to 2017 $) (B) of grant-driven restoration project actions in the Klamath Basin. These are classified according to the lead implementing agency as identified in project database records, not the agency or organization funding or supporting the work. Sources of data and methods described in Appendix H.

### Box 6-1: The Klamath Basin's "Restoration Economy"

Restoration has contributed to the economy of the Klamath Basin by acting as a driver of local employment. Many restoration projects have been carried out in partnership with programs providing retraining and employment for displaced forestry workers and others through opportunities to work on restoration projects. Examples include:

- the federally-funded Jobs-in-the-Woods (JITW) Program (DeForest 1999);
- local partnerships between Six Rivers National Forest and the Karuk tribe to train tribal restoration staff during implementation of road decommissioning projects (Peluso 2004);
- the Lomakatsi Restoration Project's Klamath Tribal Ecosystem Restoration Workforce Initiative, which seeks to restore habitats in the Fremont-Winema national forest while providing workforce training and contracting opportunities to Klamath tribal workers (Fierro and Bey 2014).

Although federal funds for such programs have generally declined over time, they have provided a buffer against changing economic conditions for workers close to project sites (Moseley and Reyes 2008). A recent economic analysis from Oregon found that each $1 million invested in forest and watershed restoration contracting will generate 15 to 24 jobs, depending on the work type, and that labor-intensive contracting generates more employment than technical or equipment intensive work (Nielsen-Pincus and Moseley 2010).

### *Types and General Distribution of Restoration Actions*

Restoration action types and distribution vary widely across the Klamath Basin in response to differences in landscapes, human activities, and known limiting factors in each sub-basin. The largest share of restoration actions and spending in the Klamath Basin are dedicated to (i) reducing watershed sediment inputs through management of upland habitat and known sources of sedimentation, particularly forest road networks, and (ii) riparian habitat restoration, followed by the remaining action types.

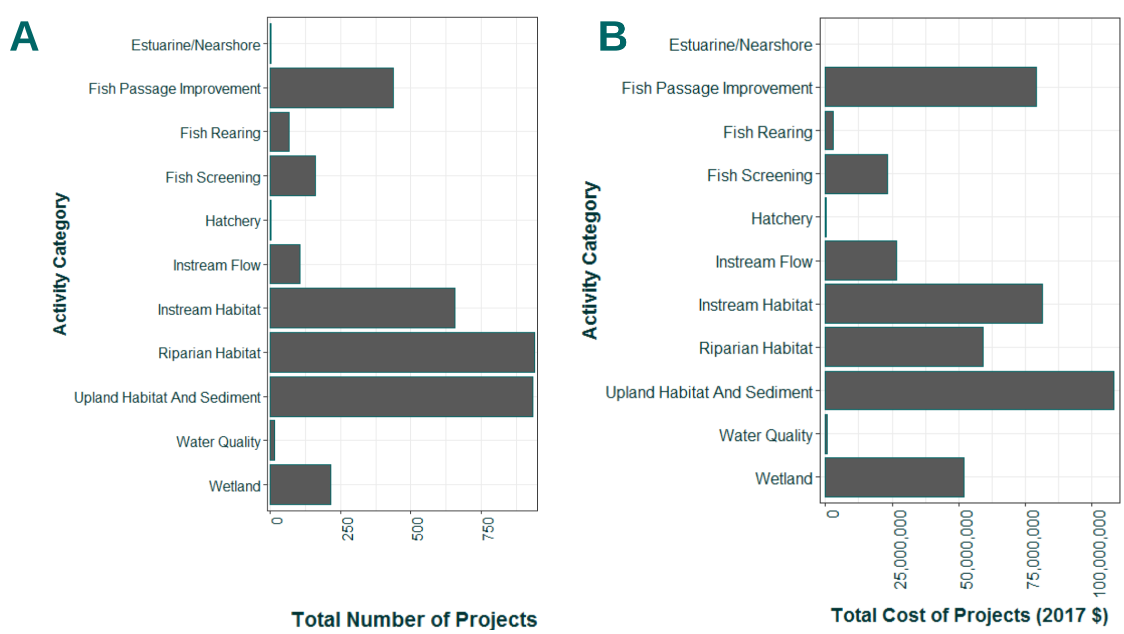
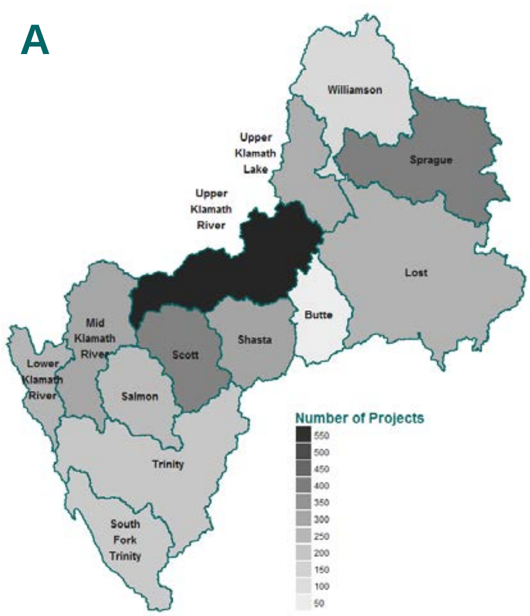
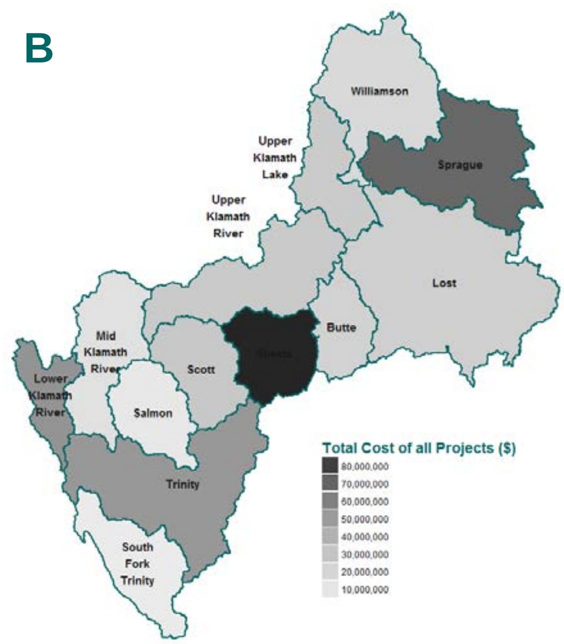



Figure 6-5: Total number (A) and costs (adjusted for inflation to 2017 $) (B) of grant-driven restoration actions by restoration category. Sources of data and methods described in Appendix H.

Grant-driven restoration actions have not been distributed evenly across the basin, and the largest share of restoration projects to date has taken place in the Upper Klamath River sub-basin where anadromous fish are still present, and where dam operations have had the greatest impacts (Table 6-6A). Most of the spending has occurred in the Shasta sub-basin, followed by the Trinity, Lower Klamath River, and Sprague sub-basins (Table 6-6B). While the Butte sub-basin features the highest mean project costs, this mean value is skewed by the presence of a few very large expenditures in this sub-basin associated with land acquisitions of the Butte Valley Wildlife Area / Meiss Lake and the Orr Lake Management Unit (Table 6-6C).



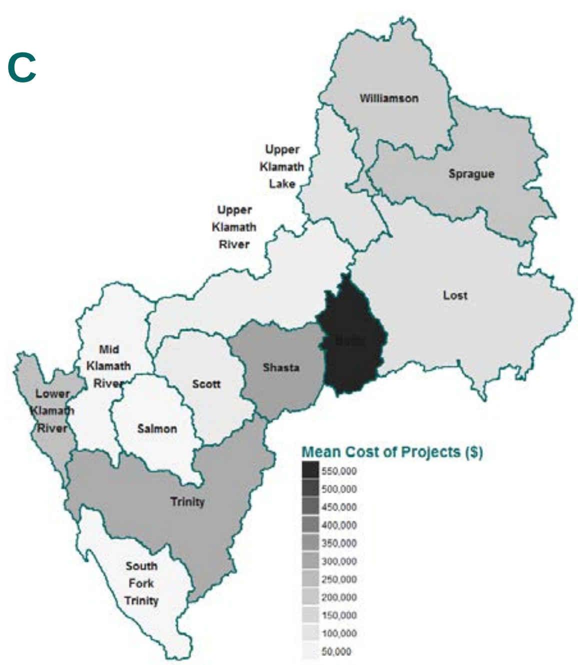




Figure 6-6: Cumulative number (A), cumulative costs (adjusted for inflation to 2017 $) (B), and mean costs (C) (adjusted for inflation to 2017 $) of grant-driven restoration projects by sub-basin. Sources of data and methods described in Appendix H.

The distributions of individual restoration action categories also varies, and while most types of restoration actions are taking place across all sub-basins, some are concentrated within just one or two (Figure 6-7 and Figure 6-8). Restoration actions such as fish passage improvement and fish rearing are generally concentrated in sub-basins below the dams, where they provide greater benefit to anadromous fish, and are particularly dense in the Mid-Klamath River sub-basin. In contrast, restoration actions such as instream flow, instream habitat, riparian restoration, and sediment reduction that are expected to provide more general benefits to a broader range of species are distributed more evenly across all sub-basins. One notable exception to this pattern is the exceptionally high number of riparian habitat restoration projects in the Upper Klamath River sub-basin. This sub-basin is arguably one of the most severely impacted by human activities, with the presence of dams and large expanses of rangelands potentially driving greater attention to restoration. The geographic distribution of project spending broadly matches the distribution of individual projects, with the exception of upland habitat and sediment management projects (Figure 6-7). This category is made up in large part of forest management and fuels reduction projects, which are generally large in scale, as well as road improvement or decommissioning projects, which are relatively expensive to carry out in comparison to other project types due to their scale and need for heavy equipment.

When compared against the stages of the conceptual model outlined in Section 3.1, most projects in the basin target habitat restoration, loosely followed by restoration to address watershed inputs, while relatively few projects directly address fluvial processes or biological response (Figure 6-9).

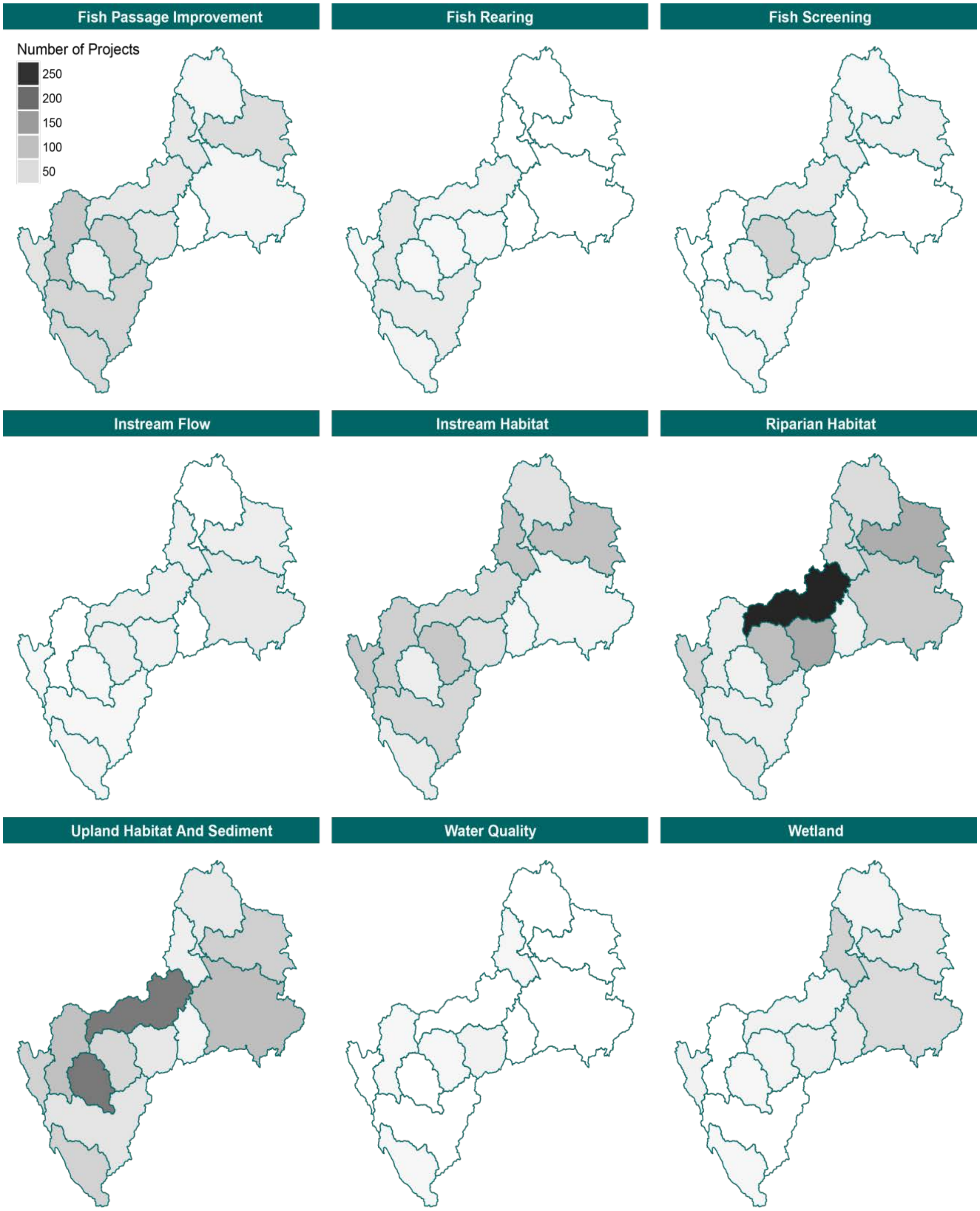



Figure 6-7: Maps shaded to represent the number of grant-driven projects implemented in each sub-basin, broken up by broad categories of restoration action. Sources of data and methods described in Appendix H.

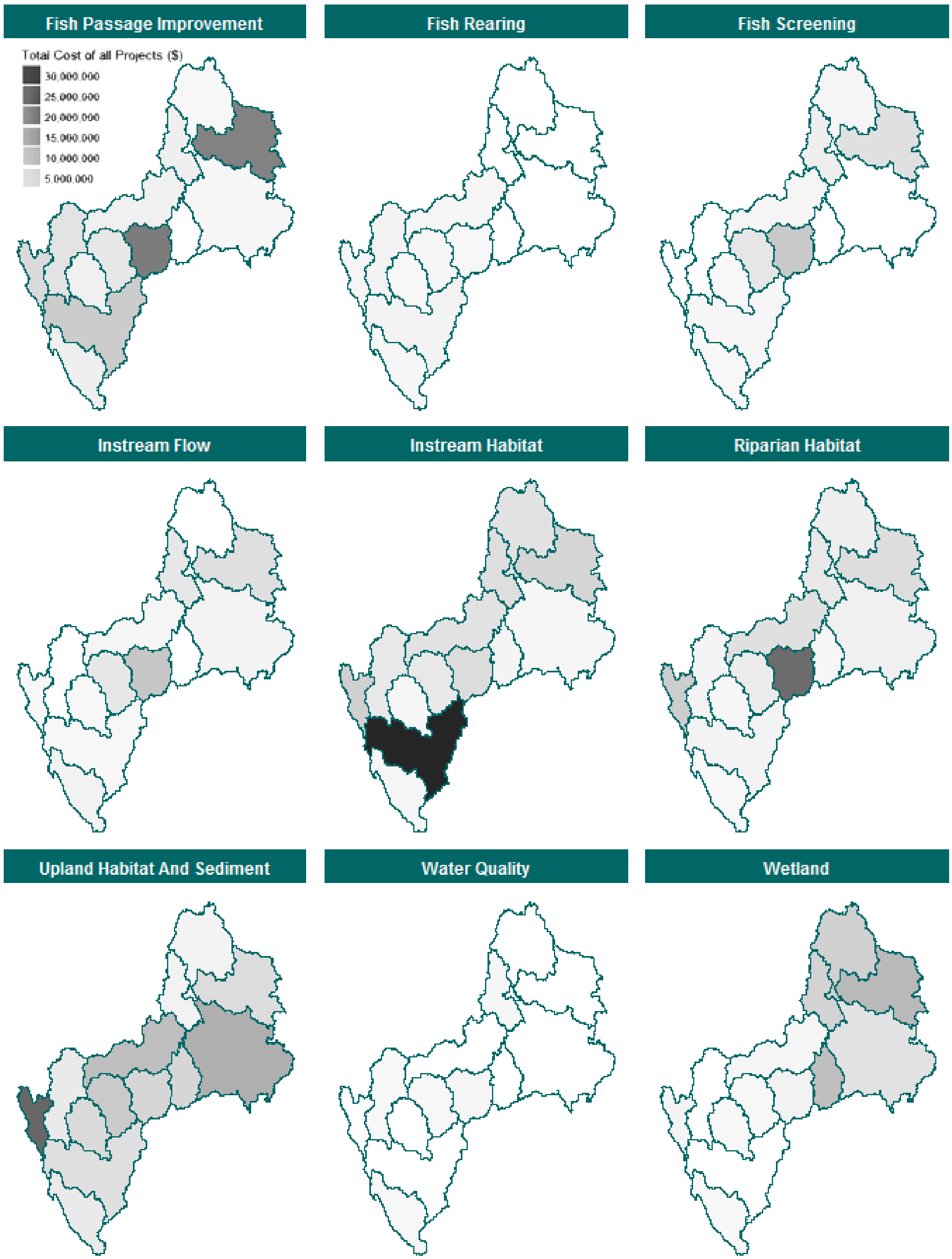



Figure 6-8: Maps shaded to represent the cumulative cost (adjusted for inflation to 2017 $) of all grant-driven projects implemented in each sub-basin, broken up by broad categories of restoration action. Sources of data and methods described in Appendix H.

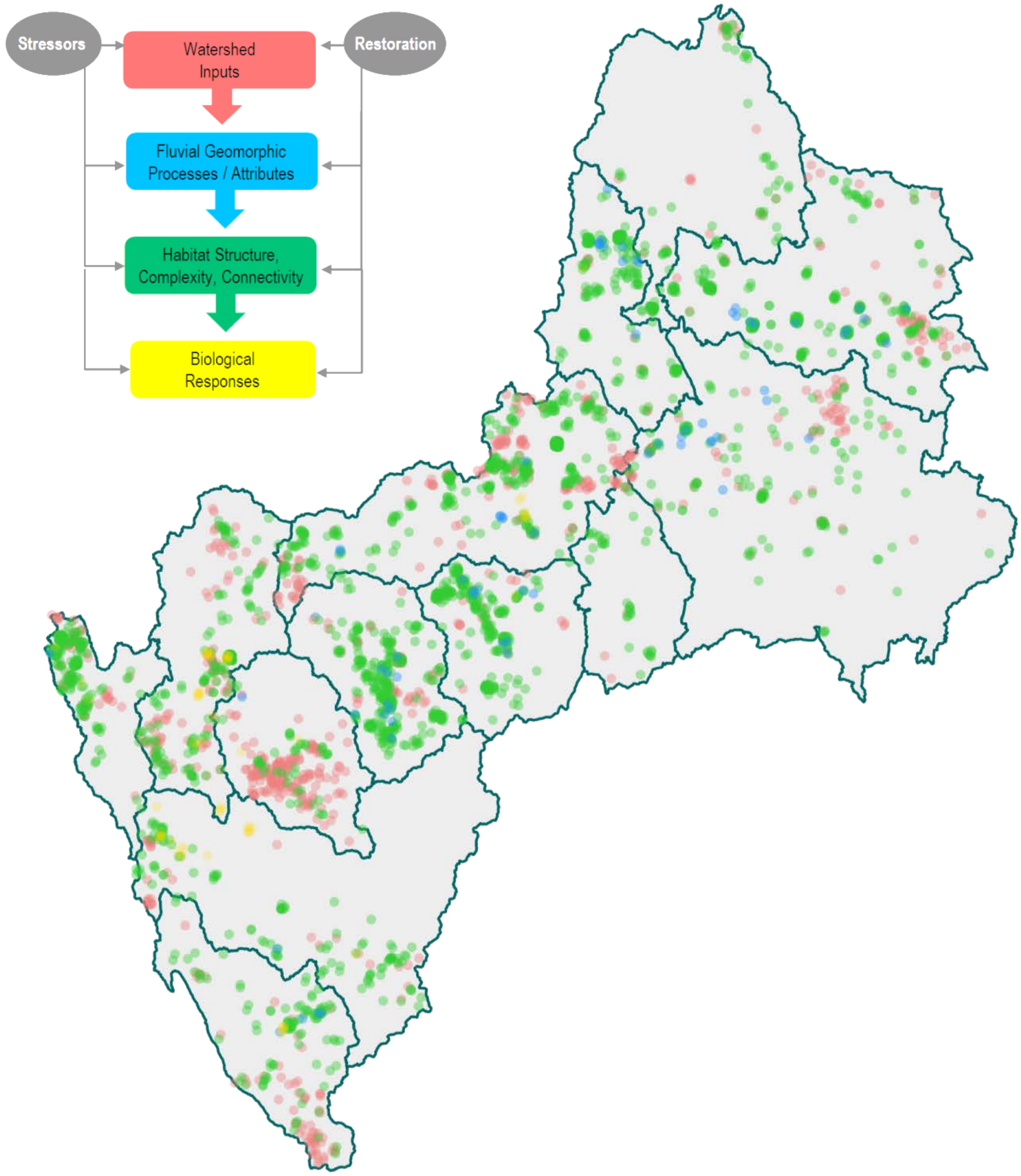



Figure 6-9: Distribution of all grant-driven project actions in our project dataset from across the Klamath Basin, colour-coded based on activity type to the corresponding element of the simple organizing framework outlined in Figure 3-1where the upper elements are explicitly recognized as influencing the outcomes of the lower elements (details on how elements were assigned to individual restoration types can be found at the end of Appendix J) . Points are translucent, such that darker colors indicate the overlap of many project actions. Projects including multiple actions that correspond to more than one conceptual model stage show these as separate points, either at the same or different work sites. For some projects (i.e., Partners for Fish and Wildlife Projects), locations are approximate to the centroid of sub-watersheds rather than actual geographical locations to protect the privacy of project partners. All points have been offset slightly so that overlapping points are easier to see. Sources of data and methods described in Appendix H.

# 6.5 Restoration Actions

## 6.5.1 Fish Passage Improvement & Screening

### *Definition and Effectiveness*

Fish passage restoration encompasses a broad suite of work types that involve removing barriers to fish passage or providing alternative passage over barriers in the form of fish chutes, pools, or ladders (Table 6-2). Fish passage and fish screening are discussed together in this section because the removal of a barrier is often accompanied by the addition of a fish screen to prevent fish entering previously inaccessible irrigation diversions. Depending on the watershed, fish passage projects can offer some of the best value-for-money among restoration projects, as the removal of a single barrier could potentially restore access to many miles of suitable habitat whereas the benefits of most other project types tend to manifest at more local scales (Hoffman and Dunham 2007).

Table 6-2: Fish Passage Improvement Project Work Types*.

| Work Type | Definition |
|---|---|
| Fish passage blockages removed or altered | Removal or alteration of blockages, impediments or barriers to allow or improve fish passage (other than road crossings). |
| Fishway chutes or pools Installed | Placement of an engineered bypass for salmonids to pass more safely around or over a barrier (other than fish ladder). This includes bedrock chutes, weirs, rock boulder step pools, chutes constructed/roughened in bed rock, and engineered channel structures. |
| Fish ladder Installed / improved | Installation or modification (upgrade/improvement) of a fish ladder. |
| Road stream crossing removal | Removal of stream road crossing and the affiliated road structures so that the stream flows unimpeded. This would include removal of culverts and other material in the channel. |
| Culvert installed or Improved at road stream crossing | Installation or improvement/upgrade (including replacement) of a culvert to a standard that provides juvenile and adult salmonid passage. |
| Bridge installed or improved at road stream crossing | Installation, improvement/upgrade or replacement of a bridge over a stream to provide/improve salmonid passage under a road. The bridge could be replacing a culvert. |

* Based on restoration work types identified in the NOAA PCSRF Data Dictionary available in Appendix J and at https://www.webapps.nwfsc.noaa.gov/j/Docs/PCSRF%20Data%20Dictionary%20ver20%2004-08-13.xlsx

### *Removal or Improvement of Road-Crossings*

Restoration of fish passage through culvert barriers has emerged as a major issue in the Pacific Northwest and beyond. Culverts pose a particularly challenging problem due to the very large number of potential barriers associated with road networks, uncertainty about the relative ability of fish to get past these barriers, and the financial costs of upgrading, removing, or replacing these barriers (Hoffman and Dunham 2007). Culverts are generally elevated, round structures that become problematic when the water velocity is too great; the volume of water in the culvert too low, there's no resting pool beneath the outfall, or the culvert placement is too high above the streambed for fish to reach (Wiest 1998). Some smaller culverts may even become plugged altogether with debris, particularly during storms or flooding. Restoration solutions typically involve improving the culvert's internal structure through the addition of stones, welded baffles, or other structures to facilitate pooling and fish passage, or culvert replacement (PSMFC 2000). Replacement involves excavating the culvert and fill around it and replacing it with a corrugated pipe-arch (a culvert flattened along the bottom to lie against the streambed), a structural plate arch (a culvert shaped like an arch that exposes the natural streambed), or replacing the entire structure with a bridge that allows the stream to flow freely beneath the road (Wiest 1998). Arch culverts and bridges are preferred for streams with migratory fish because they restore access to the natural streambed, and bridges are considered best of all because they also allow recovery of adjacent riparian habitat (Wiest 1998). Methods for identifying road crossings that constitute barriers to fish passage and design criteria for restoration of these barriers are well-established, and the U.S. Forest Service now offers a decision-support tool called FishXing to guide practitioners through the process (Hoffman and Dunham 2007, NMFS 2011)[42]. Development of methods to help prioritize culverts for restoration are still under development, and will depend on the biological and behaviour characteristics of the species targeted for restoration (Hoffman and Dunham 2007).

### *Removal or Improvement of Other Barriers, Including Dams*

In the Klamath Basin, fish passage improvement projects at barriers other than road crossings generally involve low-head seasonal flashboard dams or permanent dams that do not create impoundments, though the possible removal of larger dams is examined in the section discussing case studies of barrier removal projects. A recent analysis of U.S. projects to remove low-head dams found that dam removal was relatively uncommon prior to 1980, but has accelerated rapidly since the year 2000 due to aging infrastructure, growing interest in watershed restoration, and new policy and funding frameworks to enable dam removal. Although partial dam removal or diversion/bypass structures have also been used for stream restoration, they are less common that complete removal (ICF 2005). The removal of most small low-head dams typically costs less than $100,000, half of which goes towards the deconstruction itself, but the removal of higher low-head dams may cost in excess of $1 million (ICF 2005). A practical guide to small dam removal for project managers is available from the Oregon Watershed Enhancement Board (OWEB) (Hoffert-Hay 2008). While fish passage is often accomplished through barrier removal, it may also be achieved through the construction of fish passage facilities that allow fish to circumvent barriers.

Removal of barriers that will result in reintroductions require advance planning that includes a careful consideration of the benefits, risks, and constraints on the success of reintroduction; selection of a recolonization strategy (e.g., natural colonization, translocation, or hatchery releases); and design of a long-term monitoring plan to establish baseline conditions, measure benefits on target fish populations, and measure impacts on non-target fish populations (Peters et al. 2014, Anderson et al. 2014). Plans should also provide for periodic re-evaluation of the status of fish populations based against performance indicators, specify the stages at which performance results should trigger changes in management, and also specify the recommended

[42] https://www.fs.fed.us/biology/nsaec/fishxing/

management responses to adaptively manage fish populations and habitat during each restoration phase, as demonstrated in the Guidelines for Monitoring and Adaptively Managing Restoration of Chinook Salmon (*Oncorhynchus tshawytscha*) and Steelhead (*O. mykiss*) on the Elwha River (Peters et al. 2014).

The benefits of fish passage restoration are clear, and several studies have demonstrated recolonization of salmonids into historical habitats following removal or modification of barriers. Many of these documented cases of recolonization have taken place in Washington State:

- Steelhead migrated into historical reaches of Beaver Creek in the first spawning season after the conversion of seven irrigation diversion dams into passable rock weirs in 2005, and fish had progressed 12 km beyond the location of barriers 3-4 years after removal (Weigl et al. 2013).
- Both coho and Chinook salmon (*Oncorhynchus tshawytscha*) voluntarily recolonized 33 km of upstream habitat in the Cedar River after more than 100 years of extirpation following the installation of a fish ladder at Landsburg Dam in 2003. The total density of salmonids roughly doubled in the mainstem closest to the dam 3 years after removal (Kiffney et al. 2009), while dispersal of anadromous fish into tributary habitats occurred more slowly over the next 5 years (Burton et al. 2013). Both the proportion of all redds found in upstream reaches and the proportion of upstream spawners that were born in those reaches have been increasing over time, demonstrating the successful transition between recolonization to self-sustaining upstream populations (Anderson et al. 2015).
- Tule fall Chinook salmon were translocated to upstream reaches of the White Salmon River in the same year as the removal of the Condit Dam in 2011, one of the largest ever removed in the USA. Translocations in this first year were intended to circumvent the disruption of downstream spawning habitat by temporary sediment flows resulting from dam breaching, while natural migration was allowed in subsequent years. Roughly 10% of the Chinook population spawned upstream of the former dam site in the year following removal and both total escapement in the river and the proportion of returning fish born in upstream reaches is increasing over time (Engle et al. 2013, Hatten et al. 2015, Allen et al. 2016, Liermann et al. 2017).

A more comprehensive review of effectiveness for 40 salmon-driven dam removal projects along the west coast found that fish successfully recolonized upstream habitats in ~50% of full dam removal projects and ~30% of partial dam removal projects, but notes that poor monitoring for many of these projects has made effectiveness difficult to establish (Brewitt 2016). Rates of natural recolonization will vary depending on both the circumstances of the watershed and the life history characteristics of the recolonizing species. Some species of interest in the Klamath Basin have a greater tendency towards expanding into habitat within existing streams but a low tendency of colonizing new streams (e.g., lamprey, coho salmon) whereas others are just as likely to expand in existing streams as colonize new streams (e.g., steelhead, Chinook salmon) (Pess et al. 2014). These characteristics may influence the success of natural recolonization and suggest which species are more likely to require assisted reintroductions (described further in Section 6.5.2). Beyond the benefits of recolonization for fish populations themselves, recolonization of previously inaccessible reaches also restores the flow of new food resources to upstream portions of the watershed in the form of salmon eggs, fry, and carcasses, resulting in an overall boost to ecosystem nutrient budgets and productivity (Tonra et al. 2015).

The benefits of barrier removal, however, come with trade-offs. Rapid drawdown of the impoundment generally exposes large areas of riverbed and deposited sediment. The days to years following dam removal are characterized by geomorphic channel adjustments and a significant downstream export of excess sediments, embedded nutrients, and contaminants that have accumulated at the bottom of the dam impoundment over its lifetime (Hart et al. 2002). Immediately following removal, excess mobilized fine sediment can clog pools, fill the interstices between coarse sediment in spawning habitat, and cause direct fish mortality (Stanley and Doyle 2003), as was observed following the removal of the Elwha Dam (East et al. 2015). Moreover, excess fine sediment can accumulate in and substantially alter the function of downstream estuaries, which may require further restoration efforts (Shaffer et al. 2017). However, fine sediment in the former impoundment can sometimes be removed or stabilized using vegetation and instream structure to help mitigate flushing (Doyle et al. 2005). The USFWS recommends that fisheries professionals working on dam removals work closely with geomorphologists to better understand and plan for sediment transport following removal, particularly if planning upstream translocations to areas that might be affected be sediment instability. These types of consultations may result in the creation of translocation exclusion zones to prevent the destruction of translocated salmon redds by further sediment displacement (Allen et al. 2016). Over the longer-term, benthic habitats are expected to improve with a second coarser sediment wave which gradually alters channel morphology and may expand potential salmonid spawning area as it did in the Elwha basin (East et al. 2015).

Changes in river structure and function following dam removal will also bring other changes, some desired and some not: reservoir species may experience high mortality or become extirpated as they are replaced by riverine fish and macroinvertebrates; recolonization success may vary across species due to life history characteristics; and upstream tributaries may not only be recolonized by native species, but also by invasive species and pathogens (Hart et al. 2002, Stanley and Doyle 2003, Hurst et al. 2012, McLaughlin et al. 2013, Pess et al. 2014). Moreover, these impacts have been observed following the removal of small dams as well as large dams (Doyle et al. 2005). Deconstruction of the dam is often accompanied by riparian restoration to help with erosion control (ICF 2005), although studies at former impoundment sites have shown that vegetation recovers quickly following dam removal according to typical successional patterns. Dam removal may not be sufficient to bring about the upstream recolonization of fish to historical habitats if these habitats are degraded, and upstream habitat restoration plays an important role in ensuring recolonization success (Doyle et al. 2005). Perhaps most importantly, the restoration benefits of dam removal for overall river channel morphology and ecosystem function may not manifest for years or decades, and there may be considerable variation in the duration and extent of recovery for particular ecosystem components (Hart et al. 2002, Doyle et al. 2005, Figure 6-10).

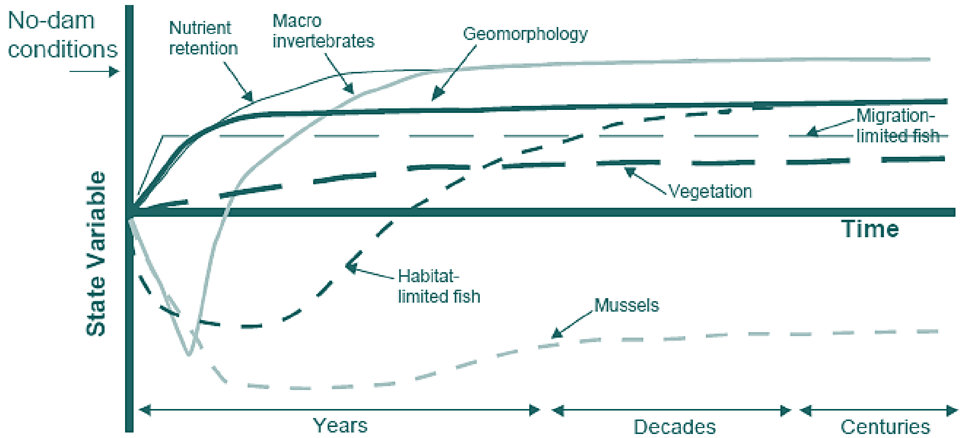



Figure 6-10: Conceptual model of ecosystem recovery following dam removal reproduced from Doyle et al. 2005, presuming that some species are able to make a full recovery to pre-dam conditions while others such as mussels that are particularly susceptible to the negative impacts immediately following dam removal may only achieve partial recovery.

### *Fish Screening*

Fish screens are physical barriers designed to prevent fish entrainment into diversions while allowing water to pass for its intended purpose. Several types of fish screens exist that have been designed for different sites and flow rates (Table 6-3).

Fish screens must be designed and built following state and federal criteria to ensure safe, timely, and efficient fish passage past diversions (NMFS 2011). These criteria specify screen mesh size, approach velocity, and orientation of the screen in relation to the river, among other features, to minimize the potential for entrainment or impingement of fish. Fish screening criteria have become more stringent in recent years to prevent entrainment of juvenile fish as well as adults, requiring lower approach velocities and smaller screen sizes that become more difficult to keep clean (PSMFC 2000, NMFS 2011). Criteria also specify robust construction to help prevent widespread losses due to poor placement and design that were common for early fish screens during floods of the 1930s and 1940s (SRCD 1995b). Most fish screens are designed to protect salmonids, and there is growing recognition that sensitive Pacific Lamprey (*Lampetra tridentata*) which are comparatively poor swimmers may not be adequately protected by fish screens. The Oregon Department of Fish and Wildlife have recently opened a Lamprey Test Facility to help set criteria that can protect both salmon and lamprey (ODFW 2013).

Fish screens are widely considered to be highly effective in reducing fish mortality for a moderate degree of effort and cost required for installation on small diversions (NMFS 2011, Newfields and Kondolf 2012). Although little field data exists to quantitatively document the effectiveness of older fish screens (Moyle and Israel 2005), design improvements in recent years have consistently demonstrated more than 98% diversion of juvenile salmonids past intakes with minimum delay, loss, or injury (NMFS 2011). One cost-benefit analysis conducted for a new fish screen installation in the Scott River sub-basin estimated that the new screen would prevent entrainment of roughly 17,000 juvenile salmonids every ten years, based on prior sampling at that site. This recovery rate is translated to ~$200,000 in economic benefit from the revenues generated through sport fishing of surviving adults over the 20-year lifespan of the screen, a substantial gain over the $14,000 cost of the project (SRCD 1995b).

Fish screens on larger diversions or river segments with high flows (200-3000 cfs) can cost well upwards of $1 million. However, the smaller irrigation diversions more commonly screened in the Klamath Basin have flows on the order of 1.5 to 10 cfs and typically cost less than $100,000 (e.g., SRCD 1995b), although two projects in the project database come in close to $500,000 and two more approach $1 million. Both Oregon and California provide incentives for the installation of fish screens through state programs, cost share grants, and tax credits. In Oregon, matching grants are available through the Fisheries Restoration and Irrigation Mitigation Act (FRIMA) funding and tax credits for fish screens are available through the Oregon Department of Fish and Wildlife among others; in California, these funds are accessible through the California Department of Fish and Game and several water bond acts among others; and in both states matching funds are also available through NOAA's Pacific Coast Salmon Recovery Funds (PCSRF) (PSMFC 2000, ODFW 2013). In addition, federal and state fish and wildlife agencies operate a number of "screen shops" where such screens can be manufactured. Before-after evaluations of the benefits of screens on salmon returns need to adequately control for other confounding factors affecting freshwater and marine survival, which may increase or decrease the apparent benefits in the absence of control sites (Marmorek et al. 2004).

Table 6-3: Principal types of fish screens, adapted from USBR2006. Screen types marked with an asterisk are still considered to be experimental technology by regulators and are not in widespread use (NMFS 2011).

| Type of Screen | Typical Setting | Characteristics |
|---|---|---|
| Flat Plate Screen | River, canal, diversion pool | Widely used in rivers and canals<br>Suitable for a wide range of diversion flow rates |
| Drum Screen | Canal, diversion pool | Suitable where water level is stable (controlled to 0.65-0.85 drum screen diameter). Currently used mostly for small flows, although has been used for large flows |
| Travelling Screen | Secondary screening in bypass, river | Because of expense, usually used for small flows |
| Cylindrical Screen | River, diversion pool | Typically applied at intakes to pumping plants |
| Inclined Screen* | Secondary screening in bypass, canal, diversion pool, river | Adverse slope – Suitable where water level is controlled<br>Inclined plate – Best applied along river banks |
| Horizontal Flat Plate Screen* | Canal, river | Typically applied in river with good sweeping flow<br>Currently used for small diversions (less than 100 ft3/s) |
| Coanda Screen* | River, canal | Limited to small diversions (less than 150 ft3/s) |
| Farmer's Screen[43] | Off-stream channel | A type of horizontal flat-plate screen developed by the Farmers Conservation Alliance which are widely used in Oregon, including in the Upper Klamath Basin. |

## *Status and Trends in the Klamath Basin*

Fish passage improvement projects were one of the most common early interventions for fisheries restoration in the 1980s, with many projects focused in the Trinity sub-basin and carried out by the USFS in the Klamath National Forest. Fish passage projects became less common throughout the 1990s due to a shift in focus towards instream and riparian habitat

[43] http://farmerscreen.org/farmers-screen/about/intro/

restoration to address the underlying ecosystem drivers of fish decline. The release of biological opinions for coho and sucker as well as the Klamath Basin water crisis that led to a significant fish kill coincided with renewed interest in fish passage improvement after the year 2000 to open up more upstream spawning and rearing habitat (Figure 6-2). Many of these more recent fish passage projects have been led by Tribal Agencies on tribal lands, the USFWS Partners for Fish and Wildlife Program on private lands, and the USFWS National Fish Passage Program on both public and private lands. To date, more than 400 fish passage and 150 fish screening projects have been carried out in the Klamath Basin (Figure 6-11). Many of these projects involve removal or alteration of a barrier other than road crossings, including many small permanent diversion dams, temporary flashboard diversion dams, spillways, beaver dams, dense log jams, and other blockages. The remaining fish passage projects involve improving fish passage at road crossings through removal of road crossings, replacing problematic culverts, and replacing previous barriers with new culverts or bridges. The majority of these projects have historically taken place in the lower basin, particularly in the Shasta Basin, where they provide more benefit to anadromous fishes by opening up previously inaccessible spawning habitat. A large share of both road-crossing removals and removal of other types of barriers has taken place in the Lower Klamath Basin, primarily in the Scott and Shasta basins (Figure 6-12). Recent examples of fish passage projects are explored in the next section to provide context for how these projects are implemented. Not included in our collection of project information but looming large in the public discourse is the potential removal of four mainstem Klamath River dams, which is discussed in more detail later in this section.

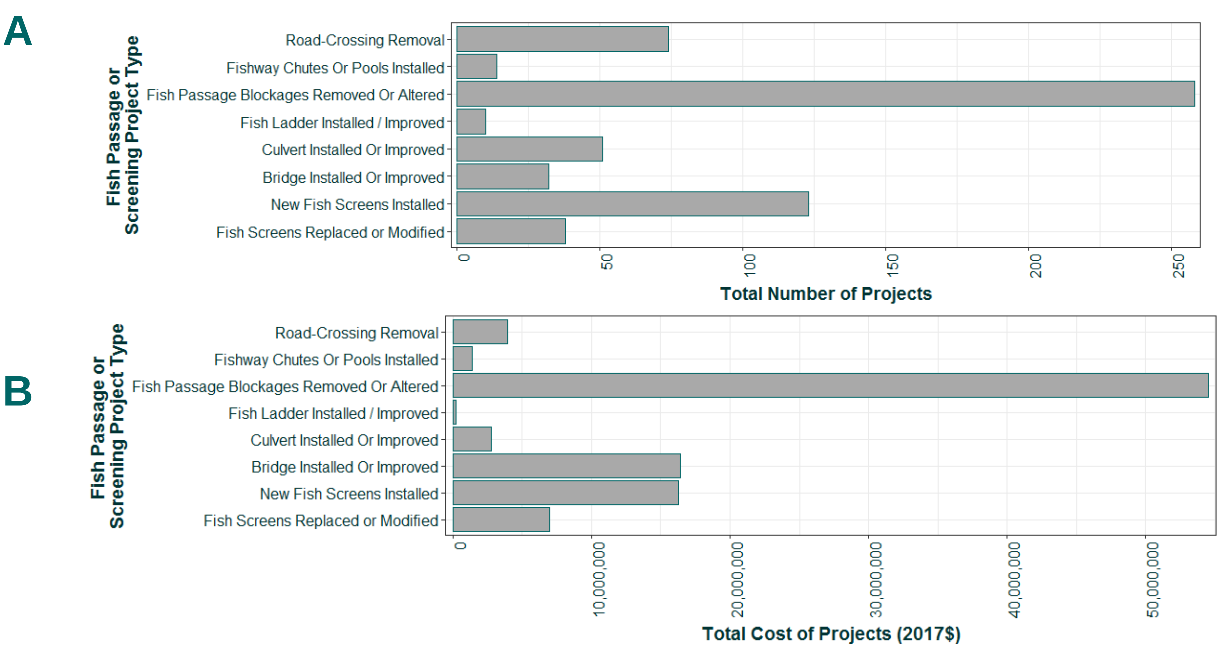



Figure 6-11: Distribution of the total number (A) and total costs (adjusted for inflation to 2017 $) (B) of grant-driven fish passage and screening projects across specific activity types. Sources of data and methods described in Appendix H.

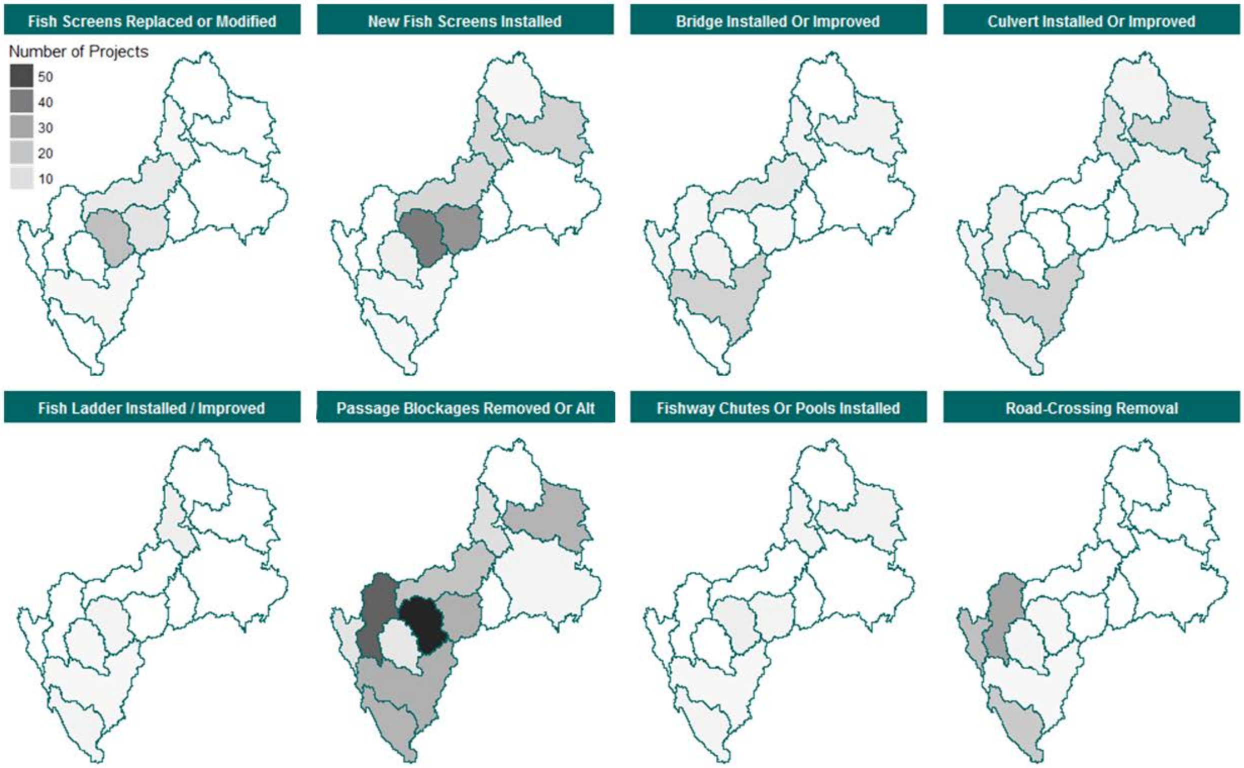



Figure 6-12: Distribution of the number of grant-driven fish passage and screening projects of each action type across sub-basins. Sources of data and methods described in Appendix H.

## *Examples of Implementation in the Klamath Basin*

Here, we provide brief case studies of four completed, ongoing, or anticipated fish passage projects in the Klamath Basin to provide more context for representative projects in this class.

### *Whites Gulch Migration Barrier Removal Project*

This project is typical of road-crossing removal projects in the basin and involved the removal of an elevated arch culvert with a single-span concrete bridge, improving access to 3.5 miles of anadromous fish habitat on the North Fork Salmon River in Siskiyou County. The new bridge provides for natural stream channel conditions, improved capacity to convey peak flows, and renewed access to upstream cold-water refugia, spawning habitat, and rearing habitat for juvenile and adult Chinook salmon, steelhead trout, and threatened Southern Oregon Northern California Coast Coho salmon (Five Counties 2010). This project complemented two upstream dam removal projects that were completed in 2008 by the Salmon River Restoration Council, CDFW and the NOAA Open Rivers grant program (Five Counties 2010).

This project was sponsored by the Five Counties Salmonid Conservation Program in partnership with Trinity County, Siskiyou County, the CDFW, and the USFS, with financial support from a Klamath River Restoration Program grant and a Fisheries Restoration Grant Program grant. The barrier was selected for replacement following identification as a high-priority barrier in the 2002 Siskiyou County Barrier Inventory using the USFS FishXing road-crossing barrier prioritization tool. This barrier was ranked as high-priority due to the severity of the barrier for all life stages of salmonids, the significant stretch of high-quality habitat that lay above it, and the presence of steelhead, coho, and Chinook in downstream reaches (Five Counties 2010). Prior to construction, temporary fish screens were installed above and below the barrier and fish between the screens were relocated to avoid harm. The construction phase spanned 3.5 months and involved excavation and storage of fill material, restructuring of abutments and stream banks, installing the bridge, and conducting revegetation. Monitoring following the project showed gradual downstream channel adjustment to a more natural grade.

The project was completed in 2010 at a total cost of $429,427 and complemented two upstream dam removal projects carried out in 2008 by the Salmon River Restoration Council and the CDFW. As of the 2015, spawning ground surveys carried out by the USFS indicate that at least some spawning is occurring in this reach (Meneks 2016).


Figure 6-13: Road crossing at Whites Gulch before (A) and after (B) fish passage project (Five Counties 2010). Sources of data and methods described in Appendix H.

### *Araujo Dam Removal*

This project provides a good example of a fish passage project removing a barrier other than a road crossing. It involved the removal of a low-head flashboard dam and its replacement with a diversion pump to provide continued agricultural water supply, plus a fish screen to prevent entrainment into the diversion (SVRCD 2016).

The Araujo Dam had been used since 1857 to divert water for irrigation, but the dam and associated irrigation system blocked fish passage, suffered water loss from seepage through unlined diversion ditches, and contributed to contamination through the need for herbicides to keep ditches clear of vegetation. Planning for dam removal began in 2001, with implementation beginning in 2007. Heavy equipment was used to breach the dam, and the structure was replaced by a pump station on the side of the channel that supplies water to five ranches and a rock weir that channels water towards the pump intake. The intake is guarded by a fish screen designed to CDFW specifications to protect Chinook and Coho salmon from entrainment. In addition, unlined diversion ditches were replaced with water pipelines to minimize water loss and reduce the need for herbicides (SVRCD 2016).

This project was sponsored by the Shasta Valley Resource Conservation District and completed in 2008 at a total cost of roughly $2.5 million with funding support from CDFW, the California Water Boards, the Natural Resources Conservation Service, the U.S. Fish and Wildlife Service and the National Fish and Wildlife Foundation (NFWF). The removal of this dam has restored free-flowing water and year-round access to over 30 miles of upstream fish habitat and has improved both water quantity and quality in the Shasta River (Unkefer 2008, SVRCD 2016).


Figure 6-14: The Araujo Dam prior to (A), during (B), and after removal (C) when it was replaced by a screened diversion pump (Unkefer 2008).

### *Sevenmile Creek Fish Bypass*

The purpose of this project was to improve fish passage for redband trout and Lost River and shortnose suckers at an irrigation diversion dam on Sevenmile Creek, and provides an excellent example of a fish passage project focused on species other than salmon. The existing diversion structure was removed and replaced with a rock V-weir to provide irrigation water and allow for year-round fish passage. Approximately 175 feet of roughened channel and a small pool were created adjacent to the main channel to provide for fish passage (Figure 6-15). The project was designed to convey flood flows in the main channel while providing fish passage in a roughened bypass channel. Disturbed ground surrounding the project site was seeded with native plant species, including Bottlebrush Squirreltail (*Elymus elymoides*) and Tufted Hairgrass (*Deschampsia cespitosa*). Project partners included the Klamath Basin Rangeland Trust (now merged with Trout Unlimited), Sevenmile Ranch (landowner), the U.S. Fish and Wildlife National Fish Passage Program, the Natural Resources Conservation Service Wetlands Reserve Program, and the U.S. Forest Service Title II Resource Advisory Committee. The total project cost was $115,506.00 (Trout Unlimited, pers. comm.).

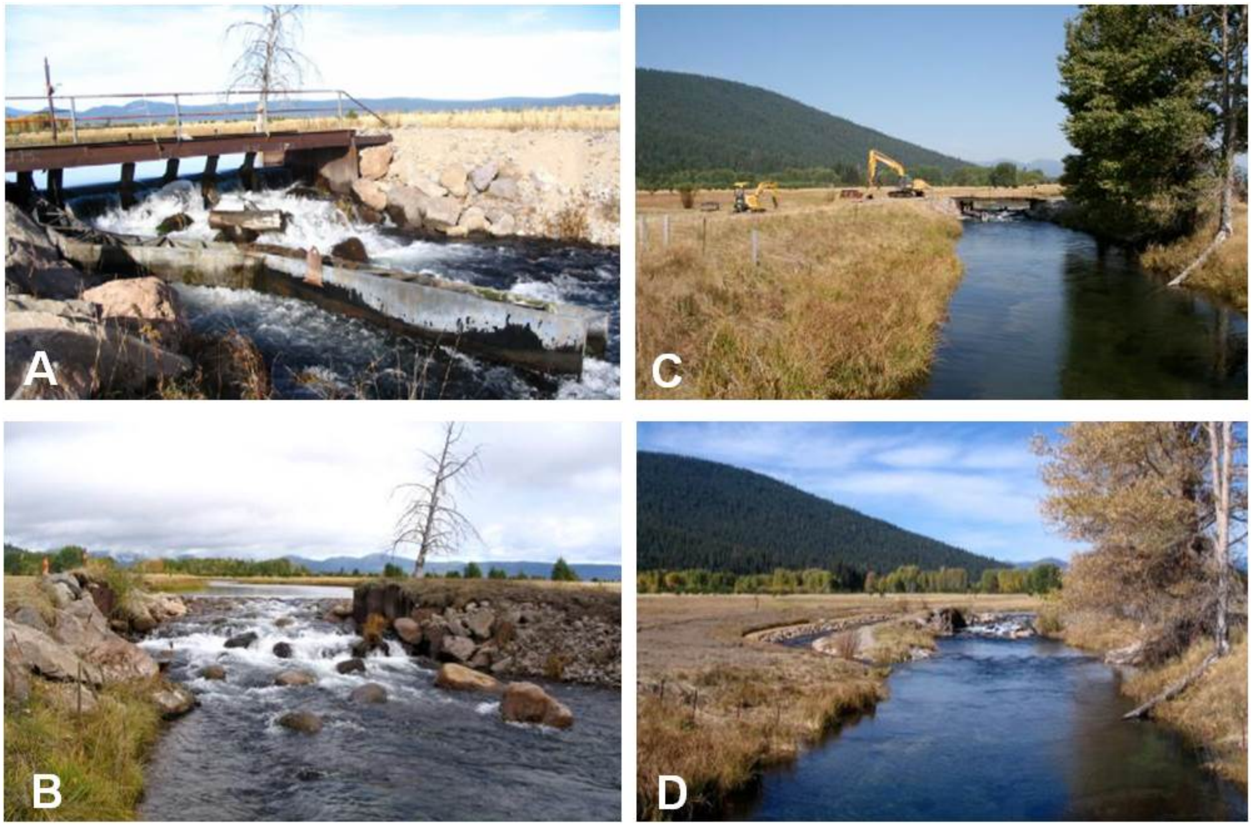



Figure 6-15: Photos of Sevenmile creek showing the main channel diversion before construction (A) and following its replacement with a rock weir during the project (B), as well as showing the entire main channel before construction (C) and following replacement of diversion structure, channel roughening, and the addition of a fish bypass on the left following construction (D). Photos reproduced with permission from Trout Unlimited.

### *Removal of the PacifiCorp Dams*

The collaborative campaign to authorize removal of the J.C. Boyle, Copco 1 and 2, and Iron Gate Dams on the mainstem Klamath River has become the pivotal element of a basin-wide approach to restoration that would help to resolve many of the fisheries, water quality, economic, and water supply challenges facing the basin.

Following numerous scientific, economic, and engineering studies as well as a public EIS/R process under NEPA and extensive deliberations described in detail in Section 1, the Secretary of the Interior determined in April 2013 that removal of the four mainstem dams was in the broad public interest and the best means of advancing fisheries restoration objectives (USDI 2012b, USDI et al. 2012, USDI 2016). On September 23, 2016, PacifiCorp and the Klamath River Renewal Corporation filed a joint license transfer application with FERC that seeks to transfer dam licenses to the Klamath River Renewal Corporation created to manage removal. Concurrent with the license transfer application, the Klamath River Renewal Corporation filed a license surrender application with FERC to decommission the Project[44]. Dam removal still

[44] http://www.waterboards.ca.gov/waterrights/water_issues/programs/water_quality_cert/lower_klamath_ferc14803.shtml

requires the approval of the Federal Energy Regulatory Commission, which has been delayed by vacancies on its five-member board (Jacobs 2017).

In preparation for approval, USBR and its contractors have developed a detailed plan for the full removal of these dams, which can be accomplished in a single year at an estimated cost of over $291.6 million. Removal is planned to take place over the year 2020, beginning with controlled drawdown of the three largest reservoirs by regulated releases from existing spillways, bypass facilities, and low-level outlets. Drawdown would occur between January and March to coincide with periods of naturally high sediment, avoid peak migration and spawning periods, and maximize flushing during high flows. High flows are expected to sweep fines and excess organic sediments out of spawning gravels and thus limit sediment impacts on fish to a single year (USBR 2012a,b, Quiñones 2015). Drawdown would be followed by deconstruction after spring runoff, most likely in late summer, to minimize flow during removal activities. Deconstruction would consist of excavation of dam embankments using earth-moving equipment and demolition of spillways, buildings, and other concrete structures through hoe-ramming or drilling and blasting. Deconstruction is expected to generate significant volumes of waste material at all sites, consisting primarily of earth fill and concrete rubble, which will be buried nearby (USBR 2012a,b).

Experience drawn from the removal of many other dams across the continental US and numerous scientific and modelling studies compiled for the Secretarial Determination and EIS provide a good idea of the anticipated geomorphic and ecological responses to removal (O'Connor et al. 2015). Removal of the dams is expected to provide access to 420 miles of historical anadromous fish habitat above Iron Gate dam, with fish capable of passing the remaining Keno and Link River dams via fish ladders (USDI et al. 2012). In the short-term (1-2 years) following dam removal, flushing of sediment from the accumulated bedload is expected to cause mortality of some fish and other organisms in downstream reaches (Stillwater Sciences 2009, 2010a,b; USDI et al. 2012). Under a worst-case scenario, the mortality rates for coho and Chinook are expected to be less than 10%, but steelhead mortality may approach 30% for adults and 19% for juveniles if removal occurs in a dry year. Although methods for removing reservoir sediment to reduce these short-term impacts were explored, they were abandoned due to findings of minimal reductions in fish mortality. Increased volume and variability of flows is expected to reconfigure downstream channels and improve bedload transport and spawning gravel recruitment downstream of Iron Gate Dam (USDI et al. 2012). In addition to geomorphic changes, dam removal is expected to bring about thermal changes. Modelling studies conducted for the Secretarial Determination on dam removal predict that, under the current climate conditions scenario, temperatures would increase 1-2 °C in the spring and decrease 2-4°C in the fall after dam removal, with impacts on water temperatures would greatest near Iron Gate Dam and attenuating in the lower reaches of the Klamath River. Dam removal was also predicted to result in an earlier phase shift of annual temperature cycles. These changes are anticipated to affect fisheries in the Klamath Basin due to their influence on outmigrating smolts in the spring and returning adults in the fall (Perry et al. 2011). Removal is also expected to reduce the incidence of acute disease outbreaks due to high densities of *C. shasta* residing in a highly infectious zone below Iron Gate Dam. These high densities are currently associated with high densities of spawning salmon and low volume and variability of flows capable of scouring out the polychaete vector for this parasite. Dam removal is anticipated to allow the redistribution of both spawners and *C. shasta* into upstream tributaries spread over a broader geographic area. However, this dispersal into tributaries is also expected to reduce localized densities of the pathogen, which is less likely to establish in tributary environments, and thus reduce the level of infectious challenge that individual fish will confront (USFWS 2016, Bartholomew et al. 2017). Finally, to the extent that fish in the river below the dams are impacted by *Microcystis* blooms and toxin from the reservoirs, exposure to this stressor will be eliminated.

Despite short-term impacts, salmonid populations are anticipated to grow in abundance and viability over the long-term recovery trajectory of the watershed. Anadromous fish will see the greatest benefits from restored access to historical habitats and cold-water refugia in the upper basin, while both anadromous and resident fish will benefit from more natural flow regimes as well as improved habitat and water quality (USDI et al. 2012, USDI 2016). The anticipated response of key Klamath fish species to dam removal has been reviewed in detail in a series of four expert panel reports examining Chinook salmon (Goodman et al. 2011), coho salmon and steelhead (Dunne et al. 2011), lamprey (Close et al. 2010), and resident fish including suckers and trout (Buchanan et al. 2011). General conclusions are summarized in Table 6-4.

Table 6-4: Anticipated responses of Klamath Basin fish to dam removal (Fagan 2012).

| Species | Anticipated Response to Dam Removal |
|---|---|
| Coho salmon | Will benefit from improved access to tributary spawning habitat downstream of Keno Dam and likely less exposure to disease. A modest or substantial increase in populations upstream of Keno Dam is less certain, but probable. |
| Chinook salmon | Fall-run and particularly spring-run Chinook will benefit from improved access to mainstem spawning habitat downstream of Keno Dam and likely less exposure to pathogens causing disease, and subsequent projections anticipate an 80% increase in harvestable Chinook (Secretarial Determination Overview Report, Dept. of the Interior, 2012). |
| Steelhead | Will expand populations throughout the basin in suitable habitat; their interactions with redband trout and the resulting implications on either population are unclear. |
| Redband trout | Will expand populations, especially in mainstem reaches downstream of Keno Dam. |
| Lost River sucker<br>Short-nosed sucker | No direct benefits are expected, however, the dam removal option assessed in the expert panel report on resident fish included habitat restoration in the upper basin which would benefit suckers. |
| Pacific lamprey | Will be able to access historical habitat, but the rate of recolonization in the absence of reintroduction and the long-term effects on resident lamprey populations is uncertain. |

Under the provisions of the ESA, a condition of FERC re-licensing of the dams is that functioning fish passage structures be installed at all three dams if removal was delayed, such that access to upstream habitats will be restored under all future scenarios, whether by unimpeded or aided fish passage (USDI et al. 2012). Assuming that the biological opinions for Klamath coho and sucker remain in force, agency funding for fish restoration would be expected to continue under such a scenario at current levels and that the Iron Gate Fish Hatchery would continue to operate to the detriment of natural population recovery (USDI et al. 2012, Hamilton et al. 2011). Should dam removal be delayed, operators will also need to manage operations to improve water quality by meeting the TMDLs established by state agencies for impaired water bodies in the basin (USDI et al. 2012).

## 6.5.2 Hatchery Rearing & Reintroduction

### *Definition and Effectiveness*

Fish rearing encompasses hatchery operations that collect and spawn adult salmon for the purpose of rearing and out-planting fry or smolt, as well as small-scale rearing programs that rear artificially spawned or wild-caught fry in streamside rearing ponds to improve survival prior to release (Table 6-5). The historical focus of the hatcheries has been to provide fish for recreational, tribal and commercial fisheries, however in recent years more emphasis has been placed on the role hatcheries have in species recovery and ecological interactions with native fishes.

Table 6-5:Hatchery Production Project Work Types*.

| Work Type | Definition |
|---|---|
| Fish reared/released | Fish fry/smolt that are produced and released. |
| Hatchery operations - facility or equipment | Purchase, replacement or modification of hatchery facility equipment or structures necessary for fish production (not for marking/tagging fish). This includes acclimation ponds, pumps, fish transport, traps, weirs, and costs for design/ construction. |
| Fish outplanted | Fish fry/smolt by species that are outplanted to re-establish salmonids to an area or to supplement a wild population. |
| Native/wild broodstock collection/relocation | Collection of native/wild broodstock for hatchery production or for relocation above barriers or other streams |

* Based on restoration work types identified in the NOAA PCSRF Data Dictionary available in Appendix J and at https://www.webapps.nwfsc.noaa.gov/j/Docs/PCSRF%20Data%20Dictionary%20ver20%2004-08-13.xlsx

Hatchery rearing of salmonids for the purposes of stock enhancement has been practiced across the North Pacific since the early 1950s, and stock enhancement efforts have gradually increased since that time. Total salmon abundance of all species across the North Pacific is higher now than at any point over the past 60 years due to a combination of favorable environmental conditions for more northern populations and releases of hatchery fish. However, the proportion of hatchery-origin salmon varies widely across species. Although stocking has increased the overall abundance of many populations, numerous studies have reported the potential for deleterious effects of stocking on wild populations (Araki and Schmid 2010), which are described in more detail in Section 3.5.2. These potential effects are most pronounced in the absence of strict genetic management protocols include increased competition with wild stocks, potentially increasing harvesting pressure on wild stocks, reduced fitness of hatchery-raised fish, loss of genetic diversity in the overall population, and the potential of hatchery fish to spread disease to wild stocks (Araki and Schmid 2010, Maynard and Trial 2014, Miller et al. 2014)(see also Section 3.5.2).

Comprehensive reviews of research on stock enhancement efforts to date have reported that few studies show a positive effect of hatchery rearing on fitness after release or provided direct evidence for enhanced wild stock after release. Although there have been some cases in which enhancement did not appear to lead to deleterious effects for wild populations, such cases are rare and the magnitude of the benefit is generally small (Naish et al. 2007, Rand et al. 2012, Araki and Schmid 2010, Blount et al. 2017). Importantly, the nature and severity of these effects will likely differ between hatcheries aiming to recover threatened populations as opposed to those whose main objective is supporting commercial fisheries (Miller at al. 2014). Overall, most experts conclude that while they may increase overall abundance, it cannot be assumed that hatchery programs will necessarily help wild stocks (Rand et al. 2012, Araki and Schmid 2010).

## *Status and Trends in the Klamath Basin*

Salmon enhancement through the use of hatcheries has been practiced in the Klamath Basin since the early 1900s (Leitritz 1970). The earliest efforts focused collection of steelhead eggs at Camp Creek, Bogus Creek, and the Klamathon Egg-Collecting Station from 1910-1940 for distribution to other hatcheries in the state to compensate for fisheries take, but the first true hatchery in the basin was built at Fall Creek in 1919 to compensate for the construction of the Copco 1 dam, which was considered too high for fish to pass using a ladder. The Fall Creek hatchery reared Chinook and steelhead until 1948. In the late 1950s, plans for the construction of three new dams downstream prompted the construction of an experimental hatchery below the proposed Iron Gate Dam in 1959 to assess the suitability of that location for fish rearing, and a permanent facility now known as the Iron Gate Hatchery was ultimately established. The Trinity River hatchery was built soon after in 1963 to compensate for the loss of upstream fish habitat due to construction of the Lewiston Dam[45]. In addition to these facilities, the Mount Shasta hatchery on the upper Sacramento was often used to increase capacity by rearing eggs collected from the Klamath such that juveniles could be planted back into the Klamath River to coincide with natural migration (Leitritz 1970). The Klamath Hatchery near Upper Klamath Lake in Oregon was built in 1929 to produce rainbow, brown, and cutthroat trout (*Oncorhynchus clarki clarki*) to enhance harvest rather than for restoration, and so is not discussed further in this report (ODFW 2017). Of note, more than 60 of the hatcheries historically established in California were later abandoned, reflecting the difficulty of finding suitable sites and conditions for hatchery success (Leitritz 1970).

In addition to large-scale hatcheries, at least 30 small-scale rearing programs took place in the Klamath Basin in the 1980s and 1990s. These programs were located primarily in the Lower Klamath and Trinity Basins, and most were implemented in partnership with Tribal organizations. Many of these programs operated as small hatcheries which captured wild salmonid spawners using weirs or gillnets, spawning them, and raising spawned young in streamside rearing ponds. Other programs caught and reared wild-spawned juveniles, including juveniles rescued from poor habitats or diversions, to improve survival before release. However, these programs have since been eliminated in favor of focused rearing at the larger hatchery facilities operated by state fish and wildlife agencies.

Overall, there were too few instances of individual rearing programs in the project database to generate informative summary figures. Instead, we provide a map of the locations of smaller scale rearing projects and major hatcheries (Figure 6-16).

[45] https://www.wildlife.ca.gov/Fishing/Hatcheries/Trinity-River/History

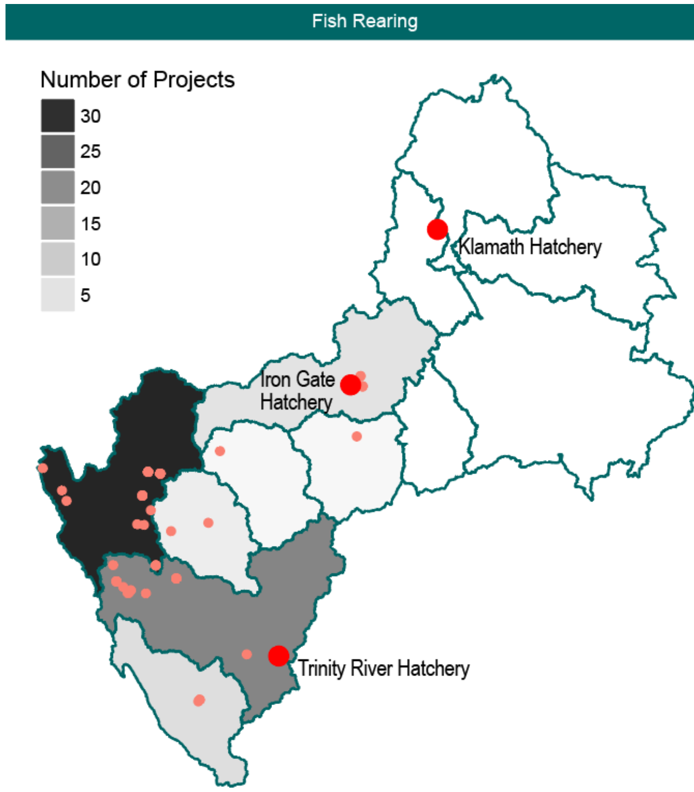



Figure 6-16: Location of former grant-driven small-scale rearing projects (pink) and the persisting major hatcheries (red) in the Klamath Basin which are funded by federal and state fish and game agencies. Sources of data and methods described in Appendix H.

More recently, there has been renewed interest in small-scale rearing programs for endangered suckers, and potentially green sturgeon, to supply enhancement and reintroduction programs of these threatened species. However, many of these programs are still in the research phase and have yet to see large-scale implementation.

## *Examples of Implementation in the Klamath Basin*

### *Hatchery Operations*

At the time of writing, three hatcheries are still operating in the Klamath Basin. The Iron Gate Hatchery and Trinity Hatchery are operated for restoration purposes to mitigate lost habitat and fish production above impassable dams, whereas the Klamath Hatchery is operated for harvest purposes and so is not discussed further here.

Iron Gate Hatchery

The Iron Gate Hatchery in California was built to mitigate for habitat lost due to construction of Iron Gate Dam, and now produces Chinook salmon, coho salmon, and steelhead. This facility was completed in 1962 and construction was financed by PacifiCorp and is operated by the California Department of Fish and Wildlife. The management paradigm has shifted in recent years due to the listing of coho salmon in the basin as threatened under Federal and State ESA statutes. At the time of writing, the goal of hatchery operations were to aid in the conservation and recovery of the Upper Klamath Population Unit by conserving genetic resources and reducing short-term extinction risk prior to the future restoration of fish passage above Iron Gate Dam (CDFW and PacifiCorp 2017). This development, along with heightened concern for other natural stocks, precipitated the development of a “Hatchery and Genetic Management Plan” (HGMP) for coho salmon (CDFW and PacifiCorp 2017).

The Iron Gate Hatchery and Genetic Management Plan for coho in particular was approved along with associated operational permits in 2014. The plan mandates minimizing the ecological and genetic impacts of hatchery operation on wild stocks through a variety of supporting objectives such as maintaining a low proportion of hatchery-origin adults on the spawning ground (pHOS), using local broodstock, and restricting the introduction of disease agents. Whereas the NMFS SONCC recovery plan recommends a pHOS <0.05, the Iron Gate HGMP cites a pHOS target of 0.50 to 0.80, reflecting the very low abundance of wild-origin coho in the basin and the heavy reliance of these populations on supplementation with hatchery stocks (NMFS 2014a, CDFW and PacifiCorp 2017). Some of the main tenets of this program are integration of wild brood stock, real time genetic evaluations of brood stock, releases of excess brood stock to the river to supplement other coho populations, in-hatchery modifications to increase survival, and monitoring of other proximate wild coho populations.

The production goals by species in the current Iron Gate Hatchery HGMP are shown in Table 6-6, although steelhead. Since 1998, production of coho yearlings has regularly exceeded the target of 75,000 fish and in some years produced over 100,000 yearlings, although the hatchery has not been meeting this target in recent years (W. Sinnen, pers. comm.). On average, the smolt-to-adult survival ratio of these releases was about 1%, translating to roughly 800 returning adults each year, with some variation between years (CDFW and PacifiCorp 2017).

Table 6-6: Annual production targets per species specified in 2016 the Iron Gate Hatchery HGMP for operations from 2014 through 2024 (CDFW and PacifiCorp 2017).

| Species | Life Stage | Annual Production Target |
|---|---|---|
| Chinook | Yearling | 900,000 |
| | Smolts | 5,100,000 |
| Coho | Yearling | 75,000 |
| Steelhead | Yearling | 200,000 (although none currently produced here as per CDFW) |

The hatchery also has two biological assessment teams, the Hatchery Evaluation Team (HET) and the Hatchery Coordination Team (HCT), that review data, reports, on-going management, federal or state recommendations and assessments for making recommendations to improve the facilities effectiveness and to reduce impacts to wild populations (CDFW and PacifiCorp 2017). The HET is specific to coho HGMP implementation and assessment and is led by NOAA - Fisheries staff, while the HCT is a state led team that has broader responsibilities which include formulating recommendations for all species managed and reared at the facility (CDFW and PacifiCorp 2017). Both teams incorporate tribal, federal and state partners within their memberships.

Future management of the Iron Gate Hatchery is considered a part of the KHSA. For the time being, it is assumed that Iron Gate Hatchery will continue to operate at current levels of production to meet mitigation requirements and PacifiCorp would continue to fund 100 percent of operational costs. Future removal of Iron Gate Dam would require the elimination of the water supply pipeline from the penstock intake structure to the fish hatchery and the fish handling facilities at the base of the dam, but Iron Gate Hatchery would remain operational under the administration of the CDFW (USDI 2012b). Within six months of the Dam Removal Entity (DRE) acceptance of the FERC surrender order, PacifiCorp would propose a post Iron Gate Dam Mitigation Hatchery Plan that would ensure hatchery mitigation goals are met for eight years following dam removal (Interim Measure [IM] 19 of the KHSA). Under IM 20 of the KHSA, PacifiCorp would also be required to provide funding to Iron Gate Hatchery or “other hatcheries necessary” to meet current mitigation requirements for eight years after dam removal. Hatchery goals would focus on Chinook salmon production, with consideration for steelhead trout and coho salmon, and may be adjusted downward from current mitigation requirements by the CDFW, NOAA - Fisheries, and the USFWS in consultation with other Klamath River fish managers, in response to fish monitoring trends (USDI 2012b).

After eight years, continued hatchery operations would depend largely on: 1) realized and projected benefits of restored access to additional habitat above the current location of Iron Gate Dam; 2) the success of habitat restoration efforts through a future agreement similar to the now-defunct KBRA; and, 3) success of the reintroduction program identified in a future agreement similar to the now-defunct KBRA, and 4) a continued source of funding. Due to this uncertainty, CDFW, in consultation with NOAA Fisheries Service, USFWS, and other Klamath River fish managers would evaluate the need for continued hatchery operations and identify funding for continued operations if it was determined that continued operation is desirable. (USDI 2012b).

Trinity River Hatchery

The Trinity River Fish Hatchery, operated by the California Department of Fish and Wildlife, has a production capacity of roughly 40 million salmonid eggs and produces steelhead, coho, and Chinook salmon. It is located immediately downstream from Lewiston Dam. The hatchery was constructed and operated to help mitigate for lost production of habitats upstream from the Trinity River diversion[46].

Mitigation goals for lost adult production were determined from pre-project studies of anadromous fish populations in the basin (California HSRG 2012). The USFWS and CDFW estimated that 5,000 coho; 3,000 spring Chinook, 8,000 summer Chinook and 24,000 fall Chinook; and 10,000 steelhead (no run timing was designated) passed above the Lewiston Dam site prior to its construction. Total annual adult production goals (catch plus escapement) for Trinity River Hatchery were further defined in 1980 to be 7,500 coho, 6,000 spring Chinook, 70,000 fall Chinook and 22,000 steelhead. Escapement goals to the hatchery were further defined in 1983 as 2,100 coho, 3,000 spring Chinook, 9,000 fall Chinook and 10,000 steelhead (California HSRG 2012). This hatchery is currently in the process of developing a HGMP as part

[46] http://www.trrp.net/background/ops/

of the settlement to litigation by the Environmental Protection Information Center (EPIC) stating that operation in the absence of such a plan violates the ESA (WELC 2014).

The Trinity River Hatchery fish production goals are anticipated to continue unaffected by the implementation of any future dam removal.

### *Reintroduction Programs*

With regards to reintroduction, the Klamath and Yurok Tribes commissioned a conceptual plan for the reintroduction of anadromous fish into the Upper Klamath Basin in 2006 (Huntington et al. 2006). In 2008, the Oregon Department of Fish and Wildlife (in collaboration with the Tribes) released a Plan for the Reintroduction of Anadromous Fish in the Upper Klamath Basin as a proposed amendment to their previous Klamath River Basin Fish Management Plan, in place since 1997 (ODFW 1997, 2008). The overarching goal of these plans is to set the stage to reintroduce anadromous fish into areas of historical distribution in the Upper Klamath Basin, including amending of the Oregon Administrative Rules to include anadromous fishes in the Klamath Basin Plan. The plan proposes a phased approach beginning with reintroduction of Chinook into Upper Klamath Lake and its upstream tributaries, followed by the potential for reintroduction of coho salmon, steelhead, and/or Pacific Lamprey only in the event that natural recolonization is slow or absent (ODFW 1997, 2008). At the time of writing, the ODFW and The Klamath Tribes have been collaborating on a salmon reintroduction implementation plan for the Upper Klamath Basin. Reintroduction above removed dams is anticipated to occur through natural re-colonization after fish passage facilities are installed or dams are removed, or through active re-introduction if natural recolonization is slow or absent, and active re-introduction of Spring Chinook above Link Dam is also planned (ODFW 1997, 2008).

### *Experimental Rearing of Suckers and Sturgeon*

In addition to salmonid rearing programs, experimental rearing programs have been carried out for endangered sucker and sturgeon to determine the feasibility of supplementing these small populations (Van Eenennaam et al. 2001; Day et al. 2016a,b). The USFWS developed a Sucker Assisted Rearing Program (SARP) in 2015 with the objective of rearing 8,000 to 10,000 age-0 Lost River and shortnose suckers to >200 mm for reintroduction into the Upper Klamath Lake system. The program involves the capture of wild-origin age-0 fish through inter-agency efforts that are then reared in a series of earthen ponds at a private grow-out facility. To minimize interactions between reared and wild fish, juveniles are captured in relatively low numbers, checked for parasites before use, and reared to a sufficient size such that they will not compete with wild juveniles after release. This rearing program fulfils the recommendation for “captive propagation” laid out in the NMFS and USFWS 2013 Biological Opinion on the Effects of Proposed Klamath Project Operations (Day et al. 2016a). Since its inception, the program has nearly doubled rearing capacity to over 20 ponds, has achieved 70% survival to ponding for over 4,300 juveniles, and developed a reintroduction plan with Reclamation, ODFW, and the Klamath Tribes. The reintroduction plan is currently undergoing the NEPA process that is expected to be completed by spring 2017 (Day et al. 2016b).

A second experimental spawning project, carried out by UC Davis in collaboration with the Yurok Tribal Fisheries Program, has also demonstrated the feasibility or artificial spawning and rearing of green sturgeon (*Acipenser medirostus*) (Van Eenennaam et al. 2001). This program captured and induced spawning in Klamath River green sturgeon using injections of reproductive hormones. Ovulated eggs were fertilized with collected milt achieving a ~40% fertilization rate and ~28% hatch rate. Larvae fed a mix of commercial and live foods mimicking a natural diet had 85% survival to metamorphosis at an age of 35 days and a length of 66 mm (Van Eenennaam et al. 2001). Although this experiment has shown artificial spawning and rearing of green sturgeon to be viable, there were no further plans to pursue rearing of this species at the time of writing.


Figure 6-17: Sucker Assisted Rearing Program (SARP) rearing pond (A) and wild-caught sucker larvae being counted and assessed prior to pond stocking (B,C) (Day et al. 2016 a,b).

## 6.5.3 Instream Flow Restoration

### *Definition and Effectiveness*

Instream flow projects aim to maintain and/or increase the flow of water to provide needed salmonid habitat conditions. This can include purchases or leases of water rights, improvements in irrigation practices to reduce flow into fields, and water conservation projects to reduce stream diversions or extractions (Table 6-7). Restoration of instream flows are also recognized as one of the best tools to help mitigate the potential for fish disease outbreaks, which can be exacerbated by low flows contributing to stagnant water characterized by low oxygen and high temperatures (USBR 2016a). However, the benefits incurred from these programs depend on their scope – permanent dedication of instream flows and conservation measures that reduce flow demand (such as retiring of croplands) are considered to confer greater restoration benefits than short-term flow buying.

Table 6-7:Instream Flow Project Work Types*.

| Work Type | Definition |
|---|---|
| Water flow gauges | Water gauges installed to measure and regulate water use. |
| Irrigation practice improvement | Improvement of irrigation practices (where water is removed from a stream) to protect fish. This includes: reducing withdrawals; installing a headgate with water gauge to control water flow into irrigation canals and ditches; regulating flow on previously unregulated diversions; or, replacing open canals with pipes to reduce water loss to evaporation. |
| Water leased or purchased | Water that is leased or purchased, and thus not withdrawn from the stream. This includes the purchase of water rights. |
| Maintaining adequate flow or reducing withdrawals | Preventing or reducing water withdrawals from stream. |
| Unspecified or other instream flow project | Unspecified or other instream flow project (not included in above). |

* Based on restoration work types identified in the NOAA PCSRF Data Dictionary available in Appendix J and at https://www.webapps.nwfsc.noaa.gov/j/Docs/PCSRF%20Data%20Dictionary%20ver20%2004-08-13.xlsx

Withholding of irrigation water from farms during the Klamath Project water crisis of 2001 spurred investigations along two lines of inquiry. The first was to better understand hydrological processes and identify major sources of water loss from farm and ranch lands. The second was to develop techniques that could improve irrigation efficiency so that farms and ranches could operate on less water (Freeman and Burt 2004).

A study of water balance on lands included in the Klamath Project within the Upper Klamath Basin in 2004 found that nearly all of the water diverted from the rivers and its tributaries for agricultural use was lost through evapotranspiration from agricultural fields (although there are substantial tailwater returns to the Lost and Klamath Rivers today). At that time, the outcome was due partly to the fact that extensive water recirculation and reuse systems were already in use at the time of the crisis. The study concluded that significantly increasing the amounts of water available to the Klamath River could not be accomplished by conventional farm modernization efforts such as canal lining or improving field irrigation efficiencies as these actions were expected to yield only minor gains (Freeman and Burt 2004). Instead, increasing flows to the Klamath River during late summer periods critical for fish would need to be accomplished through:

- decreasing evapotranspiration through a reduction in the total acreage of irrigated lands and wetlands;
- replacing surface irrigation water with groundwater; and/or
- increasing surface storage of irrigation water.

This conclusion led to a shift in approaches to instream flow restoration towards greater interest in water transaction programs that could effectively reduce the amount of water being diverted in the first place. Creating a legislative mandate for water rights can be challenging for two reasons: (1) because environmental objectives often consider specific physical and habitat parameters before considering flow; and (2) because environmental flows were not recognized as a legally defensible “beneficial use” until the 1970s. Because legal frameworks establish the priority of water rights in the order of “first in time, first in right”, environmental flows often take a back seat to preceding beneficial uses, although these uses may align in the case of Tribal Water Rights (see below) (Milner 2015, Willis et al. 2015). Moreover, the western states operate under a "use it or lose it" model where users that do not divert their entire allotted amount of water each year may ultimately be considered to have forfeited their water rights. This model can compel rights holders to divert water even when it is not needed simply to maintain their rights (Watson 2016).

These challenges have led to the rise of environmental water transaction programs that seek to secure water through lease or purchase outside of the formal requirements of water law from cooperating private water rights holders. Environmental water transaction programs are gaining momentum in the West and have now been implemented in several basins, including several areas of the Klamath Basin (Willis et al. 2016). Water transactions may involve temporary transfers, longer-term transfers, or permanent transfers and/or land and water acquisitions. For temporary transfers, water trusts generally lease water for periods of 30 to 90 days, during which the water remains in the river and the rights holder retains access to those rights and can return to using the water after the lease is over (Watson 2016). This model circumvents the lengthy regulatory review necessary for rights transfers or litigation to obtain rights, and allows for more cooperative and agile responses to low-flow conditions (Watson 2016). Although short-term transfers can occur more quickly and have a lower risk of public opposition, long-term or permanent water transfers are considered to have far greater ecological flow benefits and have been shown to provide more cost-effective returns on investment in the longer term (Aylward et al. 2016). Although water transactions are increasingly used to achieve ecological flow objectives, their ecological benefits are rarely quantified. In 2016, researchers from UC Davis and The Nature Conservancy led the development of a method to quantify the benefits of small-scale water transactions to fish and fish habitat using transactions in the Shasta River as a case study (Willis et al. 2016). The study models transaction effects on dissolved oxygen in light of discharge, pool volumes, holding habitat capacity, and fish oxygen demands, and finds that transactions can help to mitigate water quality impairments, particularly during periods of low flows when holding habitats are near capacity and oxygen demand is high (Willis et al. 2016). This results in significant increases in holding pool volume and fish capacity, particularly during short-term adverse conditions or water emergencies (Figure 6-18).

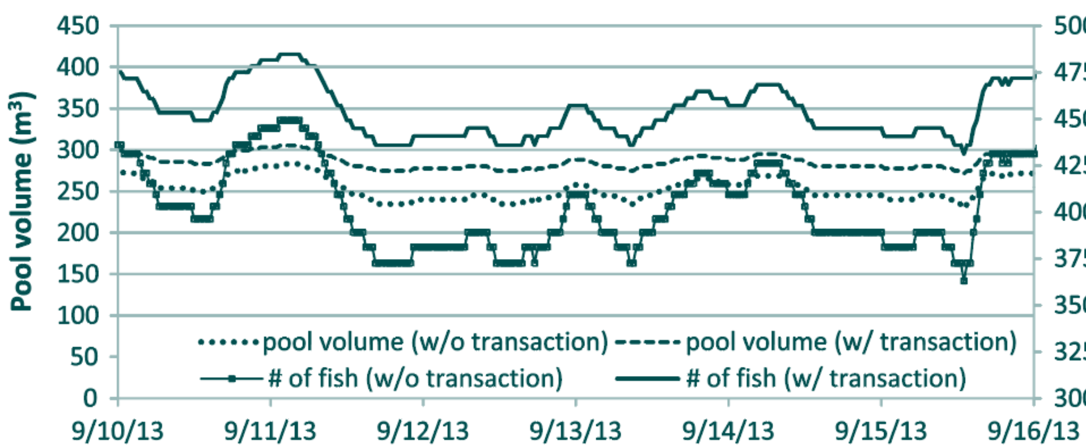



Figure 6-18: Benefits of small-scale water transactions on holding pool volume and fish capacity, given a 0.3m$^3$/s transaction. Reproduced from Willis et al. 2016 under a Creative Commons 4.0 license.

In addition to water transactions, instream flows may also be supplemented involuntarily by calls on tribal water rights. Legal precedents have determined that when the federal government created Tribal reservations, it also reserves water rights on behalf of the Tribes. Rights are assured for Tribes to fulfil the needs of the reservation for both present and future uses, may be exercised at any time, and are not forfeited if they are not used (Milner 2015). The Yurok and Hoopa Tribes the Lower Klamath Basin have reserved water rights to support fishing, and the Klamath Tribes of the Upper Klamath Basin maintain preexisting instream flow rights to protect fish despite the federal government extinguishing their reservation. Since 2013, the Klamath Tribes have issued several calls on their water rights in the Upper Klamath Basin[47].As the Karuk Tribe does not have a ratified treaty, its fishing and concomitant water rights remain uncertain – however, U.S. law protects the inherent rights that federally recognized Tribes did not relinquish through treaties or other agreements, which may include hunting, fishing, and water rights (Pierce 1998, Milner 2015, USDI 2017)(see also Section 1.4.4).

## *Status and Trends in the Klamath Basin*

Instream flow restoration has been a later development in the history of Klamath Basin restoration, with no records of this type of restoration project prior to 1995. Growing awareness of instream flow needs following the 2002 fish kill in the Klamath River has led to more activity in this category in more recent years, but effort remains low compared to other categories with an average of 5-10 grant-driven instream flow projects dedicated to fisheries restoration implemented each year (Figure 6-2). To date, over 100 projects contributing directly to instream flow, accounting for over $25 million in spending, have been completed across the basin for fish conservation purposes (Figure 6-19). A majority of these projects focused on improving irrigation systems to reduce water need, and a large proportion were led by the Klamath Soil and Water Conservation District. Instream flow projects are generally evenly distributed across the basin, and though irrigation practice improvement projects are more common than water leasing or purchase projects, the latter are much more costly (Figure 6-7and Figure 6-8). Only a handful of these projects involved installation or upgrades to wells, which are generally not considered to improve instream flows.

[47] http://www.klamathbasincrisis.org/watermanagement/watermanagementtoc.htm


Figure 6-19: Distribution of the total number (A) and total costs (adjusted for inflation to 2017 $) (B) of grant-driven instream flow projects across specific activity types. Sources of data and methods described in Appendix H.

It should be noted that the true number of such projects is likely much higher, as the restoration grant datasets used for these summaries do not necessarily include many water conservation projects carried out without fish conservation or restoration as the primary objective. For example, our grant-driven projects database does not currently capture water conservation arising from Farm Bill spending. The 2002 Farm Bill included appropriations for Klamath projects under the Environmental Quality Incentives Program (EQIP) and other programs administered by the NRCS to implement projects achieving net water savings on farms and ranches in the Klamath Basin. Overall, an estimated $100 million of Farm Bill Program Funds were distributed in the Klamath Basin within this timeframe (USDA-NRCS 2007). Although data related to Farm Bill programs are not available for download and independent analysis, data from 1999 through 2015 have been made available for public query by county via the Environmental Working Group's USDA Conservation Database. Using queries for the two largest counties encompassing a majority of Klamath Basin lands (Klamath County, OR and Siskiyou County, CA), we can determine that funds for irrigation improvements and water control were distributed primarily through EQIP accounting for an additional $31.8 million spent on irrigation and $2.5 million spent on water control on Klamath Basin farms and rangeland over this time period (Figure 6-20). However, it is important to note that not all of these projects necessarily contribute to net gains in instream flow.

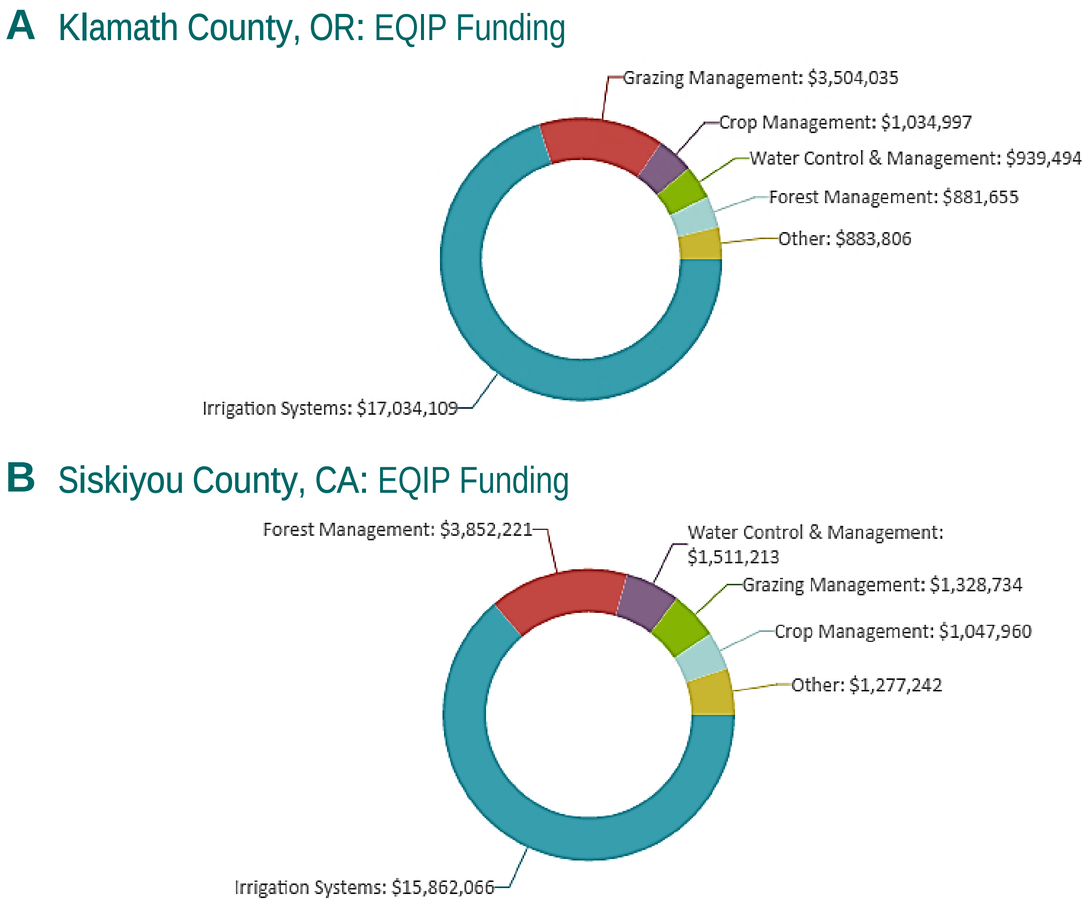



Figure 6-20: Distribution of USDA EQIP grant spending across activity types in Klamath County, OR, and Siskiyou County, CA, over the period from 1999 through 2015. However, it is important to note that not all of these projects necessarily contribute to net gains in instream flow. Reproduced from queries to the Environmental Working Group USDA Conservation Database.

## *Examples of Implementation in the Klamath Basin*

### *Water purchase and leasing*

Water leasing and purchase in the basin is occurring primarily in the Scott River, Shasta River, and Upper Klamath Lake sub-basins.

**The Trout Unlimited (formerly Klamath Basin Rangeland Trust) Water Transactions Program** operates a Water Transactions Program (WTP) in the Upper Klamath Lake Sub-Basin. The WTP aims to improve instream flows in part through leasing, but prioritizes permanent transfers of some or all irrigation water rights to instream use (KBRT 2011). In addition to leasing and transfer programs, this program also facilitated landowner participation in a wide range of federal and state water conservation programs including the NRCS' Environmental Quality Incentives Program, Conservations Securities Program, Wetland Reserve Program, Agricultural Water Enhancement Program, and the SWCD's Conservation Reserve Enhancement Program. Economic analysis of water values in the region was used to set purchase prices at a fair market value based on land value and water use intensity. This analysis yielded a price range for purchases between roughly $1,500 and $2,700 per acre of rights holder land (KBRT 2011). Financial support to pay these leasing and transfer feed is obtained largely through Farm Bill funds, as well as from many smaller funding agencies. Following the merger of KBRT into Trout Unlimited in 2016, TU continues to facilitate permanent water transactions with financial support from the OWEB Water Lease and Transfer Grant Program, most recently in Salt, Threemile, and Crake Creeks (OWEB 2017).

**The Scott River Water Trust** is a non-profit organization that negotiates voluntary water rights agreements allowing farmers to lease water rights to the Trust during low flow periods. At the outset of the program, non-participating farmers would occasionally increase their water use in response to upstream leasing that improved flows. In response, the Trust developed a new pricing model offering flat prices per acre-foot of water that are proportional to the need for water in that year and also offered bonuses for neighbours for collective enrollment to improve overall outcomes along longer sections of river (Watson 2016). During the first three years of operation, the summer program added and estimated 279 to 330 acre-feet of water to priority streams, improving 3.7 to 6.1 miles of instream rearing habitat, while the fall program added an additional 280 to 481 acre-feet and improved 53 miles of spawning habitat on the Scott River's mainstem. In the critically dry summer of 2013, contributions to the Scott River doubled to 800 acre-feet. Implementation of the Trust in 2011 has benefited coho returns in the Scott River basin and has helped participating farmers and ranchers feel a greater sense of trust and community in relation to the restoration process (Watson 2016). The Nature Conservancy developed a very similar Shasta River Water Transactions Program in the Shasta Basin, which has been operated in partnership with the Shasta Valley Resource Conservation District since 2012[48].

### *Salmon Rescue in Drought Emergencies*

Despite water conservation practices and water leasing and transfer programs, extreme drought conditions can still jeopardize large numbers of fish. Such scenarios often demand rescuing fish cut off from suitable habitat by drought. Severe drought conditions in late 2013 cut off returning coho from many of their usual spawning tributaries and forced fish to spawn in the mainstem Scott River. These conditions persisted into 2014 and raised concerns that fry emerging from these spawning sites would be unable to reach suitable rearing habitat and that up to half of the entire brood year might be lost. In response to this concern, the Siskiyou County Resource Conservation District and the Scott River Water Trust, in partnership with the CDFW, Tribes, and other agencies, led one of the largest scale rescue and relocation of juvenile coho salmon in the history of the basin. These efforts are estimated to have relocated some 116,000 juvenile coho to suitable rearing habitats in upper tributaries and prevented the untimely demise of a large proportion of that year's reproductive output. Roughly 1,872 (2%) released juveniles were PIT tagged to evaluate their survival following the transfer, and monitoring of these fish is ongoing (CDFW 2015). However, subsequent surveys showed that only 20 of these tagged individuals outmigrated from the river and that none returned as adults, likely indicating high levels of mortality following transplantation and suggesting that rescue efforts are not an

[48] http://svrcd.org/wordpress/projects/shasta-river-water-trust/

effective method for mitigating against mortality caused by stranding during droughts (CDFW 2016b).


Figure 6-21: Translocated juvenile coho salmon resting in an upstream tributary (A) following capture (B) and transplantation at suitable sites (C). Snorkel surveys were carried out following the transfer to monitor the survival of translocated fish (D). Reproduced from CDFW 2015.

## 6.5.4 Instream Habitat Restoration

### *Definition and Effectiveness*

Instream habitat restoration projects encompass a number of work types that increase or improve the physical conditions within the stream environment to support increased fish populations (Table 6-8). We consider wetland restoration projects within the same section because many juvenile salmonids, suckers, and other fish use wetlands as rearing habitats. The water quality benefits provided by wetlands are considered separately, in Section 6.5.7.

Table 6-8: Instream and Wetland Habitat Project Work Types*.

| Work Type | Definition |
|---|---|
| **Instream Flow Work Types** | |
| Channel reconfiguration and connectivity | Changes in channel morphology, sinuosity or connectivity to off-channel habitat, wetlands or floodplains. This includes instream pools added/created; removal of instream sediment; meanders added; former channel bed restored; removal or alteration of levees or berms (including setback levees) to connect floodplain; and, creation of off-channel habitat consisting of side channels, backwater areas, alcoves, oxbows, ponds, or side-pools. |
| Channel structure placement | Placement of large woody debris or rocks/boulders (including deflectors, barbs, weirs) to collect and retain gravel for spawning habitat; deepen existing resting/jumping pools; create new pools above and/or below the structure; trap sediment; aerate the water; channel roughening; or, promote deposition of organic debris. This includes floodplain roughening or fencing. |
| Streambank stabilization | Stabilization of the streambank through resloping and/or placement of rocks, logs, or other material on streambank. |
| Spawning gravel placement | Addition of spawning gravel to the stream. |
| Plant removal/control | Removal or control of aquatic non-native plants, invasive species or noxious weeds growing in the stream channel. |
| Beavers | Introduction or management of beavers to add natural stream complexity (beaver dams, ponds, etc.), or use of artificial structures as beaver dam analogs. |
| Predator/competitor removal | Control or removal of salmonid predators or competitors (e.g., non-native fish, invasive animals) from the instream habitat. |
| **Wetland Restoration Work Types** | |
| Wetland planting | Planting of native wetland species in wetland areas. |
| Wetland plant removal / control | Removal and/or control (treatment) of non-native species, noxious weeds and other plants or invasive species that adversely affect the wetland area or water table. |
| Wetland improvement/ restoration | Improvement, reconnection, or restoration of existing or historic wetland (other than vegetation planting or removal). |
| Artificial wetland created | New (artificial) wetland created in an area not formerly a wetland. This is wetland area created where it did not previously exist. |

* Based on restoration work types identified in the NOAA PCSRF Data Dictionary available in Appendix J and at https://www.webapps.nwfsc.noaa.gov/j/Docs/PCSRF%20Data%20Dictionary%20ver20%2004-08-13.xlsx

A great many reviews have been carried out to assess the various types of instream restoration actions and their relative effectiveness (e.g., Roni et al. 2010, Stewart et al 2009, Whiteway et al. 2010, Newfields and Kondolf 2012), as well as their costs. Importantly, the full potential benefits of instream habitat and wetland restoration actions summarized here may not be fully realized if persistent poor water quality, degraded riparian habitat, and other stressors remain as factors limiting fish abundance (Roni et al. 2008).

### *Instream Structure Placement*

The most common type of instream habitat intervention is placement of in-channel structures primarily to alter flow and scour patterns, increasing habitat diversity. Instream structures also provide shade, increase habitat complexity, recruit woody debris, and provide cover from predation (Whiteway et al. 2010). Types of structures include structures intended to provide cover, which are the most commonly used, followed by deflectors, weirs, large woody debris, and boulders, with many projects more than one type of structure (Figure 6-22). Many design elements must be considered for these projects to achieve their objectives. For example, specific engineering guidelines are available to help project managers choose the right type of wood and its placement to maximize the longevity and hydraulic performance of wood structures in rivers (Abbe et al. 2003).

A meta-analysis of 221 stream restoration projects to determine their overall influence on habitat quality and salmonid abundance provides valuable insights into the effectiveness of this restoration activity. All methods were associated with a significant increase in pool area, average depth, large woody debris, percent cover, and decrease in riffle area following installation, with some variation among types. Deflectors and cover structures, for example, were far more effective at recruiting large woody debris than other types of structures (Whiteway et al. 2010). All structures were also associated with a significant increase in salmonid abundance in the majority of projects examined, with a mean effect size of 0.51 or 167% increase. Across species, rainbow trout benefit by far the most from instream structures, followed by coho salmon, cutthroat, brown, and brook trout, and steelhead, which experienced the smallest gains. However, not enough studies involving Chinook were available for a comparative analysis. Differences in response were also observed for different size classes, with larger fish (>15 cm) experiencing the greatest benefit (Whiteway et al. 2010). A U.S. Forest Service project conducted a similar evaluation of instream structures specifically within Klamath Basin streams with specific attention to creating suitable spawning habitat. This work found that Chinook preferred to spawn in habitat created by boulder deflectors, while steelhead preferred to spawn near any structure that produced suitable pocket water, particularly boulder assemblages including root wads. However, free rock weirs backfilled with suitable spawning gravel did not attract significant spawner use (Olson and West 1989). A similar study in the Elwha basin sought to measure the effectiveness of instream structures in larger mainstem habitats of large river systems, and found that placement of logjams generally resulted in greater species richness and higher densities of salmonids across multiple life stages than in areas without logjams (Pess et al. 2005).

The cost of instream structures depends largely on the number of structures installed. The cost of individual cover structures is estimated to range between $1,200 and $7,000 depending on size and complexity, and costs per river mile ranging from $5,000 to 70,000 depending on the density of structures (Hampton 2000). The need to anchor structures using cables, rebar, or wooden posts driven into the streambed can be costly. In some suitable reaches, direct felling of streamside trees into rivers and other unanchored methods of augmentation was found to be similarly effective as anchored wood and significantly reduced the costs of placing instream structures (Carah et al. 2014).

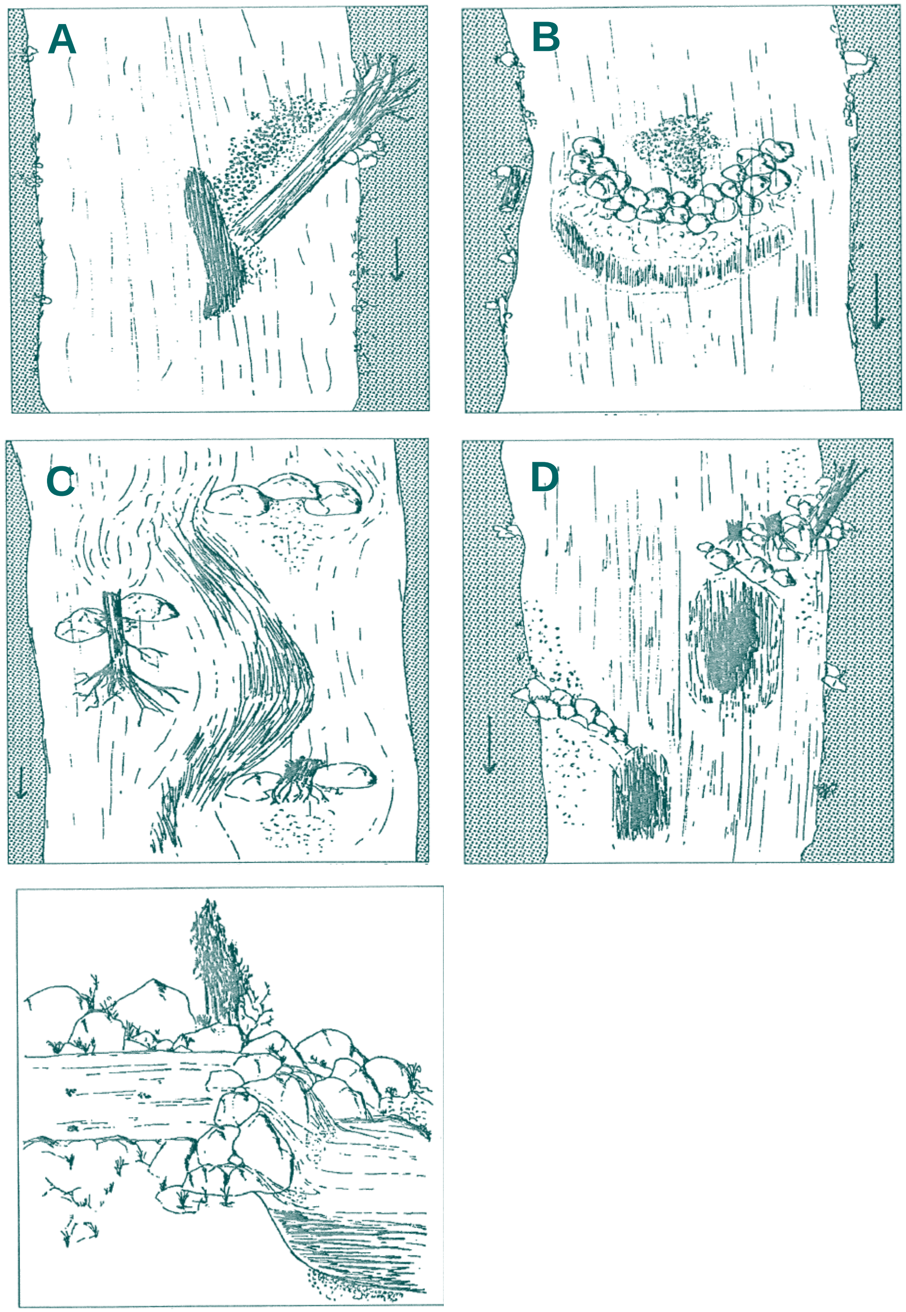



Figure 6-22: Schematics of the types of structures commonly used for instream habitat restoration, including digger logs (A), free boulder weirs (B), boulder groups with and without root wads (C), deflectors (D), and stream spanning boulder weirs (E). Adapted from Olson and West 1989.

### *Channel Reconfiguration and Connectivity*

Channel reconfiguration and connectivity projects may involve breaching levees, excavating new channels to reconnect sloughs, lakes, or springs, remeandering a straightened stream, and similar interventions. These activities promote natural channel migration, restore biological connectivity, allow more natural transport of sediment and nutrients, and tend to decrease stream grade. Reducing stream grade in particular helps to reduce the potential for fast flows, which can erode stream beds and banks, thereby preventing further loss of habitat. In the case of reconnecting springs, restoring cool groundwater inputs into the main river can help to expand thermal refugia for fish (Roni et al. 2008, Newfields and Kondolf 2012). Recent work in other river systems provides practical recommendations for preserving existing thermal refugia, augmenting existing thermal refugia, and creating new thermal refugia in uniformly warm reaches (Kurylyk et al. 2014). Another approach to channel reconfiguration has been the construction and connection of new off-channel habitats to provide more suitable holding and rearing habitat that may not be available in the main channel. Reconnection of side-cannels and floodplain ponds as well as construction of off-channel habitat have been shown to provide critical habitat for and increase the survival of juvenile salmonids, including coho and Chinook salmon (Roni et al. 2008, Krall 2016).

### *Streambank Stabilization*

Unstable streambanks are common along sections of river that have been heavily grazed and denuded of natural riparian vegetation, contributing to faster erosion and larger sediment inputs to the stream. Streambank stabilization is intended to arrest the immediate erosion process through resloping and/or placement of rocks, logs, or other material on streambank, and is often paired with riparian fencing and planting to re-establish stabilizing vegetation (SRCD 1996). Practitioners have moved from simple physical armouring techniques towards more natural methods that provide the added benefit of fish habitat, including deflectors, log cribbing and bank armor, debris jams, tree and boulder revetments, willow baffles, and similar methods (Figure 6-23) (SRCD 1996, Flosi et al 2010). Cribbing, armor, deflectors and similar structures physically shield the streambank from eroding flows and are often used on banks that are eroding too quickly for riparian plantings to successfully establish. Revetments and willow baffles are less invasive methods reserved for mildly eroding banks. These structures are typically placed on the outside of a meander where the highest velocity part of the stream (thalweg) is closest to the bank where they function to slow down flows. This has the dual effects of reducing erosion to allow streambank vegetation to return and encouraging the deposition of sand and silt which build up into a flatter, more stable bank slope (SRCD 1996). Streambank stabilization structures often incorporate live wood cuttings, often willow, which will root into the structure over time and help further stabilize banks (SRCD 1996, Flosi et al. 2010a,b)

All of these methods are generally considered to be effective for reducing erosion, but their success also depends on correcting the factors contributing to erosion in the first place, such as unsustainable riparian grazing pressure. The cost of bank stabilization projects can vary widely depending on the techniques used, but estimates from Washington State suggest a range of $46,000 to $222,000 per river mile (PSMFC 2010).

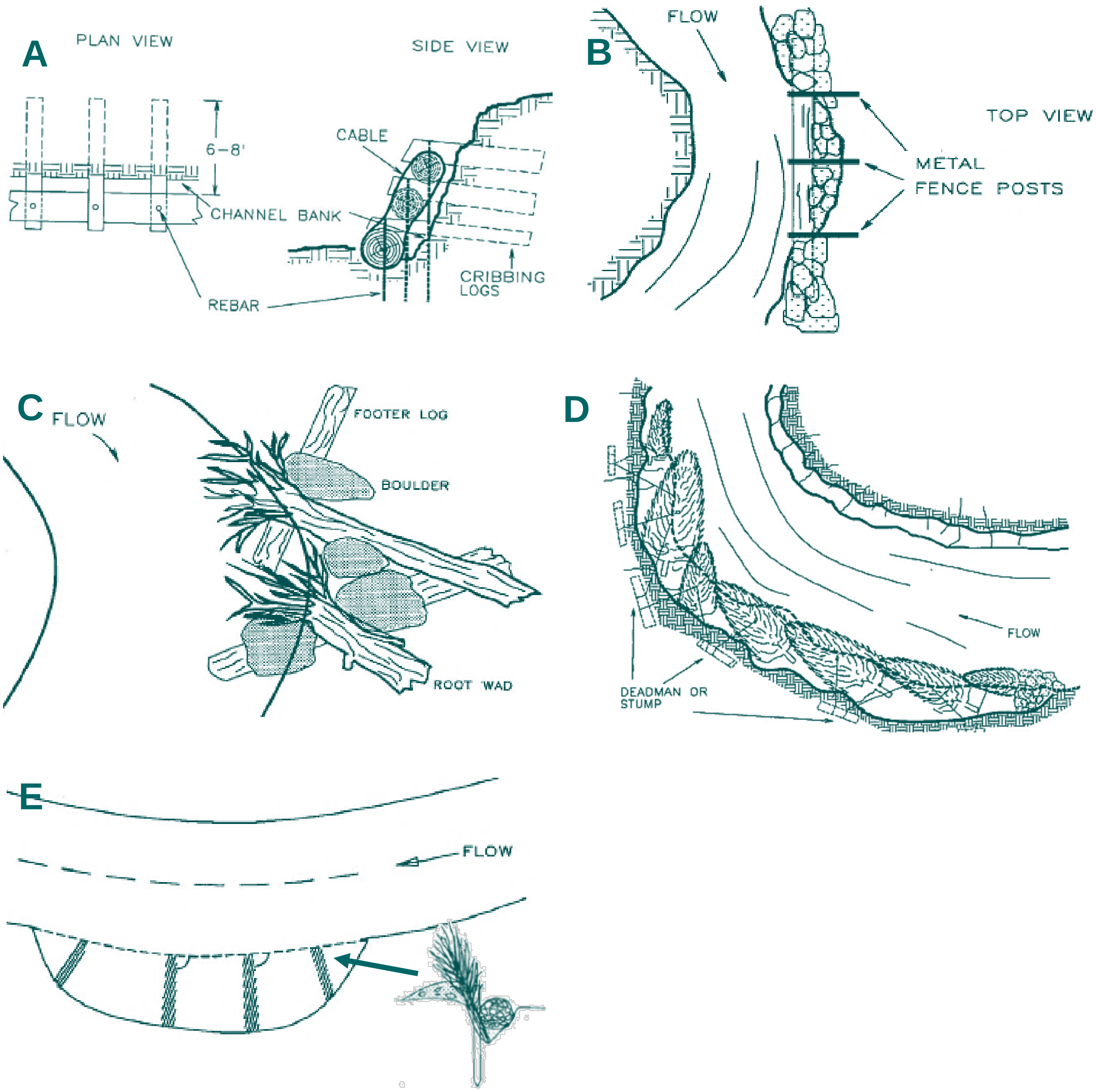



Figure 6-23: Schematics of some of the types of structures commonly used for streambank stabilization, including log cribbing (A), log bank armor (B), native material revetment (C), tree revetment (D), and willow siltation baffles (E). Adapted from CDFW / Flosi et al. 2010.

## *Spawning Gravel Placement*

Altered sediment transport and flow regimes in regulated rivers can limit the transport and deposition of suitable spawning gravel in otherwise healthy stretches of river. Spawning gravel placement typically involves depositing clean spawning gravels into piles along the edges of a river, usually just downstream of a dam. Gravel is placed under the assumption that high flows in the near future will entrain and distribute gravel downstream as bars or riffles. Instream structures may be deployed at the same time to help recruit gravel downstream. (Wheaton et al.

2004). Where flows are not sufficient for entrainment, gravel may need to be placed directly at the target location for spawning enhancement. Historically, much of the research on spawning gravel augmentation techniques and effectiveness has been in the research literature and inaccessible to practitioners. In response, a group of researchers at UC Davis developed the Spawning Habitat Integrated Rehabilitation Approach (SHIRA) to condense best practices into a step-by-step guide for practitioners interested in pursuing spawning habitat rehabilitation in a systematic way (Wheaton et al. 2004). This framework aims to maximize the effectiveness of spawning gravel rehabilitation projects through design testing in a modelling framework to ensure, for example, that hydrodynamic conditions at proposed restoration sites are suitable for gravel distribution or retention (Wheaton et al. 2004). Uncertainties in gravel restoration remain, and research into the best methods and approaches continues (CALFED 2005).

Supplementing appropriate reaches with gravel expands the amount of suitable spawning substrate and also benefits later life stages by providing habitat for macroinvertebrate food sources (Wheaton et al. 2004). Evaluations of the effectiveness of this restoration technique in the literature are limited primarily to short-term studies, but generally report a positive response in salmonid habitat use, spawning, and or embryonic survival (Roni et al. 2008).

The costs of gravel placement are typically calculated by cubic meter, and costs for gravel purchase, cleaning, placement, and labour can be as high as $20 /ton for gravel injection at upstream locations or up to $33 / ton for direct placement at target spawning sites. Ideally, gravel is sourced from within the same basin, but should not borrow from other streams. In the Klamath Basin, reclaimed tailings from gold dredgers may serve as a suitable source of gravels for these types of projects (Cramer Fish Sciences et al. 2010).

Beyond spawning gravels in upstream reaches, gravel habitat along floodplains may have been degraded by gravel pit mining operations that were once common in this region. The Nature Conservancy and EcoTrust have developed the Prospect-R[49] decision-support tool to help users determine the feasibility of former gravel pit mine restoration in the Willamette Basin, with wider applicability to other systems.

### *Beaver Dams and Analogs*

Beavers are ecosystem engineers that play a large role in shaping the hydrology of rivers where they are present, sometimes to the benefit of salmonids when dams raise water levels during spring runoff, and sometimes to their detriment when dams completely inhibit fish passage.

In some circumstances, it is possible to successfully reintroduce beavers into a watershed that would benefit from dams (Pollock et al. 2015). Where reintroducing beavers is not desirable or possible (e.g., relocation is illegal in California), restoration programs sometimes seek to replicate the ecosystem engineering effects of beaver using beaver dam analogs (DeVries et al. 2012, Pollock et al. 2012, 2017). One method that has been successfully implemented is the construction of several log flow choke structures throughout a stream segment that mimic the function of beaver dams in slowing flow while allowing fish passage. However, other channel-

[49] https://www.conservationgateway.org/ConservationByGeography/NorthAmerica/UnitedStates/oregon/freshwater/willamette/Pages/Prospect-R.aspx

spanning designs such as those employed in the Scott River watershed may limit or prevent upstream passage of juveniles. When placed at appropriate locations, these structures promote increased frequency of flooding and produced deeper, cooler pools, restored connections with floodplain swales and relict channels, and promoted the development of riparian vegetation (DeVries et al. 2012). Slowing flows also has the effect of contributing to elevation of the water table and increased groundwater recharge (Pollock et al. 2015). Moreover, these structures create conditions that tend to attract more beaver into the area in watersheds where they are present. This method was found to be a simple, inexpensive, and effecting means of “kick-starting” natural floodplain restoration processes in a more holistic way than riparian replanting alone (DeVries et al. 2012). These and other beaver dam analogs require regular repair and maintenance, just as do natural beaver dams, and this requirement should be considered in project planning and implementation (Pollock et al. 2015). The USFWS has produced an extensive Beaver Restoration Guidebook providing guidance for managers wishing to plan and implement projects for voluntary beaver recolonization, trapping and relocate beavers, or installing beaver dam analogs (Pollock et al. 2015). Recent studies have begun to quantify the ecosystem benefits of beaver dams and their analogs. A watershed-scale experiment in eastern Oregon found that beaver dam analogs significant increased density, survival, and production of juvenile steelhead without affecting migration (Bouwes et al. 2016b). Beaver dams and analogs enhance groundwater-surface water connectivity, buffer against large diel temperature ranges, and create thermal diversity (Weber et al. 2017)


Figure 6-24: Natural beaver dams (A) and beaver dam analogs (B) can slow flows, encourage flooding, and promote river meander and reconnection with floodplain and relict channels, and promote regrowth of riparian vegetation, while in most cases still allowing for fish passage. Photos by Michael Pollock, reproduced from USFWS / Pollock et al. 2015.

## *Wetland Restoration*

The conversion of wetlands into agricultural land can significantly reduce the availability of larval and juvenile rearing habitat for resident fish, particularly endangered suckers. Projects to restore these habitats typically involve grading and eventual breaching of levees, using heavy equipment or explosives, which were originally built to hold back and then drain water from the lands. Lands are rapidly flooded again following breaching, and historic channels may need to be excavated to fully re-establish hydraulic connections between the rivers, wetlands, and lakes (Erdman et al. 2011, TNC 2017). Breaching has been found to be more cost-effective than maintaining aging levees, and provides new fish and wildlife habitat, improves water quality, and creates new recreational opportunities (PSMFC 2000). Natural recruitment of wetland vegetation back into restored areas is generally sufficient, but planting is sometimes carried out on high wetland areas to speed restoration (Steere 2000). In some cases there may be a drive to create new wetlands in areas where they did not exist before. In such cases, the soils, geology, and hydrology of the site must be carefully considered to determine whether it will hold water, which is generally a given for the sites of historic wetlands (Bonsignore and Liske 2000).

The effectiveness of wetland restoration projects is fairly unequivocal – fish species like sucker that depend on wetland recruit to restored sites and have been shown to be more abundant in larger restored wetlands than in lakeshore fringe wetlands that have not undergone restoration (Erdman et al. 2011).

As with many other types of projects, the costs of wetland restoration can vary widely depending on the scope of the project and nature of the surrounding land use. Costs may range from $1000/acre for very simple projects to over $100,000 per acre for complex tidal wetland restorations, presuming that a land purchase is not required. However, a general average cost for these projects has been estimated at $20,000 to $30,000 per acre. Of the total cost, an estimated 80% is spent on construction activities while the remaining 20% goes towards planning and permitting (Steere 2000).

## *Status and Trends in the Klamath Basin*

Many of the earliest projects in this category focused on the placement of instream structures, which became a popular stand-alone technique for erosion control from the 1920s through the 1960s. However, critical evaluations of instream structure effectiveness in the late 1960s concluded that these techniques were not as successful in steeper Western streams as they had been in the Midwest (KRBFTF 1991). Growing awareness of the underlying stressors driving fish population decline has led to a more holistic approach to instream restoration in recent years, where instream structures are used more judiciously and generally in combination with other channel rehabilitation techniques. Overall the frequency of instream habitat restoration projects has remained steady over time, while spending on these projects has increased dramatically in recent years to reflect the trend towards whole-channel rehabilitation. Examples in the Klamath Basin have included several large-scale channel rehabilitation and reconnection projects such as those carried out as part of the Trinity River Restoration Program.

More than 600 instream habitat restoration projects totalling over $130 million in spending have been carried out in the Klamath Basin, the largest share of which have involved placement of instream habitat structure such as large woody debris, baffles, or deflectors. Although there are more projects involving structure as compared to channel reconfiguration and connectivity, spending on the latter far exceeds spending on instream structures (Figure 6-25). This reflects the high relative cost of channel reconfiguration and connectivity projects, which typically require excavation using heavy equipment and take more time to complete than simply placing structures in a channel. Instream restoration actions are generally evenly distributed across the sub-basins with the exception of structure placement, which is strongly concentrated in the Lower Klamath River and Mid Klamath River sub-basins (Figure 6-26).

Wetland restoration is a more recent development, with little activity prior to the year 2000, followed by growth to a steady frequency of 10 to 20 projects in the Klamath Basin per year. Although there have been relatively fewer wetland related projects than other project types, they make up a large share of costs in this activity category with over $50 million in spending. This pattern is driven largely by projects related to the restoration of the Williamson River Delta, Sycan Marsh, and several National Wildlife Refuge wetlands in the Upper Klamath Lake sub-basin, but also reflects a growing trend towards the restoration or creation of diffuse small-scale wetlands for the purpose of treating irrigation tailwater returns (see Section 6.5.7).

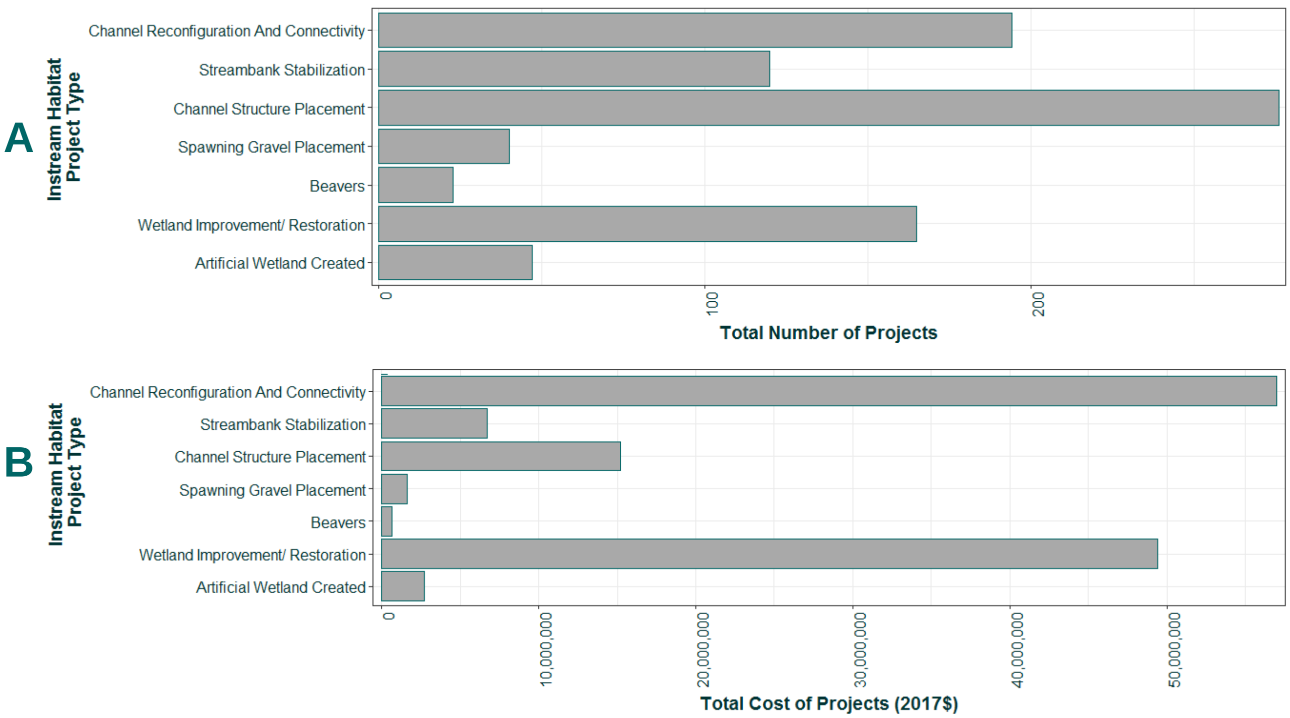



Figure 6-25: Distribution of the total number (A) and total costs (adjusted for inflation to 2017$) (B) of grant-driven instream habitat projects across activity types. Sources of data and methods described in Appendix H.

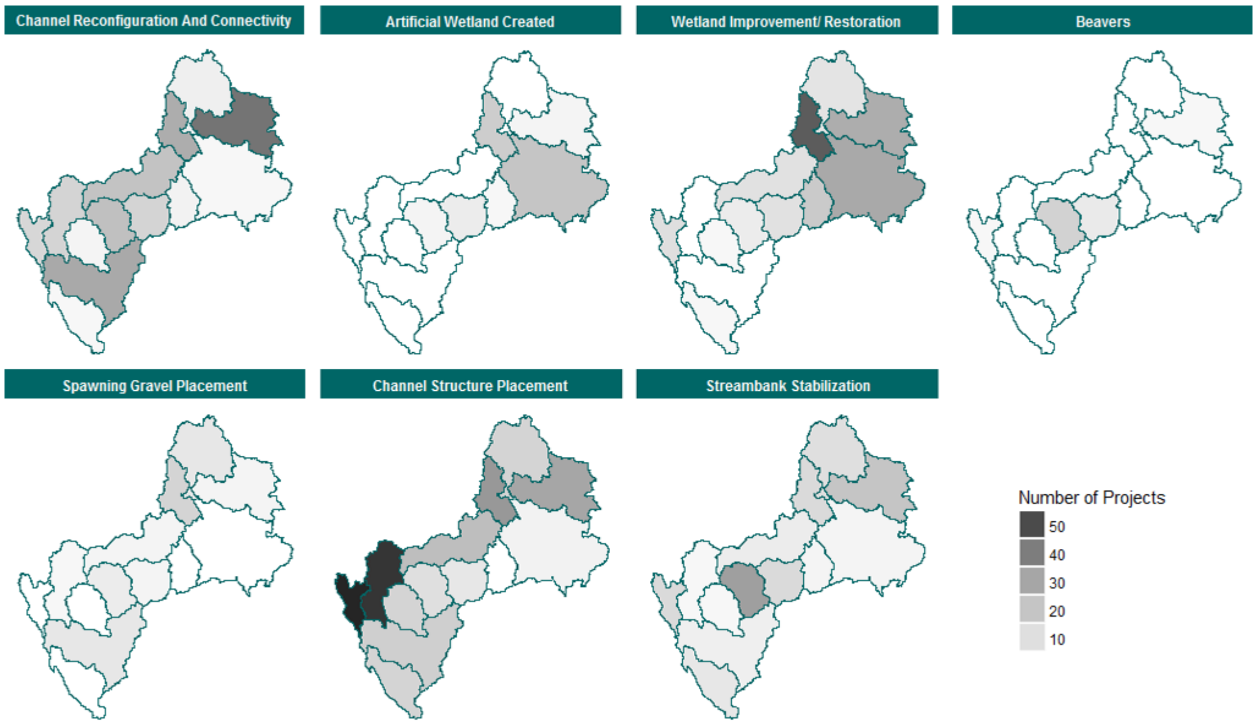



Figure 6-26: Distribution of the number of grant-driven instream and wetland habitat restoration projects of each action type across sub-basins. Sources of data and methods described in Appendix H.

## Examples of Implementation in the Klamath Basin

### *Sprague River Instream Channel Configuration and Connectivity*

In many places in the Klamath Basin, including the Sprague Basin, channels were straightened or channelized to maximize irrigation potential or flow around the boundaries of land parcels. These straightened channels often have high flow velocities that have exacerbated erosion and degraded fish habitat. A series of projects in the basin have sought to restore flows to historical channels. One such project was implemented at Bailey Flats, on the North Fork Sprague River, in 2009 and 2010 (Newfields and Kondolf 2012). This project sought to restore sinuosity to a river segment by plugging the new channelized reach to force the river back into roughly 2,000 feet of historical channel (Figure 6-27). The historical channel was excavated and this fill was used to build plugs in the straightened channel, and excess fill was used to create floodplain wetlands or off-channel ponds. Constructed banks in some parts of the historical channel were sloped and vegetated to improve stability, and large woody debris and other cover structures were added to protect banks, reduce flow energy, create pools, and enhance fish habitat for salmonids, suckers, bull trout, and other fish known to use this reach. The restored channel is intended to inundate the floodplain at flows greater than 400 cfs, helping to restore natural hydraulic processes in this area. The project was considered an overall success, and a post-project evaluation concluded that reoccupied historical channels achieved improvements in instream and riparian habitat and addressed chronic erosion (Newfields and Kondolf 2012).

However, the channel experiences higher than bankfull water levels within the first year after construction which deposited sediment in many of its pools. Although the reoccupied channel has undergone adjustments that reduced survival of riparian plantings, the channel is expected to reach a dynamic equilibrium over time without the need for further intervention. Ongoing monitoring will be required to determine if bed elevations will adjust or whether pool and riffle sequences are unsustainable in this reach under high flow (Newfields and Kondolf 2012).

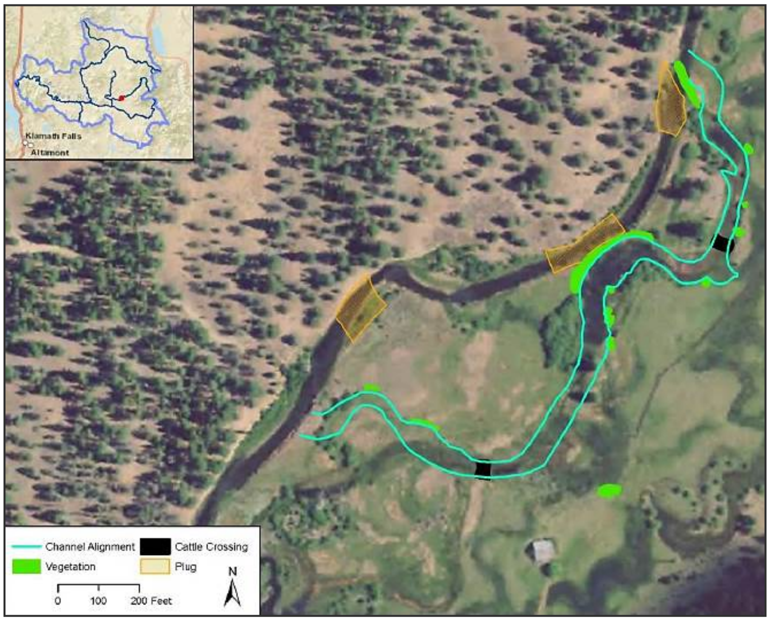



Figure 6-27: A schematic of the plans for remeandering a section of Bailey Flats on the North Fork Sprague River by plugging (orange) the channelized stream to diverting flow towards the historical channel (blue). Reproduced from Newfields and Kondolf 2012.

## *Construction of Off-Channel Rearing Habitat*

Extensive flood control berms along lower Seiad Creek have disconnected this prime floodplain habitat from the main river which would have once provided high-quality rearing habitat for threatened coho, which prefer slower, lower-gradient streams and pools than other salmonids. The Mid-Klamath Watershed Council has worked with landowners along Seiad and West Grider Creeks to construct six off-channel ponds, and has also built two other ponds at Camp Creek and Stanshaw Creek[50]. Ponds were excavated and the surrounding area seeded with grasses, and willows have been planted (Figure 6-28). These ponds have one connection to the creek and act as spring fed back-eddies that do not divert any water from the creek, but use creek level groundwater flow to fill. Subsequent studies have shown that juvenile coho now occupy most ponds throughout the summer, suggesting that they provide suitable rearing habitats (Krall 2016). In addition to their benefits for fish, these ponds are also contributing to restoration of the water table as they capture and hold winter flows that would otherwise flow swiftly downstream.

50 http://www.mkwc.org/programs/fisheries/channel-ponds/

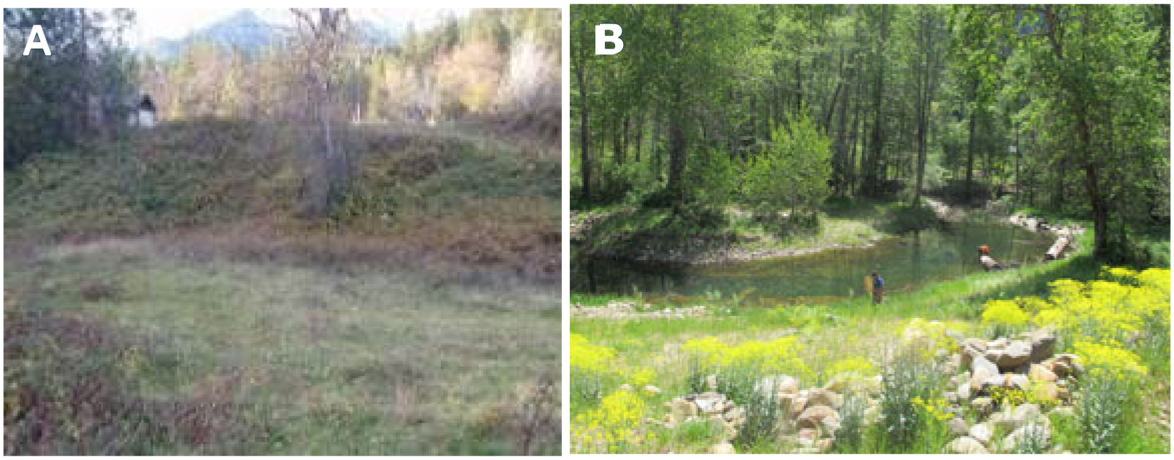



Figure 6-28: Photographs of the project site at Alexander Pond near Seiad Valley, CA, both before (A) and after (B) the construction of off-channel rearing habitat. Photos by the Mid-Klamath Watershed Council.

### *Beavers*

The Klamath Watershed Partnership has spearheaded a Klamath Basin Beaver Management Project that aims to "restore beaver to unoccupied habitat, mitigate beaver damage complaints in a timely manner, provide technical support for nonlethal control methods, identify suitable beaver colony relocation sites and provide a beaver restoration information/education network", and provide the foundation for a 10-year basin-wide beaver restoration effort.[51] To achieve these objectives, the program has convened a group of experts and volunteers to form a Beaver Management Team. To date, the team has created baseline historic, current, and potential beaver habitat assessment maps for the Sprague and Upper Williamson River areas; assisted local landowners in mitigating nuisance beaver activity causing flooding on roads and farmlands; identified suitable relocation sites and relocated several nuisance beavers to unoccupied habitat at higher elevations; and carries out ongoing outreach with the public.

In addition to managing natural beaver damming activities, other agencies in the Klamath Basin have also explored the use of beaver dam analogs. The Siskiyou Resource Conservation District (SRCD) carried out a pilot project using dams constructed from sand and covered by large sheets of plastic as analogs to slow and force flow into groundwater aquifers. Water from aquifers could then be released to improve flow conditions and fish passage during salmonid migrations. The project was considered extremely successful, with flows on the pilot section of the Scott River doubling for 17 days, and formed a foundation for future applications in the basin (SRCD 1995a). Further, in 2014, the Scott River Watershed Council (SRWC) began constructing a series of beaver dam analogues (BDAs) in Scott River watershed. Monitoring showed positive results: groundwater levels rose, a stream reach that previously went dry in summer remained wet through an entire drought year, thousands of juvenile salmonids utilized the habitats formed by the structures, and adult salmon and steelhead migrated upstream past the structures (Yokel et al. 2016).

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[51] http://www.klamathpartnership.org/BMP.html

### *Wetland Restoration*

The marsh at the mouth of the Williamson River in the Upper Klamath Lake sub-basin was once considered to be one of the most important nursery and rearing habitats supporting larval and juvenile sucker. In the early 1940s, private landowners constructed levees and drained nearly 6000 acres of marsh for conversion to pasture and cropland, resulting in habitat loss that is now considered a major driver of sucker decline. In the 1990s, The Nature Conservancy identified this area as a key restoration site and purchased the land with the intent of converting it back into wetland habitat. Two small-scale pilot restoration projects were completed on these lands in 2002 and 2003 with positive results for sucker recruitment and growth. These results set off plans for full-scale restoration of the site in collaboration with federal, state, and tribal partners. Restoration was achieved through levee breaching and hydrological reconnection to the Williamson River, Upper Klamath Lake, and Agency Lake, which restored access to roughly 2,500 acres of shallow water habitat by the time of completion in 2008 (Erdman et al. 2011, Erdman and Hendrixson 2012) (Figure 6-29). Subsequent monitoring across the project site confirmed that larval suckers are extensively using shallow areas of restored wetland and that larvae associated with wetland vegetation grew larger, suggesting that the increase of wetland vegetation accompanying restoration will further contribute to larval sucker success (Erdman et al. 2011, Erdman and Hendrixson 2012). Restoration in other areas surrounding Upper Klamath Lake will be more challenging due to the subsidence of some former wetlands after decades of diking. These areas would no longer be shallow wetlands upon re-flooding, but deeper water habitat that may require extensive construction or importation of fill or dredge material to restore elevation in order to achieve a functioning wetland that would yield ecological benefits for sucker and water quality (Erdman and Hendrixson 2012).

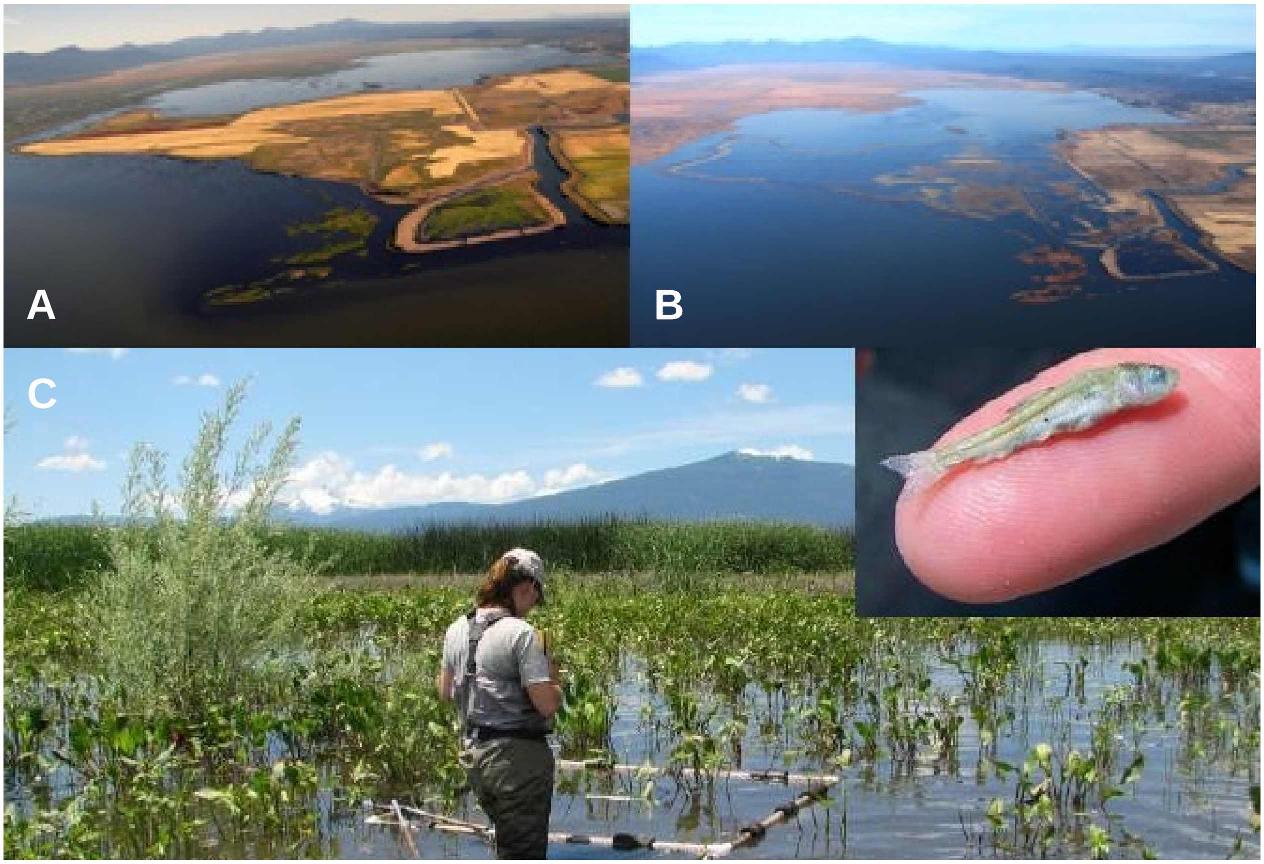


Figure 6-29: The Williamson River Delta before (A) and after (B) levee breaching and restoration activities in 2007. Subsequent monitoring (C) showed significant recruitment of juvenile suckers back into the restored wetland, demonstrating the effectiveness of the project in contributing to the recovery of endangered sucker. Photos reproduced with permission from The Nature Conservancy.

### 6.5.5 Riparian Habitat Restoration

#### *Definition and Effectiveness*

Riparian habitats provide food, shelter, and shade for large numbers of fish and wildlife species, including threatened and endangered salmonids, and play a crucial role in riverine process and function. However, a large amount of riparian habitat in the Klamath Basin has been lost or degraded due to logging, gravel mining, irrigation systems, agriculture, overgrazing by cattle, and invasion of non-native species. Loss of riparian vegetation has wide-ranging effects on river habitats, including loss of shade to temperature-sensitive streams, increasing streambank erosion, and changes in nutrient input (e.g., loss of organic nutrients, gain in inorganic nutrients from eroding soils) (Flosi et al. 2010). Riparian habitat restoration encompasses a wide range of techniques (Table 6-9) and is considered to provide high and wide-ranging benefits for relatively little effort in comparison to other methods. As a result, it is one of the most popular tools in the restoration toolbox (Newfields and Kondolf 2012).

Table 6-9: Riparian Habitat Restoration Project Work Types*.

| Work Type | Definition |
|---|---|
| Riparian planting | Riparian planting or native plant establishment. |
| Fencing | Creation of livestock exclusion or other riparian fencing. |
| Riparian exclusion | Preventing or removing access to riparian areas by means other than fencing. |
| Water gap development | Installation of a fenced livestock stream crossing or livestock bridge. |
| Conservation grazing management | Alteration of agricultural land use practices to reduce grazing pressure for conservation (e.g., rotate livestock grazing to minimize impact on riparian areas). |
| Riparian plant removal / control | Removal and/or control (treatment) of non-native species, noxious weeds and other plants or invasive species that adversely affect the riparian zone or water table. |

* Based on restoration work types identified in the NOAA PCSRF Data Dictionary available in Appendix J and at https://www.webapps.nwfsc.noaa.gov/j/Docs/PCSRF%20Data%20Dictionary%20ver20%2004-08-13.xlsx

Because overgrazing is a common cause of riparian habitat loss, many projects involve the construction of livestock exclusion fencing to prevent future overgrazing. Fencing is designed depending on the type of animals that must be excluded, and is typically set back 25 to 200 feet from the river to allow natural meander during flood events. In some cases fencing may be installed temporarily until sufficiently large streamside vegetation is established that can withstand grazing (typically 10 years). Riparian fencing may be accompanied by the installation of alternative water sources to help keep livestock away from the stream (Anderson and Graziano 2002, Flosi et al. 2010). Where unsustainable forestry practices are the cause of decline, restoration may involve changes to forest management such as implementing buffer areas to prevent harvesting directly alongside streams (Flosi et al. 2010). In other cases, the decline of native riparian species has been brought about by the invasion of noxious weeds such as the giant reed (*Arundo donax*), which exclude native vegetation and consume large amounts of water. Where this is the case, restoration will instead focus on herbicidal or preferably manual weed removal and management. In some projects, removal of native vegetation is also needed when one type of native species is outcompeting others. This type of intervention is often known as riparian thinning or vegetation release, and has been shown to improve the survival of new plantings (Anderson and Graziano 2002, Flosi et al. 2010). The detailed plan for dam removal published by the Bureau of Reclamation includes plans for managing the anticipated colonization of exposed reservoir deposits in the period following drawdown by populations of invasive weeds already established around reservoirs (USBR 2012c).

All of the above interventions are typically paired with riparian planting to help more rapidly re-establish native vegetation in previously degraded habitat. Vegetation living in the riparian zone must be extremely tolerant to withstand winter flooding during high flows and hot, dry summers characterized by low flows. These requirements limit the range of species that can be used for riparian restoration to a few hardy pioneer species that pave the way for establishment of more diverse vegetation. These species include alder, willow, cottonwood, mulefat, and others suggested in the CDFW California Salmonid Stream Habitat Restoration Manual. Revegetation may be carried out using a number of methods, including (Flosi et al. 2010):

- broadcast seeding of native grass on hillslopes;
- instream sprigging of dormant willow cuttings;
- installation of native plants propagated in a nursery;
- transplanting of emergent species such as rush, tule or sedge; and
- direct seeding of native species.

Plants that are able to survive these conditions and successfully establish can grow at remarkable rates, in some cases up to 15 feet per year. As vegetation becomes more established it will begin to trap sediment which can provide more suitable habitat for successional vegetation and may also alter the hydrology of the stream. An estimated 20-50% of riparian planting projects experience damage from grazing by wild animals, including deer and beaver, and tubes or metal screens are increasingly used to protect plants until they grow old enough to survive grazing (typically 3-5 years) (Anderson and Graziano 2002, Flosi et al. 2010). Adequate site preparation and plant protection has been shown to significantly improve plant survival and thus project investment (Anderson and Graziano 2002).

The effectiveness of riparian planting and plant protection projects are wide-ranging and long-lasting. Over 10 to 20 years after riparian fencing on reaches of the Russian River, channels within enclosures were found to be narrower, have more variability in elevation, recruit more small and large woody debris, and remain cooler during summer months than control channels (Opperman and Merenlender 2004, Lennox et al. 2011). Enclosures that prevent riparian grazing have been shown to translate to increased density of juvenile cool-water fishes such as redband trout (Bayley and Li 2008). Implementing a riparian habitat restoration project can be a lengthy, labour-intensive process requiring 4-6 months for design and permitting and several months more for implementation. In fact, riparian planting is typically considered to be the most labour-intensive aspect of stream restoration. The costs of riparian planting are largely driven by labour and are estimated to lie in the range of $4,000 to $7,000 per river mile (Bair 2000). The costs of fencing material and labour for installation are estimated at $3.50 - $3.75 per foot (Trout Unlimited, pers. comm.).


Figure 6-30: Common methods employed in riparian habitat restoration projects include planting of dormant willow stakes that will take root in the spring (A), installation of native plants raised in nurseries (B), and protection of newly planted seedlings using metal cages (C). Plantings are usually carried out across large swaths of previously disturbed riparian habitat (D). Adapted from CDFW / Flosi et al. 2010.

## *Status and Trends in the Klamath Basin*

Given the large benefits it can yield at relatively low cost, riparian habitat restoration has been an integral component of Klamath Basin restoration activities since at least the 1980s and continues to account for a large and steady share of restoration activities over time. At least 1000 grant-driven riparian habitat restoration projects totalling close to $60 million in spending have been carried out in the Klamath Basin to date. The bulk of grant-driven projects are roughly equally distributed between riparian planting and fencing, which are generally carried out together. However, much more spending is attributable to riparian planting, which can be more labour-intensive than other methods (Figure 6-31). Riparian planting projects of general benefit to stream ecosystems have been fairly evenly distributed throughout the basin, which other projects targeting specific stressors are more localized. For example, fencing projects are most common in the Upper Klamath Basin, reflecting the high concentration of ranching in this area, and noxious weed control projects are overwhelmingly common in the Upper Klamath River sub-basin (Figure 6-32). The frequency of weed control projects in this region may be related to the propensity for utility corridors, vehicle traffic, and ongoing vegetation-management activities associated with dam operation to contribute to the spread of invasive weeds (see

Section 8.8.1 of PacifiCorp 2004a), as reflected by known infestations of invasive weeds in the areas surrounding reservoir shorelines in the basin (USBR 2012c).

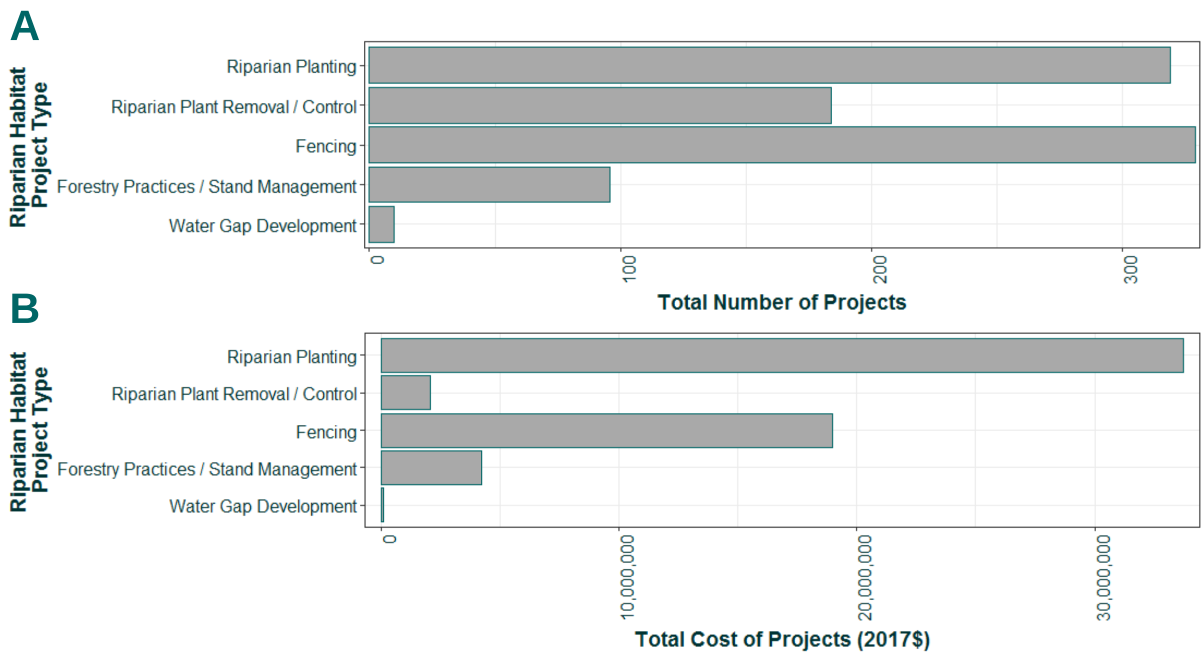


Figure 6-31: Distribution of the total number (A) and total costs (adjusted for inflation to 2017$) (B) of grant-driven riparian restoration projects across activity types. Sources of data and methods described in Appendix H.

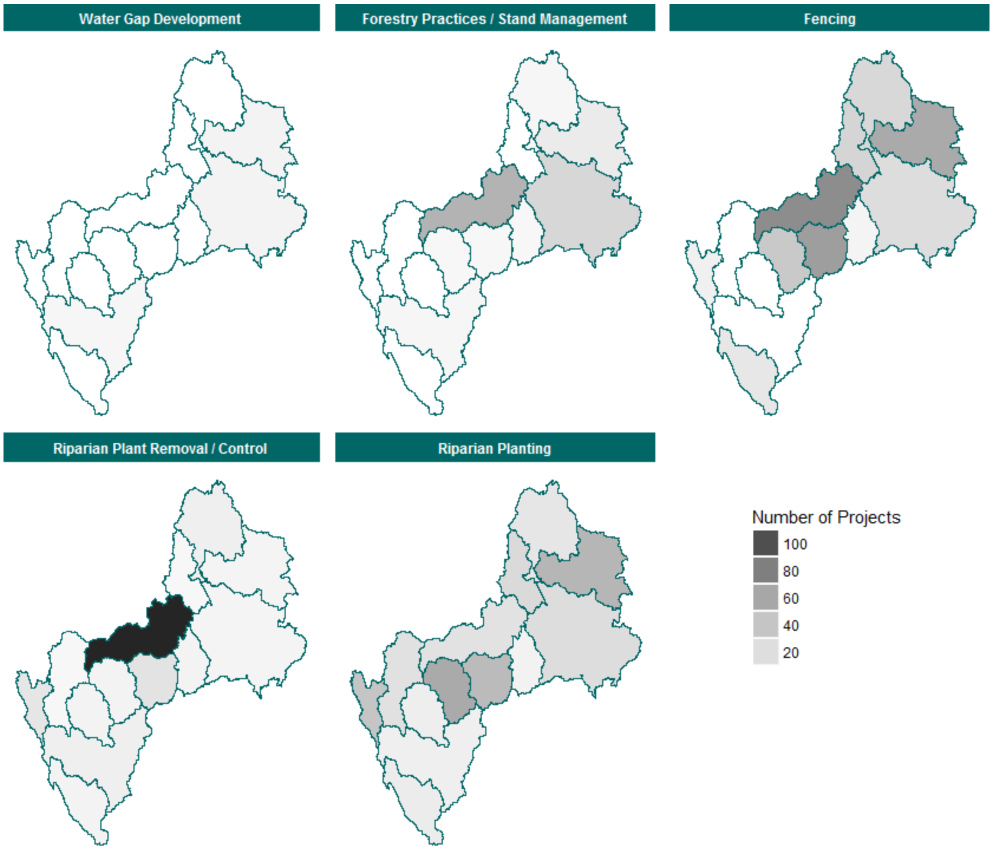


Figure 6-32: Distribution of the number of riparian habitat restoration projects of each action type across sub-basins. Sources of data and methods described in Appendix H.

## Examples of Implementation in the Klamath Basin

### *Lower Klamath Riparian Restoration and Tribal Plant Nursery Project*

The Yurok Tribe implemented a riparian habitat restoration project along two key tributaries of the Lower Klamath River that had been heavily impacted by historic logging and road-building. Restoration was carried out in Terwer Creek and McGarvey Creek, which are known to support anadromous populations of late fall-run Chinook salmon, coho salmon, steelhead, coastal cutthroat trout, and Pacific lamprey. Over 20,000 native conifers were planted over 200 acres across these two priority coastal watersheds. Survival of these trees after one year was over 80% for most species at most sites. In addition to planting, this project built and deployed 194 willow siltation baffles along the streambanks and gravel bars to help slow flows, promote fine sediment deposition and riparian growth, and provide immediate habitat benefits to fish (Hiner et al. 2011). This project also supported the expansion and maintenance of the Yurok Tribal Native Plant Nursery to provide native plants for restoration and cultural purposes, and to provide training, employment, and educational opportunities for Tribal and local community members (Figure 6-33). The project was completed in 2010 with financial support from the NOAA Coastal and Marine Habitat Restoration Program, the USFWS, the USBR, and other partner agencies (Hiner et al. 2011).

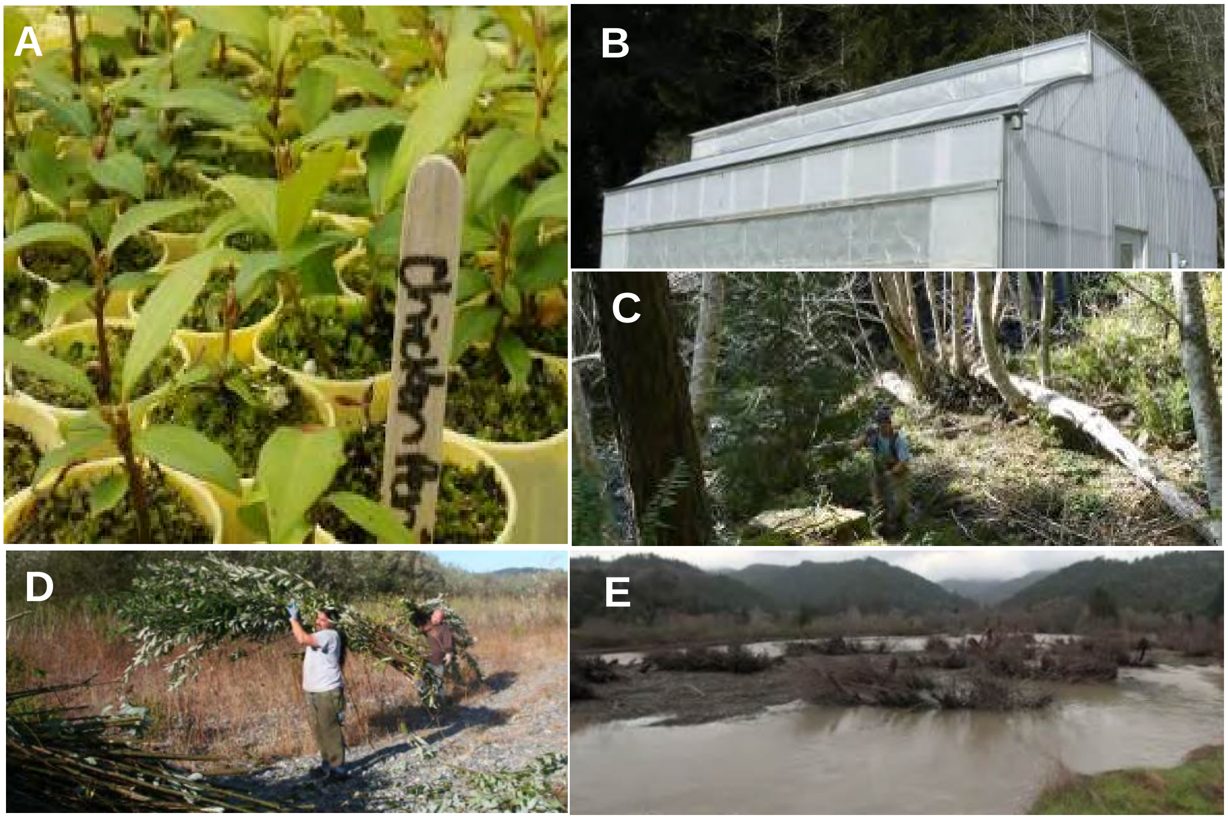


Figure 6-33: Native tree seedlings (A) from the Yurok Tribal Native Plant Nursery (B) were used in riparian planting projects at Terwer and McGarvey Creeks (C). This project also built (D) and deployed (E) willow baffles along the streambanks and gravel bars to help reduce erosion. Reproduced from Hiner et al. 2011.

### *Riparian Fencing*

The Klamath River Riparian Fence Project designed and built three segments of livestock exclusion fencing along both sides of the Klamath River 2 miles upstream of Copco Lake, near Shovel Creek (Figure 6-34). In addition to the fence, riparian planting was carried out to accelerate re-establishment of riparian vegetation and diversity. The wood post and barbed wire fences were designed and built to tie into existing natural barriers to livestock movement and also encompass a small emergent wetland area, and included public access gates for maintenance and to enable fishermen to reach the river. By the time of project completion in 2001, over 4,000 feet of fence has been constructed in 3 pastures on both sides of the river. This project was carried out by PacifiCorp and is expected to reduce grazing related impacts to riparian habitat and water quality.

Figure 6-34: Riparian fencing and new willow plantings along a previously overgrazed section of the Klamath River, near Shovel Creek. Gates were installed (inset) to prevent damage to the fence from attempts by the public to access the river. Reproduced from USFWS / PacifiCorp 2001.

## 6.5.6 Upland Habitat and Sediment Management

### *Definition and Effectiveness*

This category of work encompasses landscape-level projects implemented above the elevation of the riparian zone, above the floodplain, that are intended to benefit fish habitat primarily by reducing or eliminating excessive sediment flow from upland areas to restore a more natural sediment input balance to stream ecosystems. Characteristics of desirable sediment inputs will depend on the receiving environment and the species which use it (see Section 3.2.4). While salmonids benefit most from coarse sediments in which to spawn and may be negatively impacted by excessive deposition of fine sediments into gravels (Stanley and Doyle 2003), young lamprey ammocoetes rely on fine sediments for food and shelter in the period before they transition into juveniles (Streif 2008).

Table 6-10: Upland Habitat and Sediment Management Project Work Types*.

| Work Type | Definition |
|---|---|
| Road drainage system improvements and reconstruction | Road projects that reduce or eliminate sediment transport into streams. This includes placement of structures to contain/ control runoff from roads, road reconstruction or reinforcement, surface and peak-flow drainage improvements, and roadside vegetation. These roads may extend into or are in the riparian zone. |
| Road closure / abandonment | Closure (abandonment), relocation, decommissioning or obliteration of existing roads (including pavement such as parking areas) to diminish sediment transport into stream and/or improve riparian habitat. These roads/pavement may extend into or are in the |

| Work Type | Definition |
|---|---|
| | riparian zone. |
| Erosion control structures installed | Construction/placement of sediment basins, sediment collection ponds, sediment traps, or water bars (other than road projects or upland agriculture ). |
| Planting for erosion and sediment control | Upland projects that control erosion through planting and revegetation or grassed waterways. |
| Slope stabilization | Implementation of slope/hillside stabilization or slope erosion control methods including landslide reparation and non-ag terracing. |
| Upland vegetation management | Upland vegetation treatment or removal projects for water conservation or sediment control including plant removal (e.g., juniper removal or noxious weeds), selective tree thinning, undergrowth removal, prescribed burnings, stand conversions, and silviculture. |
| Upland agriculture management | Implementation of best agricultural management practices such as low or no till agriculture, conservation land management; or, upland irrigation water management for water conservation. |

* Based on restoration work types identified in the NOAA PCSRF Data Dictionary available in Appendix J and at https://www.webapps.nwfsc.noaa.gov/j/Docs/PCSRF%20Data%20Dictionary%20ver20%2004-08-13.xlsx

### *Road System Improvements or Decommissioning*

Many of these projects focus on improving or decommissioning unpaved forest roads, which represent one of the major source of sediment input in the Klamath Basin (Cover et al. 2008, Colombarol and Gavin 2010). Roads may deliver sediment into watersheds through three main pathways: chronic surface erosion from road surfaces, ditches, or cutbanks; road-related landslide erosion resulting from failure of fill slopes, hillslopes, or cutbanks; and stream crossing erosion resulting from washouts; and all of these sources may be aggravated by runoff from storm events. However, not all of this sediment will necessarily end up in streams and roads must be carefully assessed through a road erosion inventory and prioritized for restoration based on their realized stream inputs (Weaver and Hagans 2000). Techniques for road improvement may involve resurfacing, installation of rolling dips to help drain water off the road, or conversion of an insloped ditched road to an outslope road to help disperse road runoff . Techniques for road decommissioning generally involve excavation of the road, mulching and deposition of fill in nearby areas, and improvements at the former road site such as decompaction to improve drainage (Weaver and Hagans 2000) (Figure 6-35). Road improvements and decommissioning rely on heavy equipment and can be costly compared to other types of restoration. Costs will vary widely according to the surrounding landscape and techniques used. For example, work on ridge roads or roads in upper hillslope areas may only cost between $5,000 and $10,000 per mile, whereas decommissioning roads in steep inner gorge slopes with many stream crossings may cost upwards of $50, 000 per mile (Weaver and Hagans 2000). Cost estimates for each type of intervention are shown in Table 6-11.

Time-series analyses of sediment input into the Klamath Basin have shown high sediment loads coincident with widespread logging and road construction in the 1950s through 1970s, followed by a dramatic decline in sedimentation. This improvement has been attributed to reduced logging rates, improved forestry practices, and the implementation of treatment programs for reducing sediment input from logging roads (Klein and Anderson 2012, Warrick et al 2013).

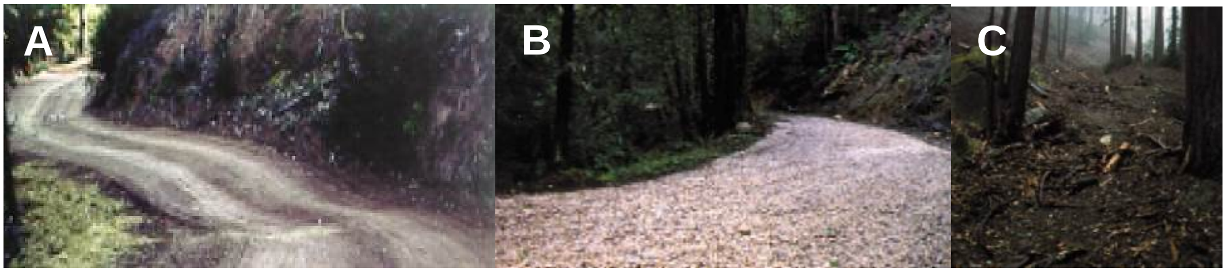


Figure 6-35: Road improvements to reduce sediment may include creation of "rolling dips" (A) or road resurfacing with gravel (B). Any removed fill may be redistributed on nearby lands and covered with straw or wood mulch to reduce erosion (C). Reproduced from PSMFC / Jani 2010.

Table 6-11: Typical techniques used in road improvement and decommissioning and their general cost range. Reproduced from PSMFC / Weaver and Hagans 2010.

| Treatment | Typical use or application | General costs[1] |
|---|---|---|
| DECOMMISSIONING TREATMENTS | | |
| Ripping or decompaction | Improve infiltration; decrease runoff; assist re-vegetation | \$500–\$1600/mile |
| Construction of cross- road drains | Drain springs; drain insloped roads; drain landings | \$1/ft (\$25–\$50 ea) |
| Partial outsloping (local spoil site; fill against the cutbank) | Remove minor unstable fills; diverse cutbank seeps and runoff | \$1/yd³; \$2500–\$9500/mile |
| Complete outsloping (local spoil site; fill against the cutbank) | Used for removing unstable fill material where nearby cutbank is dry and stable | Averages \$10,000+/mile (\$1/yd³) |
| Exported outsloping (fill pushed away and stored down-road) | Used for removing unstable road fills where cutbanks have springs and cannot be buried | \$1–\$4/yd³, depending on push distance |
| Landing excavations (with local spoil storage) | Used to remove unstable material around landing perimeter | \$1–\$2/yd³, high organics can increase costs |
| Stream crossing excavations (with local spoil storage) | Complete removal of stream crossing fills (not just culvert removal) | Averages \$1.50–\$3.50/yd³, but can vary considerably |
| Truck endhauling (dump truck) | Hauling excavated spoil to stable, permanent storage location where it will not discharge to a stream | \$3–\$5/yd³ on top of basic excavation work |
| UPGRADING TREATMENTS | | |
| Outslope road and fill ditch | Converting and insloped, ditched road to an outsloped road to disperse road runoff | \$170/1000 feet |
| Rolling dip | Constructed to drain the road surface and, if deep enough, the ditch | \$85 each |
| Rock road surface | Surface road using 1.5˝ to 2.0˝ crushed rock | \$4,250/1000 feet |
| Install ditch relief culvert | Culvert installation to improve dispersion of road and ditch drainage | \$550–\$650 each |
| Stream crossing upgrade | Culvert installation or replacement (in this case 36˝ x 40´ in a 200 cu yd fill) | \$2,445 each |
| Straw mulch | Mulch bare soil areas with 3000 lb/acre straw | \$13/1000 sq ft |
| *Costs are variable depending on material costs, equipment types and rates and operator experience.* | | |

1 - These are direct treatment costs for equipment working at a site. They do not include transportation, moving from site-to-site, overhead, supervision, layout, or any other costs. Costs will vary for site to site and from watershed to watershed. Heavy equipment treatments performed using D-6 and D-7 size tractors and hydraulic excavators with average 2 yd3 bucket size. Data from PWA and NPS, Redwood National Park (1992).

### *Upland Land Use Management*

Many other projects involve changes in upland land use practices related to vegetation, agriculture, and livestock management.

Much of the upland habitat management carried out to benefit river ecosystems in the Klamath Basin is related to managing the risks associated with wildfires. Nearly all of the native plants and animals in the Upper Klamath Basin evolved under active fire regimes, which were perpetuated by traditional Tribal burning practices (USFWS 2001). The natural regime of frequent but lower-intensity fires has played an important role in upland ecosystems by periodically clearing the fuel bed, facilitating the persistence of certain forest types (e.g., oak woodlands), and promoting the recruitment of large woody debris into streams where it increases channel complexity and improves fish habitat over longer time-frames (Harling and Trip 2014, Gresswell et al. 1999). However, these ecosystems have been disrupted by the more recent history of fire management practices that focused on maximal fire suppression, and many areas of the Klamath Basin have now not seen fire in over 100 years (Harling and Trip 2014). Such practices have resulted in changes to forest composition and the build-up of fuel biomass which have led to a greater frequency of high-severity wildfires which can lead to significant sediment input into watersheds, initially from charcoal and other fire debris, and later from bare soils no longer protected from erosion by vegetative cover (Villeponteaux and Greenberg 2005, Colombarol and Gavin 2010). The Western Klamath Restoration Partnership has been leading collaborative work in the lower basin towards a more natural fire management regime to improve forest resilience at the landscape scale and reduce the risk of high-severity fires (Harling and Trip 2014). The proposed integrated fire management plan will incorporate many typical fire management techniques, including manual or mechanical fuel reduction by thinning or clearing dense underbrush, creation of fire breaks within large stands, and prescribed burns (Harling and Trip 2014).

Upland vegetation management may also include reforestation of logged areas to reduce upland erosion. Upland agriculture management focused on implementation of best agricultural management practices such as low or no-till agriculture, conservation land management, and irrigation water management. Related upland livestock management may include the installation of off-stream watering sites to prevent the need for cattle to walk down and disturb streambanks in order to have a drink (Appendix J).

## ***Status and Trends in the Klamath Basin***

Historically, relatively little attention was paid to the role of upland habitat and sediment inputs in broader restoration efforts, with few documented projects of this nature before 1995. However, practitioners gradually came to recognize the fact that ongoing sedimentation may offset the benefits provided by other restoration actions such as riparian planting or instream structures and substantially limit the return on investment for these projects (KRBFTF 1991). This led to renewed interest in addressing sedimentation prior to or in concert with other restoration efforts. A CDFW review following the Klamath River fish kill of 2002 suggested that sediment barriers due to heavy winter runoff presented a barrier to migration, resulting in fish crowding in warm waters which contributed to mortality (CDFW 2003). This appears to have precipitated a major pulse of sediment reduction projects in 2003 and 2003 (Figure 6-2), in an effort to reduce the potential for sediment barriers to migration which are thought to have played a role in this mass mortality event. To date, at least 1000 grant-driven upland habitat and sediment management projects totalling over $100 million in spending have been carried out in the Klamath Basin. By number, the largest share of these projects is evenly distributed between upland vegetation management, which includes many fuels reduction projects, as well as road improvements or decommissioning, which has been concentrated in the Lower Klamath and Salmon River sub-basins given their long history of logging activity and many miles of unpaved logging roads. In terms of costs, however, most spending in this category can be attributed to upland vegetation management. This is partly due to the fact that many of the projects classified as upland habitat management in Watershed Conservation Board project data involve land acquisition for conservation easements (e.g., Noyes Valley Wildlife Area expansion at $1.7 million, Little Shasta Valley conservation easements at $4.1 million, Blue Creek land acquisition at $9.9 million). Projects other than road improvements and decommissioning have been roughly equally distributed across sub-basins.

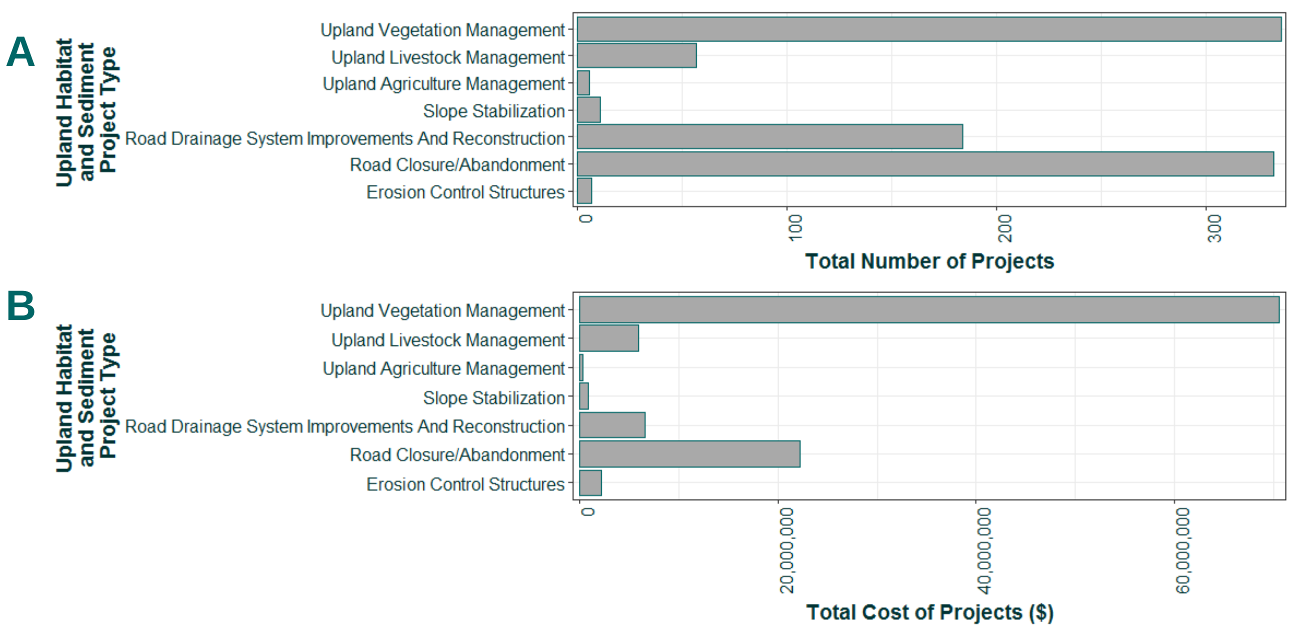


Figure 6-36: Distribution of the total number (A) and total costs (adjusted for inflation to 2017$) (B) of grant-driven upland habitat and sediment control projects across specific activity types. Sources of data and methods described in Appendix H.

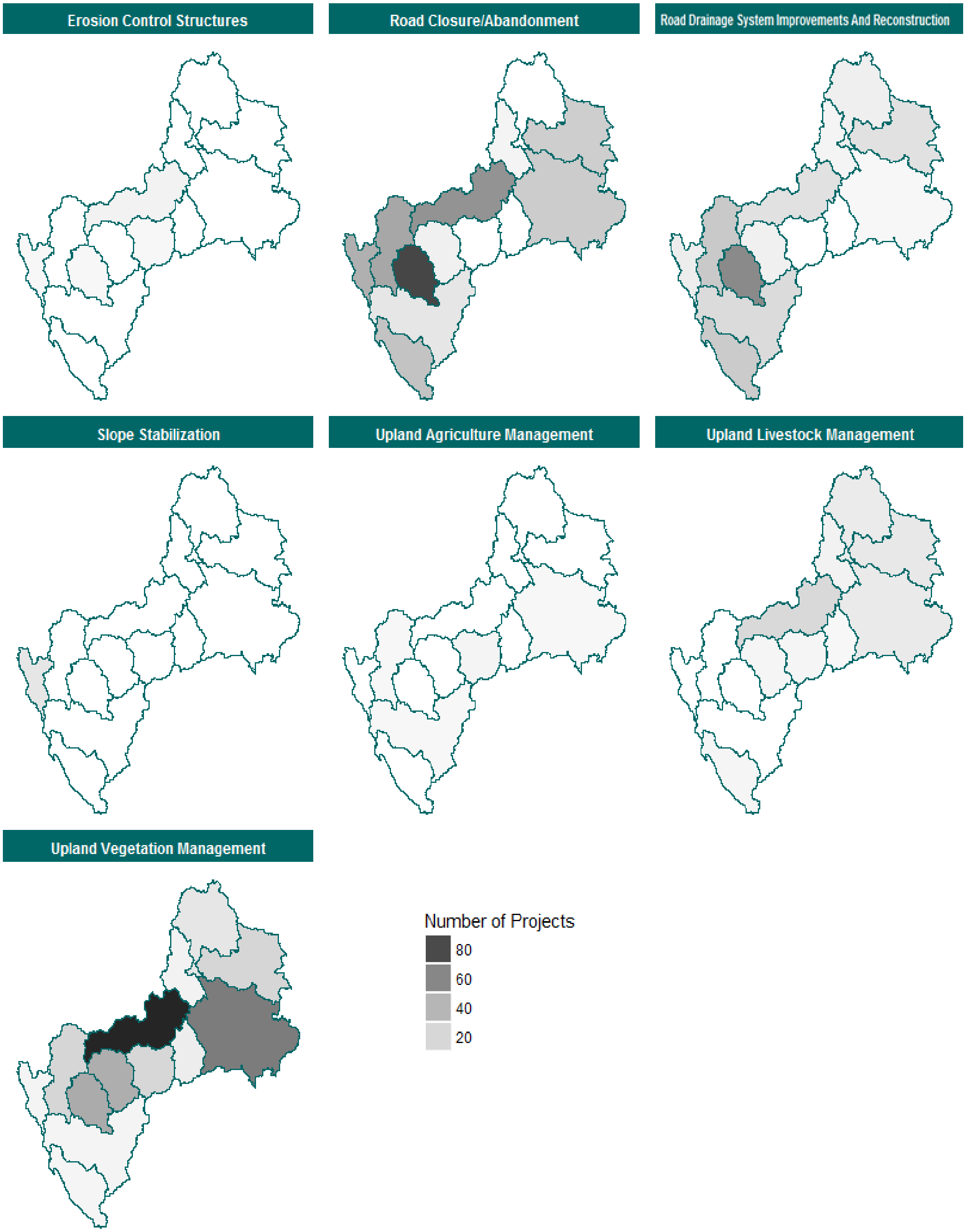


Figure 6-37: Distribution of the number of grant-driven upland habitat and sediment control projects of each action type across sub-basins. Sources of data and methods described in Appendix H.

## *Examples of Implementation in the Klamath Basin*

### *Road Decommissioning*

The Karuk Ecosystem Restoration Program began as a collaboration between the Tribe and the Klamath and Six Rivers National Forests to work towards mutual ecosystem management and watershed restoration goals and objectives, while providing training and employment opportunities to tribal members and the wider community (TerraWave 2001). This program initially focused on decommissioning unpaved forest roads contributing sediment into priority watersheds as determined from a prior road environmental assessment. The first project implemented by the program was the decommissioning 5.2 miles of Steinacher Road in the lower Salmon River sub-basin which was contributing sediment to Wooley and Steinacher Creeks. Full decommissioning was completed in three years and removed nearly 200,000 cubic yards of fill material, which was redistributed to stable road sections and mulched to reduce erosion (Figure 6-38). The project also removed culverts and fill from several stream crossings. At the time the project was executed, it represented one of the largest road decommissioning projects in the Pacific Northwest. This project was initiated in 1999 and completed in 2001 at a cost of roughly $1.8 million and with the help of 16 tribal members hired as part of the Karuk Department of Natural Resources Watershed Division. This work was carried out with financial support from the Northern California Indian Development Council, Inc. (NCIDC), Bureau of Indian Affairs (BIA), CDFW, USFWS, USFS, EPA, NFWF, and others. The majority of project expenditures went towards use of heavy equipment, followed by fees for contractors and personnel (TerraWave 2001). Subsequent phases of the overall program focused on decommissioning 64 miles of road in the East Ishi Pishi watershed and 74.5 miles of road in the Thompson watershed and converting a portion of these road systems to trails (TerraWave 2001). Since completion of this project, the Karuk Tribe has led the decommissioning of many more miles of road in this watershed as well as in the Happy Camp, Red Cap, Bluff Creek and Pearch Creek watersheds, along with many others (NCRP 2017a,b).

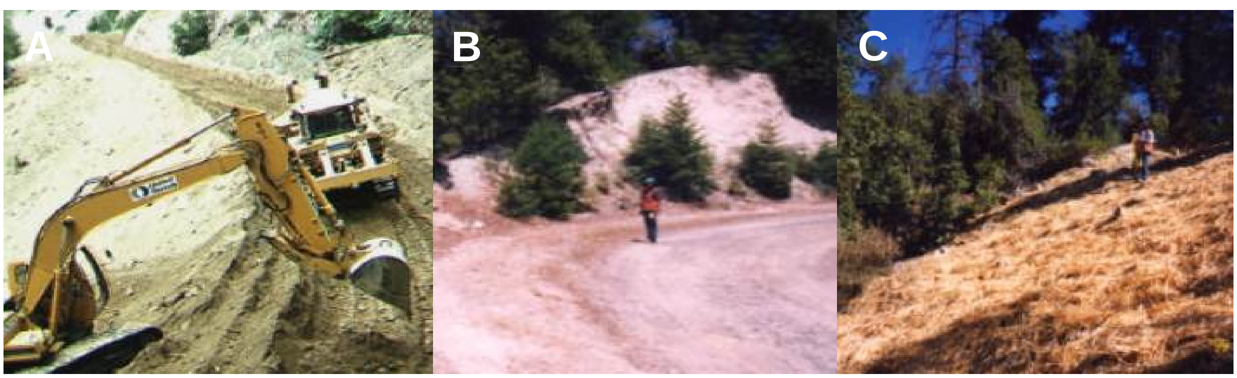


Figure 6-38: Road decommissioning along Steinacher Road in the Salmon River sub-basin. Fill excavated at some road segments (A) is used to backfill other through-cut road segments without fill (B), and is then covered with straw or mulch (C) to reduce erosion until vegetation can establish. Reproduced from NewWave 2001.

### *Upland vegetation management, fuel reduction, and fire management*

The Salmon River Restoration Council has implemented several upland vegetation management projects, including the Salmon River Shaded Fuel Break Construction & Riparian Fuels Reduction Project. The Salmon River sub-basin is recognized as having one of the highest degrees of fire risk in the Klamath National Forest. Over 44% of the basin has burned at some point over the last 100 years, and roughly 30% has burned or re-burned between 1985 and 2005, such that fire is considered to be the number one threat to fisheries and ecosystems surrounding the Salmon River. Whereas traditional tribal burning practices once helped to maintain a natural fire regime, over fifty years of fire suppression have led to the accumulation of flammable debris contributing to a high risk of catastrophic fires (Villeponteaux and Greenberg 2005). Fire fuels reduction is now a key component of watershed restoration activities in this basin to help prevent further fires which can denude riparian and upslope areas, generate significant sediment inputs, and contribute to higher stream temperatures in the short term through direct heating, and in the long term through loss of shading vegetation.

This project provided a crew of displaced timber workers from the community to help implement a comprehensive fuels reduction program and create fuel break systems, in addition to other restoration activities, across 71 acres of private lands in collaboration with private property owners. Shaded fuel breaks were created on priority parcels by thinning out more flammable species, removing dead vegetation, and trimming remaining trees and shrubs. This method reduces key fuel species while maintaining the overstory shading needed to prevent unwanted growth of flammable brush species in recently cleared areas. Breaks were designed to work in conjunction with natural barriers such as ridges, roads, and skid trails to maximize efficacy and were also created near riparian vegetation to protect riparian zones from advancing fire. Fuel reduction also provided an opportunity to remove invasive and noxious plant species to help promote further growth of beneficial species (Villeponteaux and Greenberg 2005). This project was completed in 2001 over the course of 200 worker-days and at a cost of approximately $30,000 and with financial support from the USFWS.

To help coordinate ongoing fuel reduction activities, the Salmon River Restoration Council has led the creation of a Salmon River Fire Safe Council and the development of an interagency Fire Management Strategy, in cooperation with the managing agencies, local tribe, local fire and rescue and community members (Villeponteaux and Greenberg 2005).


Figure 6-39: Workers carrying out manual removal (A) and stacking for disposal by controlled burning (B) of understory vegetation that contributes to increased fire risk in coastal forests. (USFWS / Villeponteaux and Greenberg 2005).

## 6.5.7 Water Quality Restoration

### *Definition and Effectiveness*

**See Also Box 1-1 – Ecosystem Components Considered by The Integrated Fisheries Restoration and Monitoring Plan and its Relationship to Water Quality**

This category of restoration actions include projects that directly improve instream water quality conditions for salmonids and other native fish such as Lost River and shortnose suckers or reduce the impacts of instream point/non-point pollution. This includes improved water quality treatment; return flow cooling; removal or prevention of toxins, sewage or refuse; reduction or treatment of sewage outfall and/or stormwater; and/or the use of natural or artificial wetlands. As discussed in Section 5.2, it is important to stress that the PCSRF classification of water quality projects is defined primarily by the type of physical work, rather than the stressor being addressed, and that many other types of restoration work described in this section (e.g., riparian habitat restoration, upland habitat management) also contribute to water quality improvements as shown in Table 5-1.

Table 6-12: Water Quality & Wetland Restoration Project Work Types*.

| Work Type | Definition |
|---|---|
| Water Quality Restoration Work Types | |
| Sewage clean-up | Reduction or clean-up of sewage outfall including failed septic systems. |
| Toxin reduction | Clean-up or prevention of mine or dredge tailings, herbicides, pesticides, or toxic sediments. |
| Livestock manure management | Relocation or modification of livestock manure holding structures and/or manure piles to reduce or eliminate drainage into streams. |
| Stormwater / wastewater modification or treatment | Modifications to stormwater/wastewater and drainage into stream to improve water quality. Includes bioswales and rain gardens. |
| Return flow cooling | Return flow cooling projects where extracted water that has heated during use is cooled before it is returned to the stream. This can occur in power plants, large industry, and smaller applications which generally consist of replacing old open return ditches with underground PVC pipe (purpose is eliminate to thermal loading by filtering flows underground where they can cool). |
| Sewage clean-up | Reduction or clean-up of sewage outfall including failed septic systems. |
| Wetland Work Types | |
| Wetland planting | Planting of native wetland species in wetland areas. |
| Wetland plant removal / control | Removal and/or control (treatment) of non-native species, noxious weeds and other plants or invasive species that adversely affect the wetland area or water table. |
| Wetland improvement/ restoration | Improvement, reconnection, or restoration of existing or historic wetland (other than vegetation planting or removal). |
| Artificial wetland created | New (artificial) wetland created in an area not formerly a wetland. This is wetland area created where it did not previously exist. |

* Based on restoration work types identified in the NOAA PCSRF Data Dictionary available in Appendix J and at https://www.webapps.nwfsc.noaa.gov/j/Docs/PCSRF%20Data%20Dictionary%20ver20%2004-08-13.xlsx

The principal techniques used for improving water quality in the Klamath Basin are wetland restoration or construction, improvements to irrigation systems, or tailwater capture and treatment, although there has also been interest in pilot algae filtration projects. Many other project types described so far also contribute to water quality by reducing sediment inputs, these are treated separately in previous sections. Although numerous other methods are available for improving water quality, including chemical treatment, mechanical aeration, and suction dredging, they have not to our knowledge yet been implemented beyond the pilot scale in the Klamath Basin and are not discussed further here (Stillwater Sciences et al. 2013).

### *Restoration of Natural Wetlands*

Wetlands function as natural water filters to sequester sediments, nutrients, toxins, and carbon dioxide from nutrient-rich agricultural runoff that flows through them on its way into lakes and streams, in addition to providing habitat for plants and wildlife. Moreover, restoring wetlands at higher elevations can help improve the ability of the landscape to absorb and slow the release of cold water into downstream reaches. This can create important cold-water refugia and help maintain cooler late-season stream baseflows to mitigate for warmer temperatures and reduced snowpack due to climate change (Williams et al. 2015). Due to their proven effectiveness for improving water quality, their self-sufficiency and low maintenance cost once established, and their aesthetic and ecological value, wetland restoration is an increasingly common component of watershed-level restoration. While an estimated 80% of historical wetlands in the Klamath Basin have been lost to land conversion, some are now making a comeback through restoration (Stillwater Sciences et al. 2013). Recent examples of this work in the Klamath Basin include the restoration of roughly 2,800 acres of wetland and associated river channels at the mouth of the Wood River, adjacent to Agency Lake, as well as the restoration of over 5,500 acres of wetlands in the Williamson River Delta, with the latter project described in detail as a case study in Section 6.5.4. Restoration of large natural wetlands can be costly and these costs can vary widely depending on project area and intensity. A recent review estimated that restoration of a hypothetical area covering 3,200 acres with a potential operational lifespan of 50 years projected to cost between $30 million and $150 million (Stillwater Sciences et al. 2013). By comparison, restoration of approximately 5,500 acres of wetlands and about 1,000 acres of riparian/uplands in the Williamson River Delta was completed by The Nature Conservancy at a cost of approximately $9 million (excluding the cost of purchasing the property) and is expected to incur ongoing maintenance costs of approximately $200,000 per year for two full-time staff and additional restoration and monitoring spending, although ongoing costs vary year to year (H. Hendrixson, TNC, pers. comm).

### *Constructed Treatment Wetlands*

Beyond natural wetlands, constructed treatment wetlands can be purpose-built in locations between the source of agricultural runoff and the natural watercourses it will return to. Treatment wetlands might be built in an existing or excavated ditch lined with a water-tight membrane or clay, to prevent runoff water from prematurely seeping into the aquifer, and wetland vegetation planted in porous media in the center of the depression. Water is filtered as it passes through the wetland vegetation, and is then returned through an exit pipe to the canal, river, or lake where it originated (CH2M 2012, Stillwater Sciences et al. 2013) (Figure 6-40).

These projects can be designed as large treatment wetlands closer to the point of runoff origination or re-entry into watercourses, or may be designed as multiple diffuse source (decentralized) treatment wetlands (DSTWs). DSTWs are designed to accommodate the estimated amount or residence time of runoff from adjacent agricultural flow canals, provide the similar filtration benefits as larger wetlands on a smaller scale, and can help to achieve the benefits of wetland ecosystems in multiple locations throughout a watershed. Because they are very small, they are low-cost and rarely require the more complex land acquisition processes or larger wetland projects and can instead be installed next to existing drainage ditches or in natural low points on agricultural landscapes (CH2M 2012, Stillwater Sciences et al. 2013).

In comparison to large wetlands, a DSTW system covering 5-10 acres with a lifespan of 15 years may be built for between $30,000 and $50,000 (Stillwater Sciences et al. 2013). Extensive studies are available on the prospective techniques, required area, and potential benefits of building treatment wetlands in the Upper Klamath Basin. This work has suggested that an additional stage of water filtration through lime rock, alum, or other absorptive chemical agents during runoff flow into or out of treatment wetlands can help to further improve water treatment efficiency (CH2M 2012).

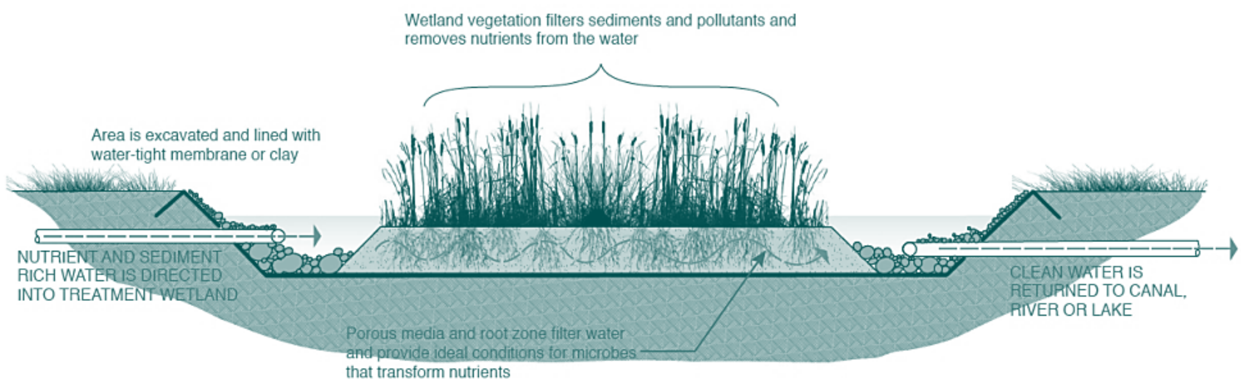


Figure 6-40: Cross-section of a typical treatment wetland. Reproduced from Stillwater Sciences et al. 2013.

### *Tailwater Reduction and Capture*

The fraction of diverted water used on agricultural fields which is not absorbed by plants, lost through evapotranspiration, or percolated into the aquifer, runs off fields as tailwater returns. Tailwater returns typically flow onto another property or back into the river, carrying absorbed heat, fine sediment, nutrients, and pollutants with them, and are considered to be a major contributor to poor water quality in many parts of the basin. Restoration projects addressing tailwater returns aim to reduce and/or capture tailwater before it reaches a stream and encourage its reuse for other purposes. Reducing tailwater is generally achieved through improving irrigation efficiency, which may involve lining irrigation ditches to prevent water loss through seepage or replacing ditches with a piped irrigation system. Capturing tailwater involves installation of piping to direct tailwater return flows away from the river and towards a pump, which collects it in a reservoir for reuse in irrigation in lieu of river water (SVRCD 2013).

### *Algal Filtering*

Filtering systems have been proposed as a restoration solution to address the prolific cyanobacteria blooms from Upper Klamath Lake currently affecting the Keno Dam impoundment (Stillwater Sciences et al. 2013). These blooms cause stressful or lethal dissolved oxygen and pH levels for aquatic species both within and downstream of Upper Klamath Lake. Additionally, some species also produce cyanobacterial toxins which can impact public health and impose an additional stressor on aquatic species (Stillwater Sciences 2013). A barge-based algae filtering system is already in intermittent use on Upper Klamath Lake to collect and refine some species of algae for commercial use as a dietary supplement. As part of KHSA implementation, the inter-agency Interim Measures Implementation Committee (IMIC) and a local algae harvest company evaluated the potential of an algal biomass removal system at the outlet of Upper Klamath Lake to remove nutrients and improve dissolved oxygen in the Keno Dam impoundment (CH2M 2016, 2017). The collected biomass could in turn be reused, depending on its toxicity, for human or animal dietary supplements, biofuels, soil amendment, compost, or landfill (Stillwater Sciences et al. 2013, CH2M 2016). Although the mechanics of this approach are understood, it remains unknown how much algae would need to be removed to significantly improve water quality. Regulatory agencies expressed concerns about the potential impact of algal biomass harvesting on endangered suckers (CH2M 2016, 2017). Due to these substantial regulatory hurdles, and the lack of a secure funding source for ongoing operating and maintenance costs, the IMIC decided not to continue evaluation of this technology (CH2M 2017). If these issues could be resolved, algal biomass removal could be the most cost-effective means to directly improve dissolved oxygen in Keno Reservoir in the interim period (i.e., years to a few decades) while waiting for watershed restoration in Upper Klamath Lake's tributaries to reduce phosphorus loading and diminish algal blooms. All IMIC project materials have been documented and are available for future use if the regulatory or funding environment changes (CH2M 2016, 2017).Status and Trends in the Klamath Basin.

Restoration efforts directed specifically to the improvement of water quality for ecosystem benefit, other than projects addressing sedimentation, have been far less common than other types of restoration in the basin. The majority of projects falling into this category involve the restoration of existing wetlands, which became more common after the year 2000, as well as the more recent trend towards the construction of new diffuse source treatment wetlands specifically built to capture and improve the water quality of irrigation tailwater returns (Figure 6-2). To date, more than 200 grant-driven water treatment and wetland restoration projects totalling over $70 million in spending have been carried out in the Klamath Basin (Figure 6-41, Figure 6-42), of which only a handful are water treatment projects not involving wetlands. However, as noted in Section 6.5.3, the true number of such projects is likely higher, as the datasets used for these summaries do not currently capture projects arising from Farm Bill spending that might also benefit water quality. Although there have been relatively few wetland related projects, they make up a large share of costs in this activity category with over $6 million in spending. This pattern is driven primarily by large-scale projects related to the restoration of the Williamson River Delta, Sycan Marsh, and several National Wildlife Refuge wetlands in the Upper Klamath Basin.

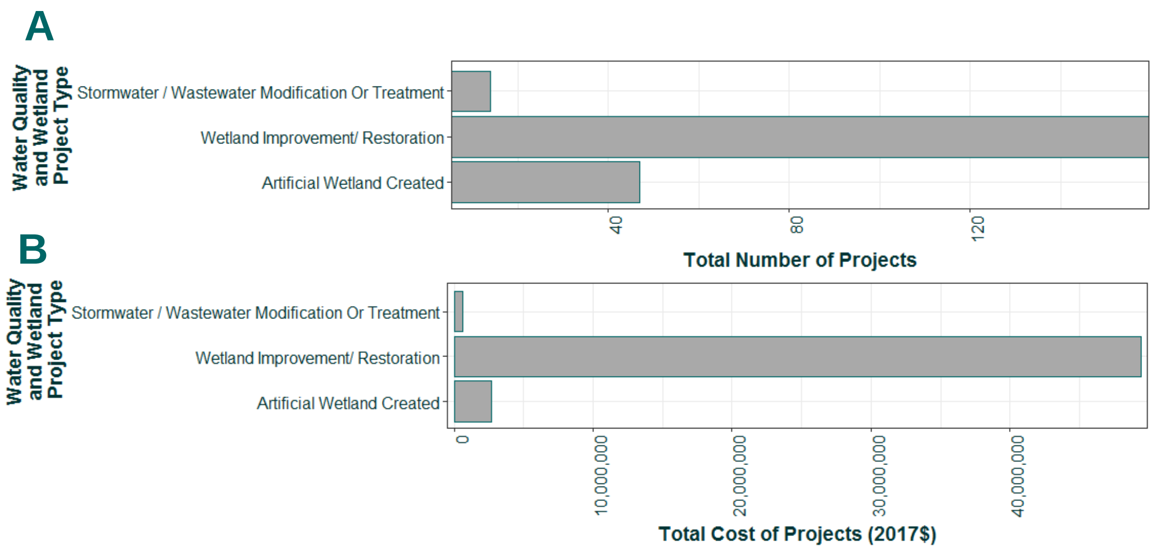


Figure 6-41: Distribution of the total number (A) and total costs ($) (B) of water quality and wetlands projects across specific activity types. Sources of data and methods described in Appendix H.

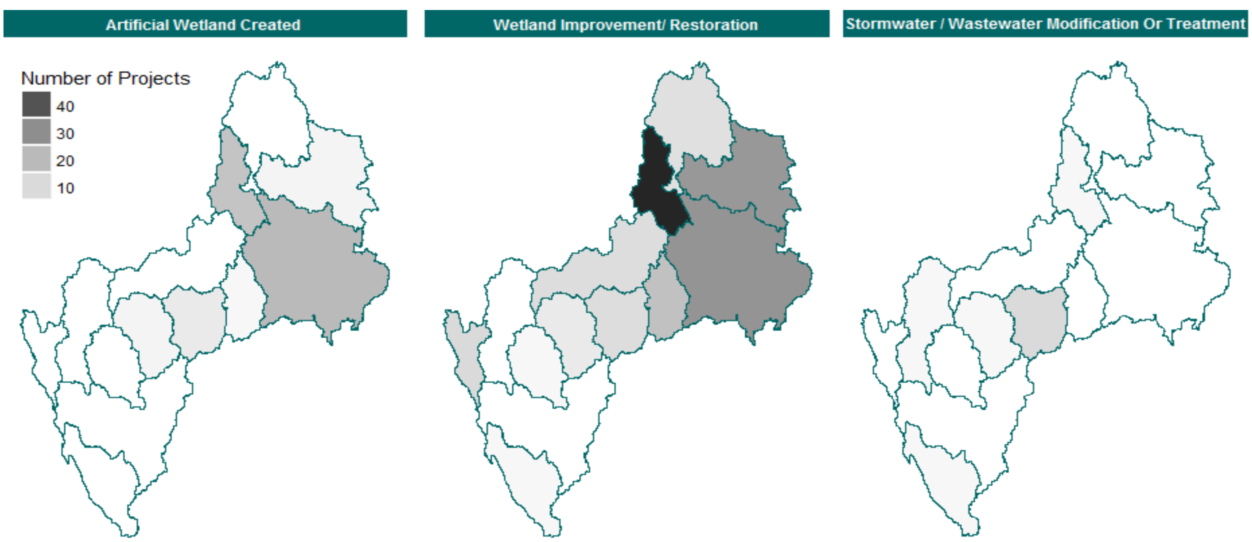


Figure 6-42: Distribution of the number of grant-driven water treatment and wetland restoration projects of each action type across sub-basins. Sources of data and methods described in Appendix H.

## *Examples of Implementation in the Klamath Basin*

### *Williamson River Delta Wetland Restoration*

We have already touched on methods of restoration used in the Williamson River Delta restoration project as well as the ecological benefits derived by resident fish in Section 6.5.4. Here, we will discuss only the effects of the restoration project on its second intended outcome of water quality improvement.

Flooding to restore the wetland initially caused the release of a large quantity of phosphorous stored in the underlying former agricultural soils. Monitoring immediately after re-flooding in 2008 indicated that phosphorous concentrations reached levels six times greater than in the surrounding lake. However, this amount was not as high as predicted by laboratory studies and is far less than the amount contributed by the active agricultural lands prior to re-flooding. This phosphorous pulse was expected to be a short-term phenomenon, and the expectation is that the wetland would eventually reach equilibrium and begin retaining nutrients again (Wong et al. 2011). Subsequent time-series analysis of nutrient budgets for Agency Lake and Upper Klamath Lake determined that decreasing trends in the total pumped inflow volumes and nutrient loads reflect the implementation of multiple wetland restoration projects in the area, including the Williamson River Preserve and Agency Lake Ranch projects (Alexander et al. 2014). Ongoing project monitoring found total phosphorous concentrations in 2012 were 2.5 times lower in shallow water habitats and 2 to 4 times lower in open water, deep water, and lake habitats that at the onset of monitoring at project completion in 2008 and is now considered to have leveled off to surrounding concentrations. Overall, the project is considered to have successfully reduced nutrient loading to Upper Klamath Lake while also restoring natural hydrologic regimes to the site and providing wildlife habitat (TNC 2013).

### *Sevenmile Creek, Wood River, and Sprague River Diffuse Source Treatment Wetlands*

This is an ongoing project to address water quality issues in the Upper Klamath Lake watershed. Treatment wetlands are intended to improve water quality by holding back water and removing nutrients and sediment though physical settling and uptake by plants. In 2014, two pilot treatment wetlands were constructed along the Sevenmile ditch and planted with tule (*Schoenoplectus acutus*) mats (Figure 6-43). At least two more wetlands will be constructed in the Wood River valley in 2017. Also in 2017, plans will be developed for the construction of additional treatment wetlands in the Upper Klamath Lake watershed, including the Sprague River basin. Project partners include Trout Unlimited, the U.S. Fish and Wildlife Service, The Klamath Tribes, the Oregon Watershed Enhancement Board, the National Fish and Wildlife Foundation, the California State Coastal Conservancy, PacifiCorp, the North Coast Water Boards, and private landowners. The estimated budget for this project is approximately $400,000 (Trout Unlimited, pers. comm.).

Figure 6-43: A photo of one of the diffuse source treatment wetlands (DSTW) that was constructed on Sevenmile Creek, along with riparian fencing to keep out livestock. Reproduced with permission from Trout Unlimited.

### *Shasta River Tailwater Reduction Project*

The North Coast Regional Water Quality Control Board identified tailwater return flows as a major factor contributing to elevated stream temperatures and nutrient enrichment/depressed dissolved oxygen levels in the Shasta River watershed (SVRCD 2013). The Shasta Valley Resource Conservation District (SVRCD) applied a watershed-wide planning and prioritization approach to identify high priority "tailwater neighbourhoods" in the watershed in need of intervention. This approach began with creation of tailwater accumulation models based on water rights allocations, land-use maps, and irrigation ditch distributions. The resulting 38 potential project sites were then subjected to a selection matrix to identify sites where significant flows return to the river, selection of sites where projects would yield the greatest benefits, and outreach was carried out with landowners to facilitate project implementation (SVRCD 2013).

This process was used to identify a suite of six sites for projects, of which three were tailwater re-use improvement projects, two were efficiency projects and one was a diversion redesign. The tailwater re-use projects installed piping and pumps at Meamber Ranch, Kuck River Ranch, and across Shasta River Water Association properties to collect and return tailwater runoff to pumps and reservoirs for re-use in lieu of river water. The efficiency projects installed a new headgate structure on Shasta Big Springs Ranch and replaced irrigation ditches with piping at Freeman Ranch, while the diversion redesign project repaired several sections of broken irrigation ditch at Hole in the Ground Ranch with new concrete lining to prevent water loss through leakage, all of which improved the efficiency of irrigation systems and allow landowners to draw less water from the river (SVRCD 2013). These projects were completed in 2013 at a total cost of nearly $1 million, with over $750,000 of these funds provided through an NRCS Clean Water Act 319(h) grant, and additional funds from Prop 50 IWRM funding and the local water resource conservation district. This work is anticipated to help improve water quality and contribute towards meeting EPA TMDLs for the Shasta River (SVRCD 2013).

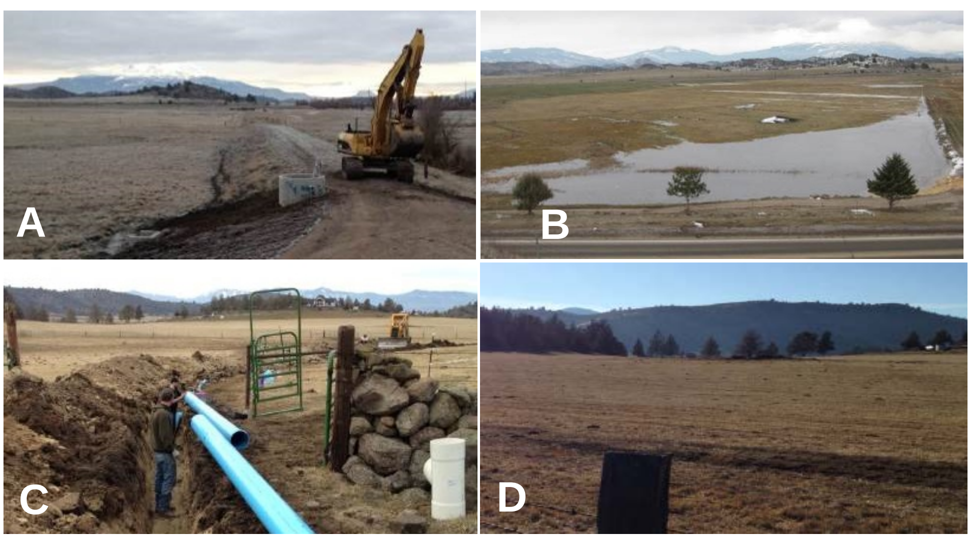


Figure 6-44: Implementation of projects part of the Shasta River Tailwater Reduction Project, showing installation of a standpipe on Meamber Ranch (A) to help collect tailwater for storage in a collection pond until re-use (B), and showing installation (C) of buried irrigation piping (D) on the Freeman Ranch to improve irrigation efficiency and reduce water loss through open diversion ditches. Reproduced from SVRCD 2013.

# 7 Monitoring Activities

This section synthesizes monitoring activities completed and underway in the Klamath Basin. Our assessment takes an integrative approach to explore the large number of monitoring activities basin-wide in a representative way. We consider projects under the two main types of monitoring identified in Section 5.4: a) Status and Trend Monitoring and; b) Project Effectiveness Monitoring. We are also careful to consider monitoring in the context of both habitat AND fish populations. This section is intended to provide baseline information to support identification of overlapping monitoring efforts, gaps, and priority monitoring objectives.

## 7.1 Overview of Monitoring and Challenges in the Klamath Basin

The collection of data relevant to fish restoration in the Klamath Basin is a multi-organizational effort that began as early as 1904 with the first U.S. Geological Survey (USGS) flow gage placed at Keno, OR (USDI et al. 2013). As with any such effort in large river basins, coordinating to avoid duplication and optimize sampling design is a challenge. During earlier stages of river basin governance, some organizations may have collaborated informally while many others worked independently in more isolated 'silos' that are largely disconnected from any sort of basin-wide goals. As common goals and inter-dependencies began to emerge over time, the need for a more integrative approach became apparent, as is currently the case for Klamath Basin fish restoration.

Integrating monitoring efforts in the Klamath Basin is an ambitious task. Differing human values and stressors for fish can fragment limited monitoring resources across multiple objectives. Over 32 organizations conduct monitoring in 12 Klamath sub-basins. How fish are valued differs throughout the basin, including: Tribes who share a deep cultural connection to salmon and suckers as a food source with spiritual and ceremonial meaning; fishers who derive livelihoods, sport and sustenance from various species; fisheries managers, academics and NGO staff who devote entire careers to improving fish populations; and farmers who benefit from healthy ecosystems to sustain crops and livestock but worry about how fish restoration efforts will affect their need for a predictable water supply. Klamath Basin fishes are faced with a complex array of anthropogenic and natural stressors, such as altered flow regimes from dams, diversions, pollution, floods, droughts, disease and invasive species. An intimate knowledge of the system is required to determine how best to track these stressors, their impacts on fish, and the effectiveness of management efforts to reduce impacts.

In the Klamath Basin, interested participants have risen to this challenge. Governance of fish restoration has been shifting in recent years from a fragmented collection of projects toward a more integrated approach that seeks to derive 'benefits of scale' by improving communication and cooperation among all participants who value the river and its network of tributaries. A collaborative foundation was built during development of the Klamath Basin Restoration

Agreement (KBRA) and the Klamath Hydroelectric Settlement Agreement (KHSA), albeit one that was shaken by a subsequent lack of funding to implement the KBRA. The Klamath Basin Monitoring Program (KBMP) also made significant headway, developing a basin-wide monitoring plan, bringing together water quality monitoring data from all corners of the watershed, developing metadata standards, and communicating/disseminating these data using interactive web mapping.

Other less comprehensive attempts at integrating information about monitoring efforts have also been rolled into restoration project databases including the CalFish California Habitat Restoration Project Database (CHRPD), NOAA's Pacific Coastal Salmon Recovery Fund (PCSRF) Project and Performance Metrics Database and Pacific Northwest Salmon Habitat Project Database, and the Klamath Tracking and Accounting Program (KTAP). Several other agencies provide monitoring data online that are specific to their focal areas. For example, time series flow data are available from USGS gages for several locations throughout the basin. In addition to data housed in formal and publicly available databases, many monitoring efforts are only tracked by implementing agencies. Information about these efforts is more difficult to synthesize since it may not be easily accessible in reports and databases that are publicly available online.

The goal of this synthesis report is not to be comprehensive in characterizing the state of fish restoration and monitoring in the Klamath Basin, but to be as representative as possible given the information collected. As such, this section relies on extensive document review, online databases, input received via key informant interviews, workshops, responses to information requests, and draft review comments. This section provides an overview of monitoring efforts in the Klamath Basin with the intent of providing representative baseline information that will support identification of overlapping monitoring efforts, gaps, and priority monitoring objectives.

Following the structure supplied in Section 5.3, we begin with Status and Trend Monitoring, (including Habitat and Population Monitoring) then Project Effectiveness Monitoring. In each section we address the different types of available information by providing: (1) qualitative summaries of major monitoring programs underway; (2) quantitative summaries of monitoring projects in existing databases (where applicable); and (3) syntheses of monitoring objectives specified in key plan documents (where applicable). In reviewing data derived from databases and represented as graphics throughout this section, it is important to note that **graphics communicating monitoring effort quantitatively are not representative of basin-wide efforts but rather a reflection of the data available in the respective database**. To understand monitoring effort in the Klamath in a representative way, it is important to combine this information with the qualitative summaries of major monitoring programs and syntheses of monitoring objectives expressed in plan documents.

### 7.1.1 Monitoring Design for Adaptive Management

The intent of monitoring for fish restoration is to increase knowledge of how best to protect and recover focal fish species, while minimizing undesirable effects and meeting authorized management purposes. Monitoring is crucial for learning and improving the effectiveness of restoration plans and actions. As discussed in Section 5.3, two types of monitoring are essential: **Status and Trend Monitoring** (to track progress towards overall goals and objectives) and **Project Effectiveness Monitoring** (to evaluate and adjust restoration and fish management actions).

Implementing monitoring within an adaptive management framework follows the adaptive cycle: (1) **Assess**; (2) **Design**; (3) **Implement**; (4) **Monitor**; (5) **Evaluate**; and (6) **Adjust** (see Section 8.2). While monitoring is a subset of the cycle, the entire series of steps can also be applied to any individual monitoring project. A monitoring plan should include appropriate statistical, sampling, measurement and response designs (Fischenich et al. 2016). **Statistical (or experimental) design** provides a logical structure for testing hypotheses, including identifying appropriate indicators and contrasts (across treatments, space and time) to meet monitoring goals. **Sampling design** delineates the process for selecting sampling units in space and time and sampling times/duration (Appendix M and Appendix N). **Measurement design** outlines specific performance measures and protocols used to monitor selected indicators at each sampling unit (e.g., watershed inputs, fluvial geomorphic processes, habitat attributes, fish populations) at the places and times defined by the sampling design. **Response design** explains how the resulting data will be analyzed to make inferences about hypotheses, status and trends, and action effectiveness.

All of these design strategies are selected using common planning stages including defining the problem, formulating options, and making decisions about those options. As described in Table 8-1, the steps of adaptive management can be blended with the steps of the Data Quality Objectives (DQO) process (EPA 2006) to determine the most cost-effective monitoring designs for providing key inputs to management decisions. This process works best when decision-makers work collaboratively with scientists and interested participants to keep technical experts focused on determining critical inputs to key decisions.

Monitoring offers opportunities to refine objectives and adjust strategies as required. Care must be taken to ensure that planned comparisons of management actions have a low risk of negative effects on listed species and habitat as well as on local people and their communities (Fischenich et al. 2016). Monitoring efforts can be monitored themselves by documenting deviations from plan design, tracking cost effectiveness, reviewing data quality and observing how and to what extent good principles for data management are applied (Fischenich et al. 2016). During evaluation, monitoring projects may be assessed based on whether key assumptions of the design were fulfilled in practice, if monitoring objectives were realized within cost targets (e.g., all specified data collection occurred within budget), and the extent to which project outputs assist in making management decisions intended to achieve overarching restoration goals (Fischenich et al. 2016).

The effects of implementing fish restoration projects should be monitored at an appropriate scale (e.g., stream reach, riparian area, upslope area, soils, groundwater, watershed, major basin), which will vary depending on the type of project and its extent of influence. The sampling design determines the best allocation of samples across space and time to answer the questions of interest, and ultimately provide required inputs to decisions.

A key monitoring objective is to support ‘actionable science’ – or science that provides data, analyses, projections and tools necessary to support decision-making (ACCCNRS 2015). The Department of Interior’s Advisory Committee on Climate Change and Natural Resource Science suggests this type of science is best produced when there is interdisciplinary collaboration among scientists, decision-makers and interested participants working in concert, clearly defined decisions requiring science-based support, and flexibility to redefine ‘actionable’ based on periodic evaluation and evolving views of risk.

## 7.2 Status and Trend Monitoring

This section splits status and trend monitoring into two main categories: (1) **Habitat Monitoring** and; (2) **Population Monitoring**.

### 7.2.1 Habitat Monitoring

In the context of the IFRMP, **Habitat Monitoring** refers to monitoring of instream and out-of-stream metrics that are necessary for fish survival, growth or reproduction across their entire life history. Table 7-1 lists examples of habitat monitoring categories and indicators that are potentially relevant in the Klamath Basin.

Table 7-1:Habitat monitoring categories.

| Category | Examples of Indicators |
|---|---|
| Barriers and Injury | dams, natural barriers, entrainment/impingement, turbines, beavers, unscreened water diversions; minor impoundments |
| Ecological interactions | primary productivity, secondary productivity, predation, invasive species, pathogens |
| Flow | peak flow, minimum flow, flood, flow regime (magnitude, timing, velocity), overallocation/diversion, variability, flow frequency curves, flow augmentation, inflow/outflow (water balance), irrigation withdrawals |
| Groundwater | groundwater pumping, aquifer levels |
| Marine/estuary | ocean conditions, loss/degradation of saltwater transition zone, loss/degradation of shallow water near-shore habitat |
| Riparian & Landscape | riparian conditions, LWD recruitment, floodplain inundation frequency, floodplain connectivity, freshwater wetlands and marshes, status of riparian corridors, stream shade, livestock, fires, macro-invertebrates, rearing habitat, urban/residential development; hillslope; landslides |
| Sediments & Gravel | fine sediment, coarse sediment, sediment transport/bedload transport, gravel augmentation |
| Stream Morphology | bed & channel form, instream structural complexity, alluvial features, bars/pools/riffles, refugia, LWD |
| Stream Temperature | peak and average water temperatures during key periods for different life history stages of focal fish species, diminished cold/cool habitats & refugia, irrigation tailwater (thermal loading) |
| Water Quality | pH, turbidity, toxic contaminants, cyanobacteria toxins, algal blooms, dissolved oxygen, nutrients, macro-invertebrates, atmospheric/wind |
| Fish Habitat | area of habitat suitable for particular life history stages of focal fish species at different flows |

## 7.2.2 Major Habitat Monitoring Programs

### Federal Agencies and Programs

**NMFS Pacific Coastal Salmon Recovery Fund (PCSRF) Database – Habitat Monitoring**

After the development of project performance metrics in 2005 and 2010, the NMFS Pacific Coastal Salmon Recovery Fund (PCSRF) launched a project database and interactive web map (https://www.webapps.nwfsc.noaa.gov). This database catalogues PCSRF grant-funded restoration projects in the Klamath Basin from 2000 to 2016, more than 92 of which had habitat monitoring objectives (NMFS 2016b). Most general habitat monitoring and water quality monitoring projects took place in the Trinity sub-basin. PCSRF funded flow monitoring was most frequently located in the Mid Klamath River and Upper Klamath River sub-basins (see Figure 7-1).

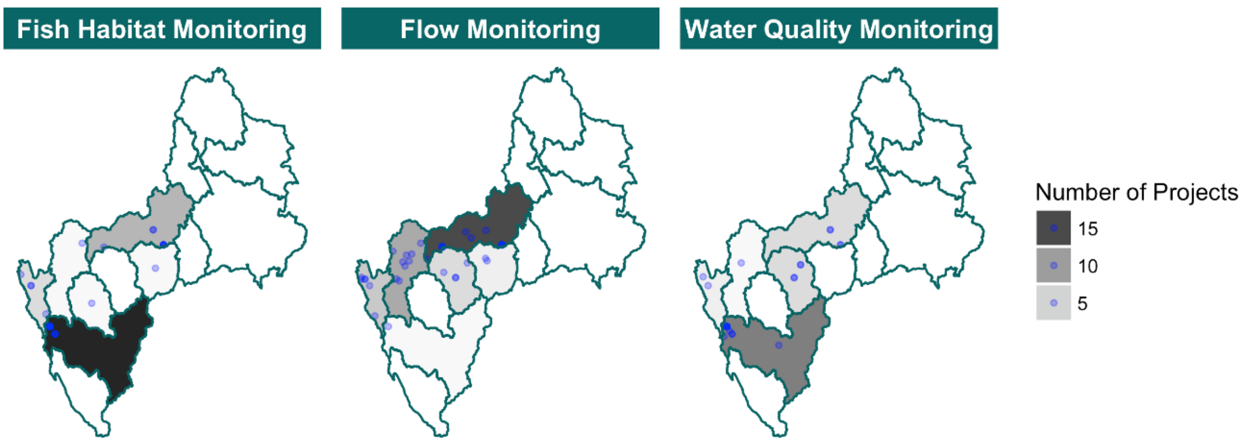


Figure 7-1: Frequency of PCSRF habitat monitoring projects by activity type and sub-basin 2000-2016 (n = 92).

Figure 7-2 indicates that general habitat monitoring and water quality monitoring activity conducted via PCSRF projects declined in frequency from 2000 to 2015. The highest spending over time was on flow monitoring. Projects involving all three types of monitoring peaked in 2004 for both frequency and cost. Spending ranged from about $1,900 to $143,000 per project (average $33,000). Note that Figure 7-2 is based on the data available in the PCSRF database, which does not indicate reasons for the decline in frequency and spending. Possible reasons include changing budgets, shifting priorities, inability to achieve data objectives via existing projects, and higher program startup costs relative to ongoing program maintenance costs.

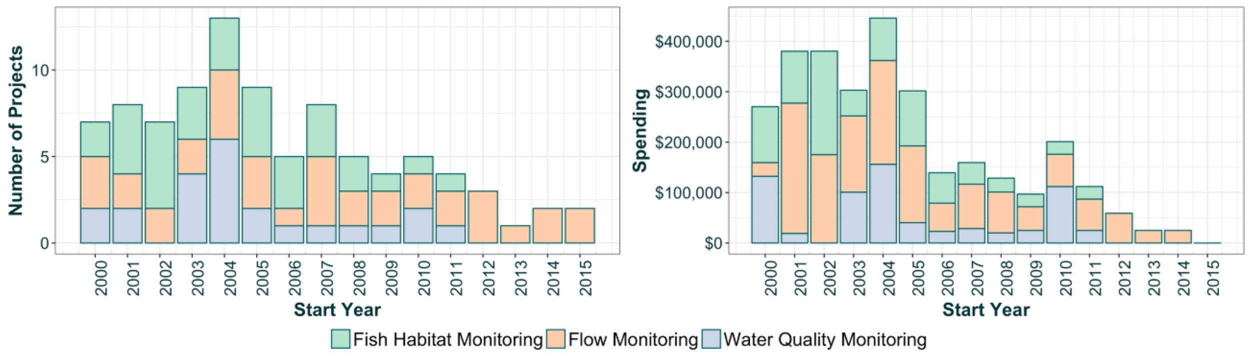


Figure 7-2: Frequency and spending for PCSRF habitat monitoring projects by start year (n=92).

### USGS Groundwater, Flow and Water Quality Gages

The USGS has operated groundwater, flow and water quality gages in the Klamath Basin since the early 1900s. We used USGS data to summarize the distribution of gages by sub-basin based on frequency and available time series (Figure 7-3) (USGS n.d.).

Figure 7-3 provides a sense of the distribution of monitoring effort across the Klamath Basin. Flow sample sites are relatively evenly distributed (Panel A), while a concentration of groundwater and water quality sites occurs in the Upper Klamath Lake and Lost sub-basins where withdrawals for irrigation and impacts from agriculture are common. Trinity sub-basin has better spatial coverage for both flow and water quality than most other basins (i.e., sites are more widely dispersed across the basin). Groundwater monitoring is also more spatially dispersed within the upper Klamath sub-basins where agriculture and livestock are common. Temporal coverage of flow monitoring is quite high (80-100+yrs) throughout most of the Klamath Basin (Panel B), with most sub-basins containing at least one site with 80-100+ year time series. Butte, South Fork Trinity, and Upper Klamath Lake sub-basins are exceptions. The best temporal coverage for water quality gages occurs in Trinity and Shasta sub-basins. Temporal coverage data for groundwater monitoring is unavailable in the dataset.

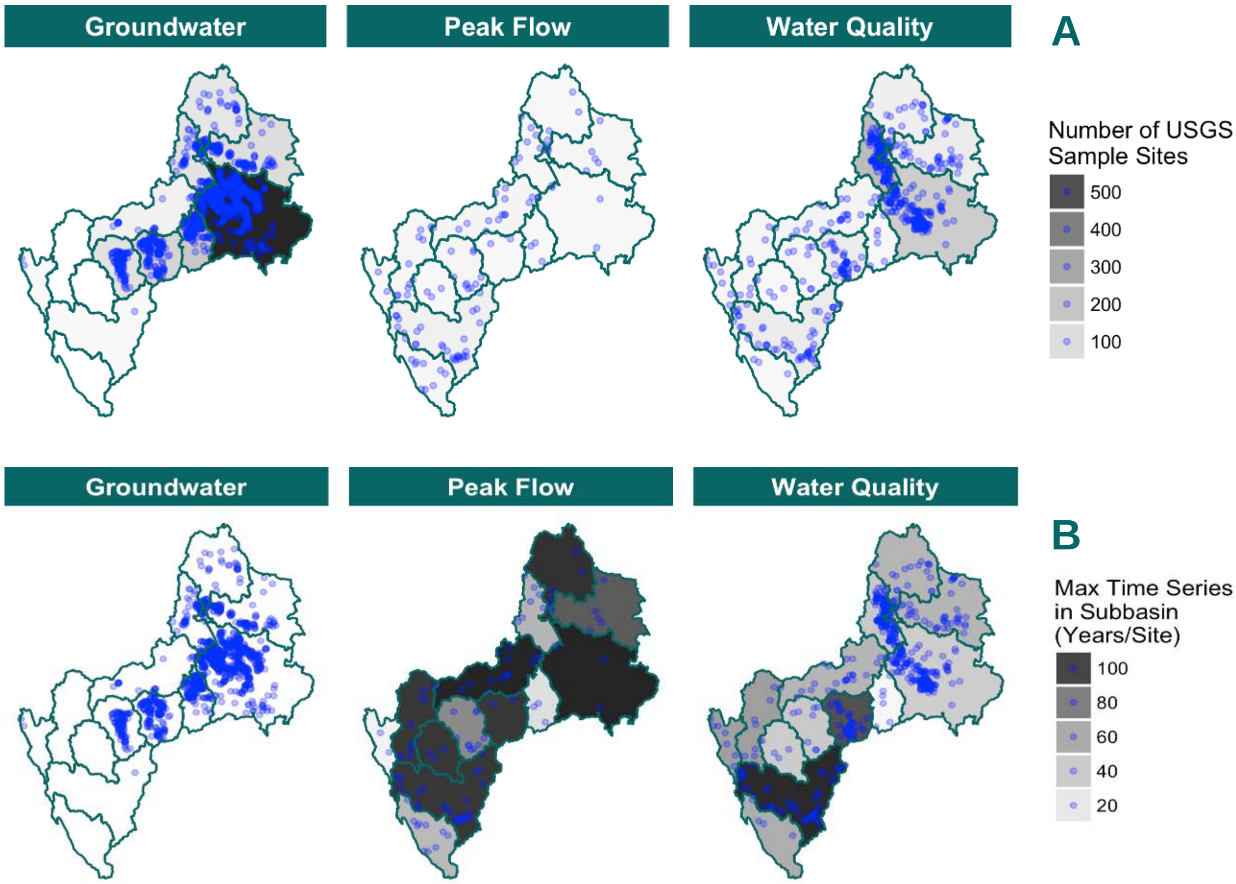


Figure 7-3: Frequency and maximum available time series for USGS groundwater, flow and water quality sample sites by sub-basin (n= 2024).

### U.S. Forest Service Klamath National Forest Water Quality and Habitat Monitoring

The U.S. Forest Service conducts ongoing monitoring of water quality (sediment and temperature) in USFS designated reference streams and managed streams across the Klamath National Forest (KNF), as well as base flow conditions in Mid Klamath tributaries. USFS designated reference streams show very little, if any, sign of human management and serve as a baseline for comparison with managed stream conditions. Between 2009 and 2015, streambed sediment was measured in low gradient stream channels located near the mouth of 79 watersheds. Summer stream temperatures were measured near the mouth of 87 watersheds representing most of the major tributary streams in the Klamath National Forest. Water quality reports can be accessed at:

https://www.fs.usda.gov/detail/klamath/landmanagement/resourcemanagement/?cid=stelprdb5312713.

In addition to water quality monitoring, the Forest Service opportunistically conducts habitat reach surveys, which include multiple physical parameters.

#### U.S. Fish & Wildlife Service Habitat Monitoring

The USFWS funds Tribal and agency research and monitoring for anadromous fish restoration in the Klamath River Basin. In 2013, the agency contributed more than $2.9 million to these efforts (NMFS 2015), which include both habitat and population monitoring. USFWS and partners conduct flow and water temperature monitoring in the Klamath and Trinity rivers (David 2017; Magneson 2016; Magneson 2015; Magneson and Chaimberlain 2015; Magneson 2014a), fish passage barrier surveys in the mid-Klamath, sediment monitoring below Iron Gate Dam (Shea et al. 2016), integrated habitat assessment in the Upper Trinity River (Alvarez et al. 2015, 2013; Martin et al. 2013a; Smith-Caggiano and Goodman 2013), and water quality monitoring for nutrient loads, community metabolism and kinetic parameters along the Klamath mainstem (Ward and Armstrong 2010; Armstrong and Ward 2008).

### State Agencies and Programs

#### Oregon Department of Fish and Wildlife Habitat Monitoring

The Oregon Department of Fish and Wildlife (ODFW) conducts a large number of fish restoration and monitoring projects in the Oregon portions of the Klamath Basin (ODFW 2016). A majority of these efforts are focused on population monitoring for a variety of listed and unlisted species (see Section 7.2.5), however, ODFW also conducts water temperature monitoring for redband trout (*O. mykiss newberrii*) habitat.

#### California Department of Fish and Wildlife Habitat Monitoring

Since 2008, CDFW has monitored water temperatures throughout the Shasta River watershed. This work was initiated as part of an early life history study of juvenile coho (*Oncorhynchus kisutch*) in the upper watershed, in which the effects of water temperature on the behavior, distribution and survival of juvenile coho were identified. The network of 39 water temperature loggers currently operating throughout the watershed allows CDFW to annually evaluate water temperatures in the Shasta River and assess the availability of habitat for coho salmon using a water classification scheme that assigns optimal, suboptimal and detrimental ranges for juvenile coho (Stenhouse et al. 2012).

### Tribal Agencies and Programs

#### Klamath Tribes Long-Term Water Quality Monitoring

The Klamath Tribes have been collecting water quality data in the upper Klamath Basin since 1990 (Kann 2017a,b). These data are critical for understanding the state of fish habitat in the upper basin and for informing restoration actions that will benefit fish. Currently, the monitoring program includes 11 lake sites and 20 river and stream sites located in and above Upper Klamath and Agency Lakes. Lake sampling includes water nutrients (total phosphorous, total nitrogen, soluble reactive phosphorous, ammonium, nitrate, nitrite, silicon dioxide), temperature, water chemistry (pH, dissolved oxygen, conductivity, oxidation reduction potential) and indicators of aquatic productivity (chlorophyll-a, phaeophytin, algal toxins, aquatic biota). Stream and river sampling includes water nutrients (same as for lake sites), physical attributes (temperature, total suspended solids, turbidity), limited water chemistry (pH, dissolved oxygen, conductivity), and discharge. These data can help to prioritize areas for restoration activities, analyze trends associated with climate change (e.g., changes in flow and temperature), and help to evaluate the effects of ongoing work to restore aquatic and riparian ecosystems. Key accomplishments include providing data for the Upper Klamath Lake Drainage TMDL and Water Management Plan, and two reports detailing nutrient and sediment loads in the Sprague River to Upper Klamath Lake. This program is on-going and typically costs about $250,000 per year.

**Yurok Tribe Lower Klamath River Habitat Assessment**

Since the late 1990s, the Yurok Tribe's Lower Klamath Division of Fisheries (YTFP-LKD) has conducted comprehensive watershed and physical habitat assessments to guide watershed restoration and species recovery efforts in the Lower Klamath River. These efforts grew out of the *Lower Klamath Sub-Basin Watershed Restoration Plan*, which prioritized upslope restoration and identified tributary-specific restoration objectives for each Lower Klamath tributary (Gale and Randolph 2000). Using the habitat assessment data, YTFP-LKD worked closely with the California Department of Fish and Wildlife (CDFW) and the National Marine Fisheries Service (NMFS) to identify and implement priority SONCC coho salmon recovery actions for the sub-basin (CDFW 2004a; NMFS 2014a).

Since the early 2000s, Yurok Fisheries staff also conducted summer monitoring of thermal refugia in the Lower Klamath sub-basin. In addition to monitoring water temperature, staff complete periodic surveys that note use of refuge areas by juvenile and adult salmonids. This information permits identification of temperature thresholds leading to the use of thermal refugia, and enables monitoring of fish behavior at thermal refuge areas during warm summer months.

The Yurok Tribe Environmental Program (YTEP) monitors nutrients, phytoplankton (including toxic cyanobacteria for public health purposes), and continuous water quality (water temperature, D.O., pH, and conductivity) at several sites on the mainstem Klamath River as well as the mouth of the Trinity River (YTEP 2013a,b). YTEP also operates streamflow gages in several lower Klamath tributaries

**Karuk Tribe Water Quality and Fish Habitat Monitoring**

Two programs at the Karuk Tribe Department of Natural Resources conduct habitat monitoring: Fisheries and Water Quality. The Fisheries program focuses on monitoring base flows and temperatures in mid-Klamath tributaries in coordination with USFS. The Water Quality program monitors over 130 miles of the mainstem Klamath and the mouths of the Salmon, Scott, and Shasta Rivers. At three mainstem sites and the three tributary sites, this program runs real-time sondes that collect continuous water quality data (temperature, DO, pH, conductivity, turbidity) (Karuk Tribe 2013). With the exception of USGS flow gages, no other water quality monitoring program covers a greater distance along the Klamath mainstem. The Karuk Tribe also samples nutrients, phytoplankton and algal toxins, which assists in fish disease monitoring conducted by Oregon State University as well as baseline public health monitoring. Real-time and archived continuous water quality data are available online at: http://waterquality.karuk.us. The Karuk Tribe is also involved in monitoring of flows, fish passage barriers, thermal refugia use, and fish health. In collaboration with USGS, the Tribe measures summer low-flow discharge rates annually on all major and most minor tributaries to the mainstem Mid-Klamath River (Soto et al. 2008). Fish use of thermal refugia and fish health is assessed in collaboration with USFWS, Yurok Tribe and Mid-Klamath Watershed Council.

#### Klamath Tribal Water Quality Consortium

The 2002 salmon die-off in the Lower Klamath River impelled a collaborative effort among the Yurok, Hoopa Valley and Karuk Tribes, the Quartz Valley Indian Reservation and Resighini Rancheria. The Consortium initiated many data collection programs and coordinates among water quality monitoring efforts, Quality Assurance Project Plans, and Standard Operating Procedure guidelines to ensure that collected data are comparable (e.g. across procedures and labs) and can be used effectively to analyze trends for regulatory processes such as TMDL development and implementation, permit applications under the Clean Water Quality Act (Section 401), and other Tribal, state, and federal processes. The group's mandate is to prevent future disasters using scientific research, data analysis and planning (Royer & Stubblefield 2016).

#### Hoopa Valley Tribe

The Hoopa Valley Tribe is active in stream flow, temperature and water quality monitoring in several tributaries of the Trinity sub-basin (Royer & Stubblefield 2016). In addition to Trinity efforts, the Hoopa conduct water quality monitoring of nutrient loads, phytoplankton and periphyton in the Klamath River at Saints Rest Bar (HVTEPA 2013). See http//www.hoopatepa.org/water.html for more information.

#### Quartz Valley Indian Reservation

Quartz Valley Indian Reservation's Environmental Department monitors stream flow, water temperature, nutrients, and bacteria at approximately 10-20 sites in the Scott River sub-basin (QVIR 2013). QVIR also monitors groundwater levels within Quartz Valley and operates a continuous water quality probe, which measures water temperature, DO, pH, and conductivity at the USGS gage on the Scott River.

### NGOs and NGO-led Programs

#### Trout Unlimited Habitat Monitoring

Trout Unlimited's monitoring efforts are focused on the Upper Klamath Basin. Data collected are used to guide future restoration actions or to allow for adaptive management of ongoing projects. Specific data gathered focus on measurements related to stream temperatures and flows, water quality metrics, and channel form and geomorphology. The organization is also partnered with Crater Lake National Park staff to document the movement of bull trout

(*Salvelinus confluentus*) in Sun Creek and to understand how Bull Trout will use the newly created habitat and its connectivity with the Wood River.

**Klamath Basin Monitoring Program and Water Quality Monitoring Plan**

Initiatives such as the Klamath Basin Monitoring Program (KBMP) recognized the need for more integrative approaches to fish monitoring. The myriad projects collecting data on water quality, fish populations and fish habitat required organization and synthesis in a way that was useable, accessible and easily communicated to fish managers, researchers and the public. KBMP explicitly seeks to coordinate basin-wide water quality monitoring efforts and publishes the project data online and in an interactive web map (http://www.kbmp.net). The organization began conducting voluntary surveys of existing monitoring projects in 2010. KBMP has built an important foundation that can help support an integrative approach to fish monitoring. The program focuses largely on water quality, but its scope also includes key fish habitat components such as sediment and stream temperature as well as disease monitoring. Currently published data include fish habitat and population monitoring projects surveyed in 2015 - the highest quality dataset gathered by KBMP to date (Randy Turner, personal communications, March 1, 2017). The program actively seeks to coordinate among the numerous Tribes and agencies engaged in monitoring (KTWQC 2016).

Figure 7-4 below shows the spatial distribution of monitoring projects surveyed by KBMP in 2015. Most projects reported on water temperature monitoring with the highest concentration of these occurring in the lower part of the basin. Water quality and flow monitoring were the next most frequently reported, with the highest concentration of water quality monitoring projects occurring in the Upper Klamath Lake, Lost and Salmon River sub-basins; flow monitoring was most frequently reported in the Mid Klamath River and Salmon River sub-basins. Weather monitoring projects were fairly evenly distributed across the basin with the exception of some clustering in the Trinity headwaters and a limited number of reported projects in Williamson and Sprague sub-basins. Sediment monitoring (e.g., Total Suspended Sediment (TSS), bedload, composition) was reported primarily along the Klamath mainstem and in the Upper Klamath Lake sub-basin. Some monitoring projects in the database specify an orientation toward fish monitoring but the exact nature of the data collection is unclear. These projects occur primarily in the Lower Klamath River, Shasta, Upper Klamath River and Upper Klamath Lake sub-basins.

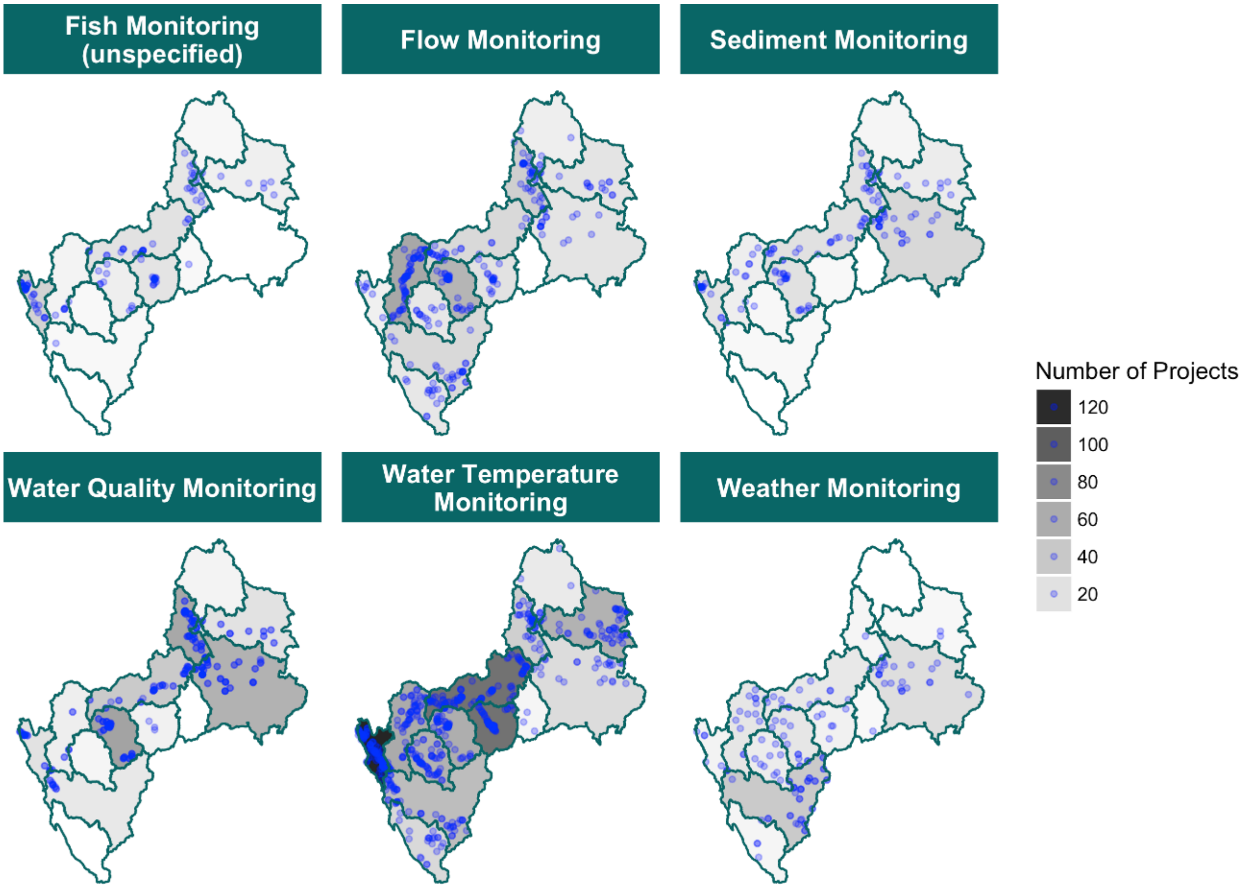


Figure 7-4: Frequency of monitoring projects in 2015 KBMP survey by type and sub-basin (n=1661).

### Community Organizations and Programs

#### Salmon River Restoration Council Stream Temperature, Flow and Juvenile Habitat Monitoring

Since the early 1990s, in coordination with the USFS Klamath National Forest (KNF), the Salmon River Restoration Council (SRRC) has conducted water temperature monitoring on the Salmon River at over 50 sites throughout the watershed. Additionally, since 2002, SRRC has conducted nearly annual flow monitoring of the Salmon River and target tributaries in coordination with the Karuk Tribe. The SRRC is also currently working with Riverbed Sciences to complete long-term temperature and flow trend analysis (report to be released in 2017).

Using the Coastal Monitoring Plan Aquatic Survey Program, SRRC implements juvenile coho habitat assessments to help ascertain habitat quality and use, presence, abundance and spatial distribution. Since 2011 SRRC has also worked with the Mid Klamath Watershed Council to annually assess and improve juvenile and adult fish passage throughout the mid Klamath basin and Salmon River tributaries to improve access to and quality of tributary cold-water refugia. This effort includes fish passage assessments pre- and post- manual manipulation at creek mouths to increase passage and quality of refugia.

**Salmon River Restoration Council Stream Temperature and Flow Monitoring**

Since the early 1990s, the Salmon River Restoration Council (SRRC) has conducted water temperature monitoring on the Salmon River. The SRRC is also currently conducting long term temperature and flow trend analysis with the help of Riverbend Sciences (report to be released in 2017).

**Public Utilities and Programs**

**PacifiCorp Water Quality Monitoring**

PacifiCorp has funded monitoring activities under the Klamath Hydroelectric Settlement Agreement (KHSA). The agreement requires water quality monitoring of the Klamath River mainstem from Link River Dam downstream through the Klamath estuary and is primarily focused on human health impacts using the same monitoring locations as the Klamath Basin Water Quality Monitoring Plan (Royer 2011). Despite the explicit focus on human health and on only a sub-section of the basin, annual water sampling conducted under the KHSA is an example of a coordinated, multi-agency effort that is integrative at a relatively large scale. The baseline water quality monitoring (e.g., stream temperature, dissolved oxygen, pH, turbidity, nutrients) conducted under this agreement supports dam removal, nutrient removal, blue-green algae monitoring, and monitoring for phytoplankton, periphyton and algal toxins, all of which impact fish species (KHSA 2016). Measures have also been adopted to monitor the effects of fish habitat enhancement (e.g., gravel placement) at JC Boyle Dam (KHSA 2016). Note that if the KHSA ends or if the license for the dams is transferred, PacifiCorp monitoring efforts under this program will discontinue.

## 7.2.3 Habitat Monitoring in Key Plans

Figure 7-5 shows the results for habitat status and trend monitoring from our review of 31 restoration and monitoring plans/documents, which we selected from over 70 documents. We chose reports based on their date of completion, depth, breadth, duration of monitoring, spatial coverage, species coverage, recommendations from interviews and workshop discussions and their relevance to fish restoration in the Klamath Basin (see Section 6.3 for an explanation of our selection method).

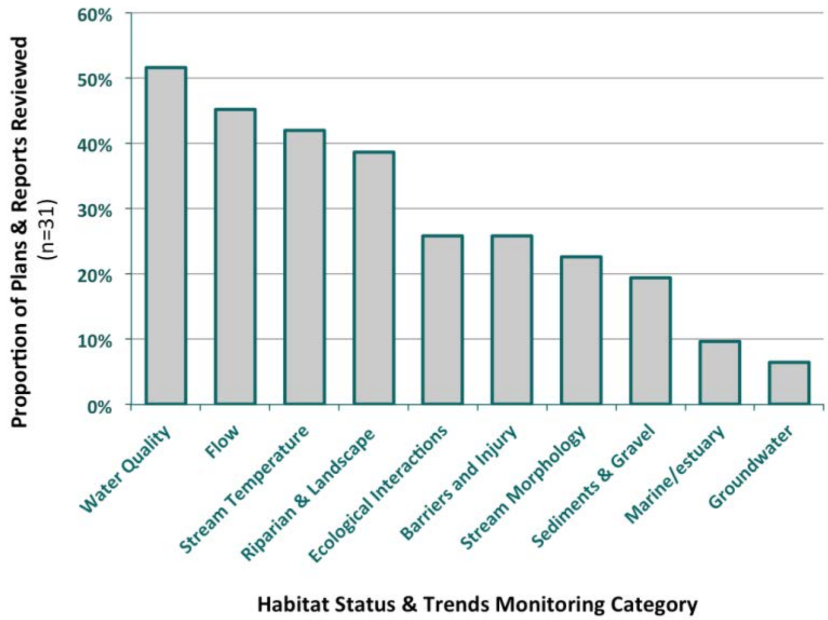


Figure 7-5: Frequency of occurrence of various categories of habitat monitoring expressed in plan objectives. See Table 7-1 for examples of indicators under each category.

Water quality, flow and stream temperature monitoring are the most frequent categories of habitat monitoring recommended and/or implemented via these 31 plans. Over 50% of the documents included water quality monitoring and over 40% included flow and stream temperature monitoring. Figure 7-5 also shows a lack of marine/estuary monitoring (~10%). Between 20% and 40% of the 31 documents specified monitoring for riparian and landscape (~40%), ecological interactions (25%), barriers and injury (25%), stream morphology (22%), and sediments and gravel (20%).

### Box 7-1: Spotlight on the Klamath Basin Water Quality Monitoring Plan

The Klamath Basin Monitoring Program (KBMP) is guided by the Klamath Basin Water Quality Monitoring Plan (2010), which recommends water quality investigations to address questions among resource managers, provides for data management, data sharing and communications about water quality, and promotes consistent sampling methods and quality assurance protocols to ensure comparability of data across agencies, watershed groups and tribal governments that conduct water quality monitoring (Royer & Stubblefield 2016). The plan is available on the KBMP website (http://www.kbmp.net) and includes useful discussion about the institutional and regulatory setting around water quality monitoring in the basin (e.g., role of the Clean Water Act, Total Maximum Daily Load implementation and associated policies, role of the North Coast Regional Water Quality Control Board, Tribal considerations, and state water quality regulatory agencies). The plan was last updated in 2016 and includes maps of gage locations and data collection frequencies for the following water quality parameters: water temperature, ammonia, chlorophyll-a, dissolved oxygen, nutrient load, pH, sediment and turbidity. The KBMP website hosts an early warning system developed by the Klamath Fish Health Assessment Team (KFHAT). The tool indicates threat levels to anadromous fish from disease and other stressors and coordinates the level of data sharing required at each stage of risk among participating organizations. Also on the website, KBMP maintains the Blue-Green Algae Tracker tool as part of an early warning system for toxic algal blooms along the mainstem Kalmath River and upper Klamath Lake.

### Box 7-2: Spotlight on Monitoring in the Klamath Basin Restoration Agreement

The now-defunct KBRA included plans for extensive monitoring to prevent excessive drawdown of groundwater levels to protect flows in spring complexes that sustain streams and provide thermal refugia for fish (USDI et al. 2013). The agreement also specified the deployment of a technical advisory team to monitor hydrological conditions and water supply in the upper Klamath to promote early detection of drought so water can be conserved for lake, river, refuge, agricultural and other uses. Implementation of the KBRA would have resulted in substantial spending in the Klamath Basin over a 15-year period on up to 112 projects, many of which included monitoring. Actions would have been implemented in Klamath, Siskiyou, Humboldt and Del Norte counties (4-county region). Total 15-year spending within the region on monitoring and evaluation under the KBRA Fisheries Program was estimated at ~$35 million. The KBRA also specified actions to improve water supply reliability in the Klamath Project, including monitoring activities conducted by state and local government workers. Under the Water Resources Program, 15 year spending on water flow monitoring and gages in the region was estimated at $3.2 million. Monitoring projects would also have been required under the KBRA Tribal Program. While the Agreement is no longer active, it is important to acknowledge its content and intent as a guide to future efforts.

## 7.2.4 Population Monitoring

**Population Monitoring** refers to tracking of fish population indicators over time and space. Table 7-2 lists and describes the full range of monitoring categories used for this section, and provides some example indicators.

Table 7-2:Categories of fish population monitoring and examples of indicators.

| Category | Examples of Indicators |
|---|---|
| Juvenile Abundance (Anadromous) | counts of anadromous juvenile life-stages (see spatial and temporal distribution below) |
| Spawner Escapement (Anadromous) | counts and spatial distribution for returning adults (see spatial and temporal distribution below) |
| Abundance (non-anadromous) | general population status and trends for non-anadromous species, adult/juvenile |
| Harvest (In-River) | tribal and non-tribal, commercial, recreational, subsistence/ceremonial, includes bycatch and scientific monitoring |
| Harvest (Ocean) | primarily commercial and recreational harvest, includes bycatch and scientific monitoring |
| Survival (In-River) | survival rates of anadromous fish in-river, incorporates freshwater predation and mortality from dams |
| Survival (Ocean) | survival rates of anadromous fish in the ocean, incorporates marine predation |
| Spatial & Temporal Distribution | periodicity/migration timing, spatial distribution of life-stages, associations with habitat attributes |
| Stock Composition | proportion of hatchery to wild fish, genetic integrity |
| Demographics | age structure, size, sex-ratio |
| Source Populations | identification of source populations for re-introduction |
| Disease | presence/absence of disease and/or disease vectors (e.g., *C. shasta*, Ich) instream, in tissue samples. |

## 7.2.5 Major Population Monitoring Programs

### Federal Organizations and Programs

#### NMFS Klamath River Coho Recovery Monitoring

NOAA's National Marine Fisheries Service developed a recovery plan for Klamath River coho salmon in 2007 and reports annually to Congress on implementation progress (NMFS 2015), including the status of research and monitoring activities. In 2014, NMFS expanded its activities in the basin to focus on environmental variation and fish response at different spatial scales and conservation of ESA-listed coho (*Oncorhynchus kisutch*), steelhead (*Oncorhynchus mykiss irideus*) and Chinook (*Oncorhynchus tshawytscha*) populations for tribal uses. Activities include fall Chinook stock assessments, evaluation of coho, steelhead/rainbow trout and Chinook population structures, genetic stock identification, evaluation of Klamath/Trinity Chinook salmon (*Oncorhynchus tshawytscha*) contributions to commercial fisheries, fish tracking studies to evaluate spatial responses of salmonids to stream temperatures, and genetic tagging and monitoring of fall and spring Chinook from the Trinity River Hatchery. Many of these activities are conducted in collaboration with other federal and state agencies, Tribes, local watershed groups and Humboldt State University.

#### NMFS Pacific Coastal Salmon Recovery Fund (PCSRF) Database – Population Monitoring

After the development of project performance metrics in 2005 and 2010, the NMFS Pacific Coastal Salmon Recovery Fund (PCSRF) launched a project database and interactive web map (https://www.webapps.nwfsc.noaa.gov). This database catalogues PCSRF grant-funded restoration projects in the Klamath Basin from 2000 to 2016, two-hundred of which had population monitoring objectives (NMFS 2016b). Most fish population monitoring projects took place in the Mid Klamath River sub-basin. PCSRF-funded disease monitoring was concentrated in the Mid and Upper Klamath River sub-basins (Figure 7-6).

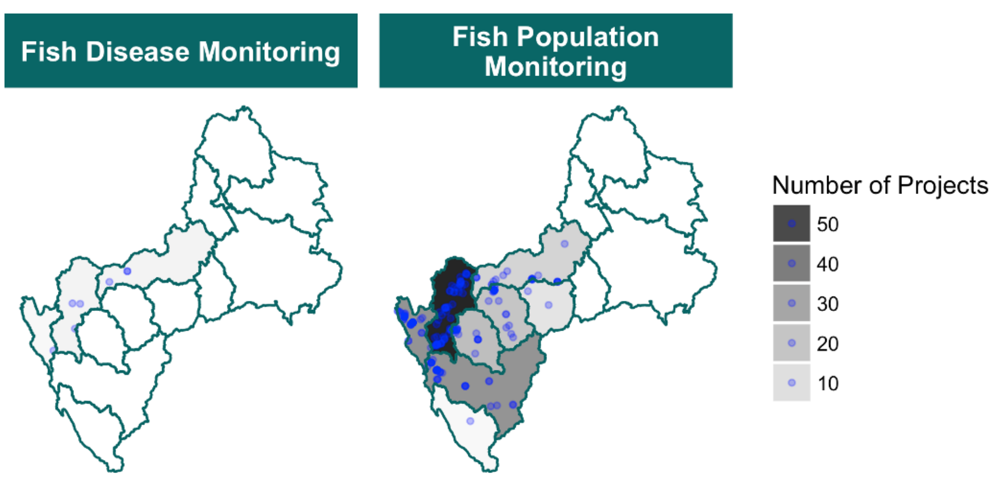


Figure 7-6. Frequency of PCSRF population monitoring projects by activity type and sub-basin 2000-2016 (n = 200).

Figure 7-7 indicates that fish disease monitoring is a relatively minor focus for PCSRF funded projects. In terms of frequency and spending, population monitoring peaked in the early 2000s, declined, then peaked again in the later 2010s. The peak in frequency from 2010-2015 was marked by an initial increase in spending then a decline – indicating that fewer funds were allocated across a greater number of projects over time. Spending ranged from about $700 to $765,000 per project (average $39,000).

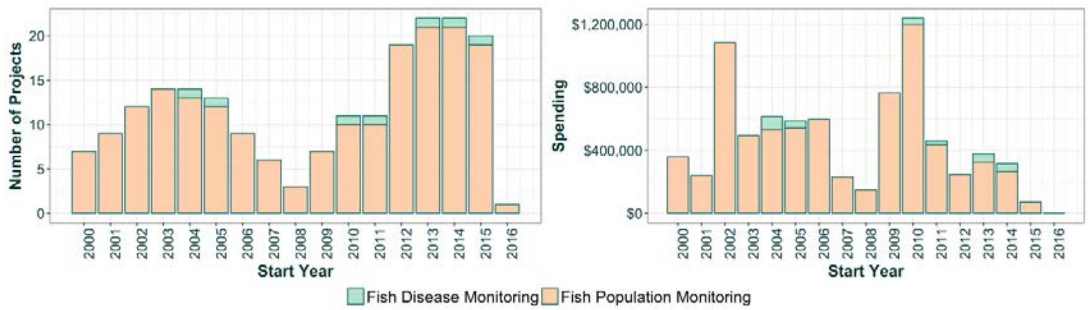


Figure 7-7: Frequency and spending for PCSRF population monitoring projects by start year (n=200).

### U.S. Forest Service Klamath National Forest Spawner Surveys

Since 1992, the U.S. Forest Service has facilitated cooperative ground surveys of spawning fall Chinook in the Klamath National Forest, involving the Forest Service, California Department of Fish and Wildlife, Yurok Tribe, Karuk Tribe, Quartz Valley Indian Reservation, Salmon River Restoration Council, and local schools and volunteers (see Figure 7-8). In addition to providing information to land managers regarding where the fish spawn (e.g., redd locations and density), these surveys are used to estimate the total in-river escapement of spawning fall Chinook salmon by the Klamath River Technical Team and the Pacific Fisheries Management Council, information that is used to determine harvest allocations for the subsequent year. Scale samples and otoliths are also taken from carcasses to help determine the age composition of the Klamath River fall Chinook run.

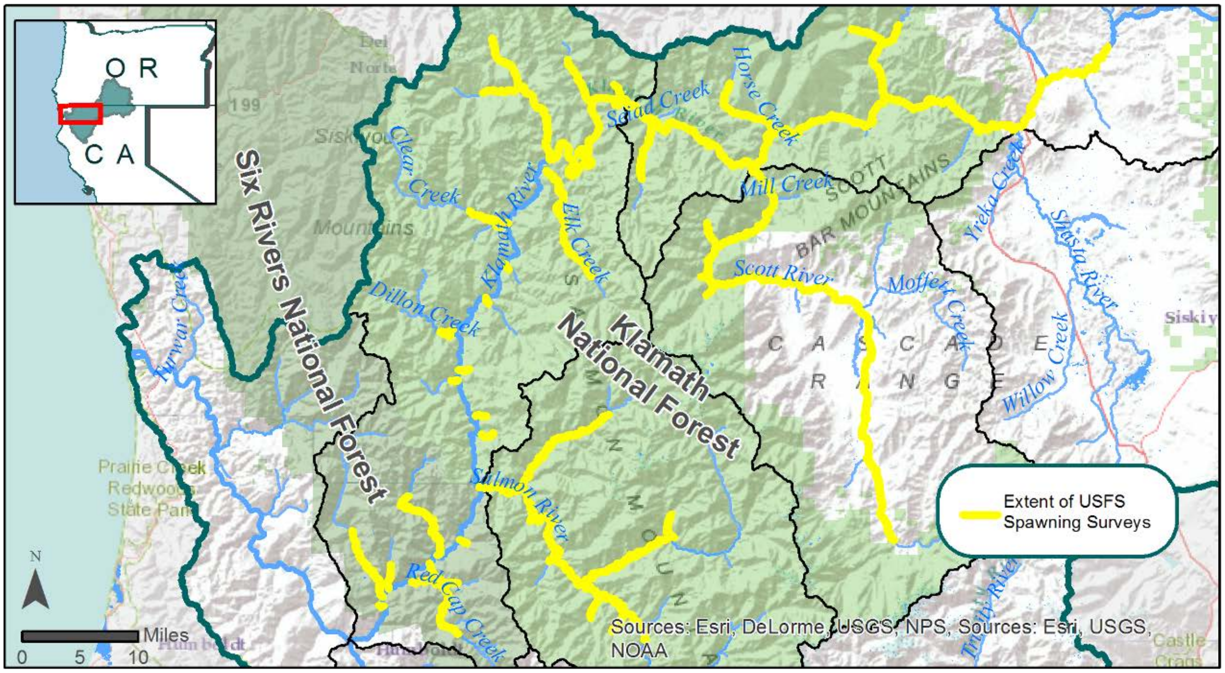


Figure 7-8: Extent of USFS Klamath National Forest spawning surveys. Source: CDFW, personal communications May 2017; USGS 2010, USFS 2015, 2016.

Since 2000 in the Salmon River watershed, spring Chinook salmon surveys have been conducted collaboratively by the Forest Service, Salmon River Restoration Council, California Department of Fish and Wildlife, Yurok Tribe, Karuk Tribe, and volunteers using redd count techniques. These surveys provide information to land managers and local resource councils regarding where the fish spawn. Additionally, the data assist in tracking trends in the usage of different sites under varying environmental and discharge conditions, and the mixing of spring- and fall-run Chinook stocks. Biological samples (scales and tissue) are passed to the California Department of Fish and Wildlife. Live spring Chinook in the Salmon River system are also enumerated during the annual Spring Chinook/Summer Steelhead Dive event. This is a long-term cooperative effort led by the Salmon River Restoration Council and Klamath National Forest. Participants include Federal, State, and Tribes, as well as volunteers.

The Klamath National Forest also conducts annual juvenile presence/absence surveys for coho salmon in select Mid Klamath tributaries and in the Scott and Salmon River watersheds, and for steelhead in the Mid Klamath tributaries where they remain (Elk Creek, Clear Creek, Indian Creek, Dillon Creek, Grider Creek, Thompson Creek, and Independence Creek).

**U.S. Fish and Wildlife Service Salmonid, Speckled dace, Sucker and Lamprey Population Monitoring**

The USFWS funds Tribal and agency research and monitoring for anadromous fish restoration in the Klamath River Basin. In 2013, the agency contributed more than $2.9 million to these efforts (NMFS 2015), which include both habitat and population monitoring. Non-anadromous species such as Lost River Sucker (*Deltistes luxatus*) and Speckled dace are also monitored.

USFWS and partners collect adult salmon escapement and stock assessment data, monitor juvenile fish abundance, size, growth and health (including Chinook, coho, steelhead and lamprey), conduct fish disease monitoring and assessment including for *C. shasta* and *P. minibicornis* in salmon and *I. multifiliis* in Speckled dace (Som and Hetrick 2017; Som et al. 2016a,b; Foott et al. 2016b), monitor fall Chinook spawner distribution, age composition and escapement, and Lost River sucker (*Deltistes luxatus*) and shortnose sucker (*Chasmistes brevirostris*) fry survival and health in Upper Klamath Lake (Foott 2004; Stone et al. 2017).

Comprehensive fall Chinook spawning escapement monitoring began in 1978 and currently occurs along the Klamath and Trinity rivers. Methods have included redd counts, carcass tag-recovery, and area-under-the-curve (AUC) escapement estimation (Romberger and Bell 2017; Rupert et al. 2017; Gough and Som 2016; Magneson 2014b; Gough 2014). Estimates are used to determine basin-wide fall Chinook natural escapement and age structure, which are combined with age structured hatchery escapement and in-river harvest estimates to project ocean stock abundance for the purpose of developing harvest management alternatives (Gough and Som 2016). Juvenile salmonid and non-salmonid trap monitoring began in 2000 at three sites along the mainstem to collect data for outmigration abundance, timing and population model calibration (David et al. 2017). Trap methods included frame nets and rotary screw traps. Traps are also set along the Trinity River (Petros et al. 2017; Harris et al. 2016). PIT tagging has also been conducted for juvenile salmonids (Beeman et al. 2012).

USFWS has also conducted, habitat, occupancy status and threats assessments for Pacific lamprey (*Lampetra tridentata*) in the Klamath basin as part of the North Coast *Regional Implementation Plan for Measures to Conserve Pacific Lamprey (Entosphenus tridentatus)* (Goodman and Reid 2015; Reid and Goodman 2016).

**USGS Sucker Population Monitoring**

Since 1995, USGS has implemented a long-term capture-recapture program to assess the status and dynamics of Lost River suckers and shortnose suckers. This record is likely the most detailed long-term dataset for any non-anadromous endangered fish in the US.

Fish from these two sucker populations were captured and tagged with passive integrated transponder (PIT) tags during their annual spawning migrations (Hewitt et al. 2014). Additionally, beginning in 2005, individuals that had been previously PIT-tagged were re-encountered on remote underwater antennas deployed throughout sucker spawning areas. Captures and remote encounters during spring 2012 were used to describe the spawning migrations in that year and also were incorporated into capture-recapture analyses of population dynamics.

Cormack-Jolly-Seber (CJS) open population capture-recapture models were used to estimate annual survival probabilities, and a reverse-time analog of the CJS model was used to estimate recruitment of new individuals into the spawning populations. Additionally, data on the size composition of captured fish were examined to provide corroborating evidence of recruitment. Model estimates of survival and recruitment were used to derive estimates of changes in population size over time and to determine the status of the populations in 2011.

These monitoring efforts have been critical in tracking and confirming the decline of these two listed species as well as identifying that, despite relatively high survival in most years, losses from mortality have not been balanced by recruitment of new individuals. PIT tag studies have also provided evidence that extreme low water in Upper Klamath Lake reduces the number of suckers that spawn in a given year (Burdick et al. 2015b).

In 2015, USGS began another monitoring program for juvenile suckers in Upper Klamath Lake and Clear Lake Reservoirs (Burdick et al. 2016). The goals of this program are to track annual variability in age-0 sucker production, juvenile sucker survival, growth, and condition. Results for the first year indicated that juvenile abundance and mortality are higher in Upper Klamath Lake than in Clear Lake Reservoir. Also, opercular deformities, skin hemorrhages, black-spot causing parasites, and *Lernaea* spp. parasitism were observed in juveniles but only the latter was more prevalent in the Clear Lake Reservoir.

**Fish Tag Data from USGS Klamath Falls Field Station**

USGS Klamath Falls Field Station maintains a basin-wide fish-tagging database that allows researchers and managers to share fish tagging data. For example, CDFW may PIT tag a coho salmon in the Shasta River that is subsequently captured in a USFWS screw trap downriver. The database provides a way for this information to be shared and cross-examined between agencies. The importance of this data-sharing platform will increase should the upper and lower basins be reconnected via dam removal.

**US Bureau of Reclamation Lost River and Shortnose Sucker Monitoring**

The US Bureau of Reclamation (BoR) funds a significant amount of fish research and monitoring in the Klamath Basin. The agency provides funding to tribal natural resource departments, other federal agencies (i.e., FWS and USGS) and to universities. The Klamath Basin Area office has been engaged in endangered sucker monitoring for nearly two decades. Monitoring of juveniles at the A Canal Fish Evaluation Station (FES) is a Monitoring and Reporting requirement within the 2013 Biological Opinion (BiOp) and is highly likely to be a component of Reclamation's Proposed Action during the current reinitiated consultation. Some level of monitoring has taken place at the FES since the A Canal fish screen and pumped bypass were constructed in 2003, though the level of sampling protocol and level of effort have only been consistent since 2012. Monitoring takes place between mid-July and late September each year with a level of effort sufficient to capture the peak of juvenile sucker abundance and estimate the number of juvenile suckers that encounter the A Canal headworks and fish screen. During this effort Reclamation crews collect bypassed age-0 and age-1 suckers at the A Canal headworks and record length, weight and affliction data for all collected suckers. In many years, FES monitoring results in the largest collection of juvenile sucker data from Upper Klamath Lake and Reclamation has partnered with the USFWS CA-NV Fish Health Center, USGS, and Oregon State University to provide samples (fish health samples, hard parts for aging/growth etc.) for additional hypothesis testing. Currently, Reclamation is providing juvenile suckers greater than 80mm standard length to the USFWS for inclusion in the Sucker Assisted Rearing

Program with the goal of rearing to a larger size and treating for external parasites before reintroduction into Upper Klamath Lake.

Between 2008 and 2011, Reclamation also monitored the adult sucker population in Lake Ewauna with the goal of better understanding its population structure and demographics. These efforts permitted a length-frequency analysis and estimates of abundance and survival. As a component of the 2013 BiOp, Reclamation continued to monitor the Lake Ewauana adult sucker population between 2014 and 2017 with the goal of transporting adult suckers to the Williamson River and augmenting adults spawning populations above Link River Dam. The monitoring primarily occurred during the spring months of March, April and May and Reclamation is currently coordinating with USGS to evaluate survival rates, movement, and the extent to which transported adult suckers have joined spawning populations above the lake. The forthcoming analysis from USGS may help inform potential future sucker capture and transport efforts from PaicifiCorp's Hydroelectric Reach.

## State Organizations and Programs

### California Department of Fish and Wildlife Klamath River Project & Yreka Fisheries Program

CDFW's Klamath River Project (KRP) has been conducting population monitoring in the Klamath River since 1978. The goals of the KRP include obtaining information on population abundance, hatchery composition, run timing, spawning distribution, fork length frequency, age composition, and sex ratios for salmonids (primarily Klamath River Fall Chinook (KRFC), but also coho and steelhead) in various tributaries to the Klamath River including the Salmon, Scott, and Shasta rivers, as well as Bogus Creek and 22 other smaller tributaries.

Run-size estimates within the Shasta River, Scott River and Bogus Creek are acquired via an adult fish video counting facility and, downstream of that facility, during spawning ground surveys. The video facility consists of a video camera, counting flume and an Alaska style weir strategically placed in a diagonal direction across the river channel. Fish immigrating upstream are directed through a narrow flume, which passes in front of an underwater video camera. The camera is connected to a time-lapse video recorder and monitor. The video recorder is set to include both a date and time stamp on every recording to accurately document run timing. The video counting facility typically operates 24 hours a day seven days a week during the adult salmon migration from early September through late December.

Below the video weir, the Cormack-Jolly-Seber carcass mark-recapture methodology (Bergman et al. 2012) is applied during spawning ground surveys. These surveys are also the primary method for carcass recovery that provides necessary biological information to estimate age composition, male and female composition and hatchery composition. Each stream is surveyed 16 times with surveys conducted twice weekly during the KRFC spawning season from early October to early December. A target of eight spawning ground surveys are conducted on the Shasta River, occurring once weekly during the KRFC spawning season from early October to early December.

Run-size estimates for the 22 selected Klamath River tributaries between the confluence of the Trinity River upstream to Iron Gate Dam are primarily based on redd counts extrapolated using an assumed number of two fish per redd. Carcass recovery is also conducted during redd surveys to provide necessary biological information for estimating age composition, male and female composition and hatchery composition in these tributaries. Surveys of these tributaries are attempted once every 10 days during the KRFC spawning season from early October to early January. Each tributary stream is targeted for six surveys throughout the season for a total of 132 surveys. Tributaries include: Aikens Creek, Bluff Creek, Slate Creek, Red Cap Creek, Boise Creek, Camp Creek, Pearch Creek, Rogers Creek, Irving Creek, Rock Creek, Ti Creek, Dillon Creek, Ukonomn Creek, Independence Creek, Clear Creek, Elk Creek, Indian Creek, Thompson Creek, Fort Goff Creek, Grider Creek, Horse Creek and Beaver Creek.

Preliminary results of run size monitoring efforts are presented to the Klamath River Technical Advisory Team (KRTAT) during its annual age composition meeting held in early February. These data are incorporated into the California Department of Fish and Wildlife (CDFW) "Mega Table" which includes the fall Chinook salmon preliminary run size estimate for the entire Klamath River Basin. Age composition breakdowns within the run are determined by KRTAT based on scale reading age determinations, length frequency distributions and Coded Wire Tag (CWT) data. These metrics are used in the Klamath Ocean Harvest Model to predict KRFC ocean abundance.

This information is necessary to determine appropriate escapement and allocate sustainable harvest levels for various user groups in the Klamath Fishery Management Zone for the following fishing season. Reported results of the age composition meeting are presented in reports for each year. The Klamath River fall Chinook salmon population forecast and harvest level alternatives for the following seasons are derived by the KRTAT are also presented in reports available on the Pacific Fisheries Management Council (PFMC) website.

Population inventories and resource assessments from the CDFW Klamath River Project provide a reference to measure the cumulative effectiveness of various restoration programs and management strategies being implemented to maintain or increase salmon stocks. Additionally in the Scott and Shasta rivers, the adult salmonid data are paired with other CDFW project data collected on outmigrating juvenile salmonids. The ability to pair returning adult abundance estimates with outmigrating juvenile abundance estimates creates a very powerful dataset permitting tracking of in-river productivity and out-of-basin survival rates over time. Having both in-river productivity and out-of-basin survival estimates are extremely important in monitoring watershed health, species recovery and effectiveness of habitat restoration efforts. This is an example of how status and trend monitoring at a larger scale can be combined with finer scale monitoring to infer the cumulative effects of restoration actions and other factors.

In addition to the Klamath River Project, CDFW's Yreka Fisheries Program has operated rotary screw traps since 2000 in the Scott and Shasta rivers for the purpose of generating population estimates for outmigrating juvenile salmon (Stenhouse et al. 2016a,b). Using rotary screw traps, all age classes of outmigrating Chinook salmon, coho salmon, and steelhead trout, as well as a variety of native and non-native fish species were sampled. The traps are installed in late winter (Julian week 5 – January 29) and operate until late spring (Julian week 26 – July 1), depending on conditions. Using the Carlson method for mark and recapture of salmonids, trap efficiencies and population estimates are produced on a weekly basis. Established age-length cut-offs for each species are used to determine fish age. Instream conditions such as flow and water temperature are also monitored. Weekly estimates for the smolt class of all species are compared to show multi-year population trends. Using multi-year seasonal production estimates and coho salmon returns to the Shasta River, adult survival and smolt production estimates are calculated.

Since 2008, the Yreka Program has used PIT tags to monitor juvenile coho movements and survival in the Shasta and Scott Rivers (Chesney et al. 2009; CDFW 2016b). Individually marking salmonids and tracking their movements using stationary PIT tag antenna stations has proven a useful tool for gathering data that can inform fisheries managers.

#### Oregon Department of Fish and Wildlife Population Monitoring

The Oregon Department of Fish and Wildlife (ODFW) conducts a large number of fish restoration and monitoring projects in the Oregon portions of the Klamath Basin (ODFW 2016). These efforts are directed toward indigenous fishes, including ESA listed Lost river sucker, shortnose sucker, and bull trout, as well as the following unlisted fish populations: Jenny Creek sucker, Miller Lake lamprey, redband trout, Pit-Klamath brook lamprey, slender sculpin, Upper Klamath Lake lamprey, largescale sucker, smallscale sucker, summer run steelhead, and speckled dace. Monitoring focuses on assessing occupancy/distribution and abundance as well as population trends, age structure, size and life history where data are available (esp. redband trout) (ODFW 2016). ODFW deploys a wide range of monitoring methods depending on the fish species and population context. Examples include mark-resight, mark-recapture, PIT-tag capture-recapture, radio tag, area under the curve spawner surveys, redd counts, electrofishing, eDNA sampling, larval trawls, video weirs, hook and line sampling, snorkel surveys and scale analysis (ODFW 2016).

### Tribal Organizations and Programs

#### Yurok Tribe Salmonid Population Monitoring

The Yurok Tribal Fisheries Department conducts numerous anadromous fish monitoring projects throughout the Klamath Basin for both juvenile and adult life stages of coho and Chinook salmon. The Tribe typically works alone within the Yurok Reservation, while off-reservation monitoring usually involves co-managed efforts with the Karuk Tribe, Hoopa Tribe, USFWS, CDFW, and USFS.

Yurok juvenile salmonid monitoring provides long-term data for abundance, timing, health, and size of juveniles emigrating from key tributaries such as Blue Creek, McGarvey Creek, and the Trinity River (since early to mid-1990s). For the past ten years the Tribe estimated emigration abundance from additional tributaries in the Lower Klamath River, including Waukel Creek, Salt Creek, and Panther Creek. These projects quantify juvenile production from tributary salmonid populations, facilitating status and trend monitoring of various populations and their life history strategies. Yurok Fisheries has also seined for juveniles in the Lower Klamath River for the past several years to collect known-origin fish (coded wire tagged from one of the two hatcheries in the basin) so the California-Nevada Fish Health Center can assess these fish for the presence of disease.

Since 2006, with funding from the U.S. Bureau of Reclamation and in coordination with the Karuk Tribe, the Yurok Tribe has conducted a juvenile coho salmon ecology project. This project involves implementation of PIT tags to track the fate of individual fish at downstream migrant traps and PIT tag receiver stations in Lower Klamath tributaries. The Yurok Tribe currently runs PIT tag detection stations in McGarvey, Terwer, Waukel, Salt, and Panther creeks. This project also includes mark-recapture population estimates in natural and human-made wetland/pond habitats of the Lower Klamath River. A key finding of the coho ecology projects is that lower Klamath tributaries provide substantial habitat, especially over-wintering habitat, to non-natal juvenile coho salmon from throughout basin.

Adult salmonid monitoring efforts include harvest and escapement monitoring for fall run Chinook salmon and, to some extent, coho salmon. These projects resulted in long-term data (>20 years) for adult fall Chinook in the Upper Klamath River, several mid-Klamath tributaries, the Upper Trinity River, and Blue Creek. The data are critical for salmon management, since fall Chinook population trends often drive ocean management along the coast of California and Oregon. Collected data also provide information necessary to assess population dynamics of Klamath fall Chinook, various modeling efforts, and the trajectory of different populations throughout the basin.

Yurok Fisheries also conducts a fall Chinook salmon age composition project. Staff mount and age scales from adult salmon. This project is essential for harvest management because it provides cohort-specific abundance estimates and permits assessment of relationships between adult abundance and environmental conditions/management activities. Yurok Fisheries staff also participate in adult spring Chinook and summer steelhead survey dives in the Salmon River, South Fork Trinity River, and the New River.

**Yurok Tribe Non-Salmonid Population Monitoring**

Non-salmonid fish species such as green sturgeon, lamprey, and eulachon, are important components of the diet and culture for Yurok People. With the exception of eulachon, these species have neared extirpation in recent decades. The Tribe has conducted 15 years of projects to assess the status, life history and/or habitat requirements of these species. The Tribe has tagged adult green sturgeon (*Acipenser medirostus*) intermittently since the early 2000s, initially using radio tags and then switching to acoustic tags for detection by acoustic receivers that were deployed by other entities along the Pacific Coast. This study yielded useful information regarding the life history of green sturgeon. For example, sturgeon adults tagged in the Klamath River were detected as far north as Vancouver Island, British Columbia, and in bay/estuarine environments along the Oregon and Washington coasts. Green sturgeon adults were typically found to return to the Klamath River every two to four years to spawn, and distinct migration patterns were observed among adults, such as emigration to the ocean in the spring rather than October/November when the fall freshet begins. In collaboration with the Karuk and

Hoopa Valley Tribes, Yurok Fisheries also recently conducted lamprey telemetry tagging studies to assess life history characteristics. Other studies have attempted to assess the presence of eulachon (*Thaleichthys pacificus*) in the Klamath River, with little success. Future eulachon studies will likely include the use of environmental DNA to assess the species' presence longitudinally in the river.

#### Karuk Tribe Spawner Surveys

The Karuk Tribe conducts spawner surveys, carcass surveys, outmigrating juvenile trapping, fish disease monitoring, and runs PIT-tag arrays for coho and lamprey located throughout the Mid-Klamath. The Tribe also conducts monitoring of coldwater refugia and off channel ponds for coho use/abundance.

### NGOs and NGO-led Programs

#### Trout Unlimited Population Monitoring

Trout Unlimited participates in fish and wildlife population monitoring led by partners, including Oregon Department of Fish and Wildlife fish sampling, U.S. Fish and Wildlife Service Oregon Spotted Frog sampling, and The Klamath Tribes wocus monitoring. The organization is also partnered with Crater Lake National Park staff to document the abundance of bull trout in Sun Creek.

### Community Organizations and Programs

#### Mid Klamath Watershed Council Spawner Surveys

The Mid-Klamath Watershed Council has participated in restoration projects in the Mid-Klamath subbasin since 2001. Population monitoring efforts include participation in fall carcass surveys along Klamath River Tributaries. MKWC also collaborates with the Karuk Tribe fisheries department to survey for spring Chinook, summer steelhead, winter steelhead, as well as green sturgeon, and participates in multi-agency fish kill monitoring efforts throughout the summer months (www.mkwc.org). Survey data are used to help determine population trends for Klamath River fish stocks, and to set harvest allocations for certain species.

#### Salmon River Restoration Council Adult and Juvenile Salmonid Population Monitoring

Since the early 1990's the Salmon River Restoration Council (SRRC), has been a lead coordinator with the USFS Klamath National Forest (KNF), Salmon/Scott Ranger District, of the Salmon River Cooperative Spring Chinook and Summer Steelhead Census Dive. This annual effort brings together volunteers and fisheries professionals to cooperative dive 100 miles of the Salmon River and main tributaries on 2-4 mile reaches during one day. This effort is the longest running live census of salmonids in the Klamath Basin and helps assess population status and trends for the critically imperiled spring-run Chinook population.

SRRC also coordinates annual spring-run and fall-run Chinook spawning and redd surveys, with volunteers (spring-run), the Karuk and Yurok Tribes, the KNF, and the California Department of Fish and Wildlife (CDFW). Collected data feeds into the Klamath River Spring and Fall Chinook Mega Tables maintained by CDFW, which tabulate and present spawning and harvest data and help set harvest guidelines for subsequent years. During these surveys, field technicians gather tissue, scale and otolith samples from carcasses. The samples have been used for many genetic and life history studies, including recent work by the UC Davis, Integrative Genetics and Genomics Group establishing the genetic uniqueness of Klamath River spring-run Chinook.

SRRC has also conducted occasional steelhead and coho spawning surveys, but hazardous winter conditions on the flashy river system and the volunteer nature of the work make this effort difficult and inconsistent. Regardless, SRRC was able to establish that a small population of coho salmon do spawn annually in the Salmon River.

Since 2000, the SRRC has conducted periodic juvenile coho assessments. These include presence/absence surveys in collaboration with the Karuk Tribe on the Salmon River and key tributaries (also includes juvenile Chinook and Steelhead), population surveys under the Coastal Monitoring Plan Aquatic Survey Program, migration trap monitoring for the Karuk tribe at their out migration trap near the mouth of the Salmon River and at Big Bar on the Klamath River, and annual assessment of juvenile and adult fish passage throughout the Mid Klamath Basin and Salmon River tributaries with the Mid Klamath Watershed Council. SRRC and MKWC manually manipulate flow and create step pools to increase access to cold-water tributaries while also adding brush bundles at refugia sites to increase cover and habitat quality. This effort includes pre and post juvenile salmonid presence/absence surveys for the first 1000 feet and/or 10 pools.

**Oregon State University Salmon Disease Monitoring**

Since 2006, the Bartholomew Lab in Oregon State University's Microbiology Department has conducted salmon disease monitoring and research funded by the US Bureau of Reclamation. This work tracks the spatial and temporal abundance of *C. shasta* in the Klamath Basin using sentinel fish exposures, river water sampling, and polychaete sampling (Bartholomew et al. 2017). Data are used to inform models that can better predict disease effects on salmonids under different temperature and flow conditions.

### 7.2.6 Population Monitoring in Key Plans

Figure 7-9 shows the results for population status and trend monitoring from our review of 31 restoration and monitoring plans/documents (see Section 5.5 for an explanation of our selection method). Overall, this type of monitoring is specified less frequently than habitat status and trend monitoring.

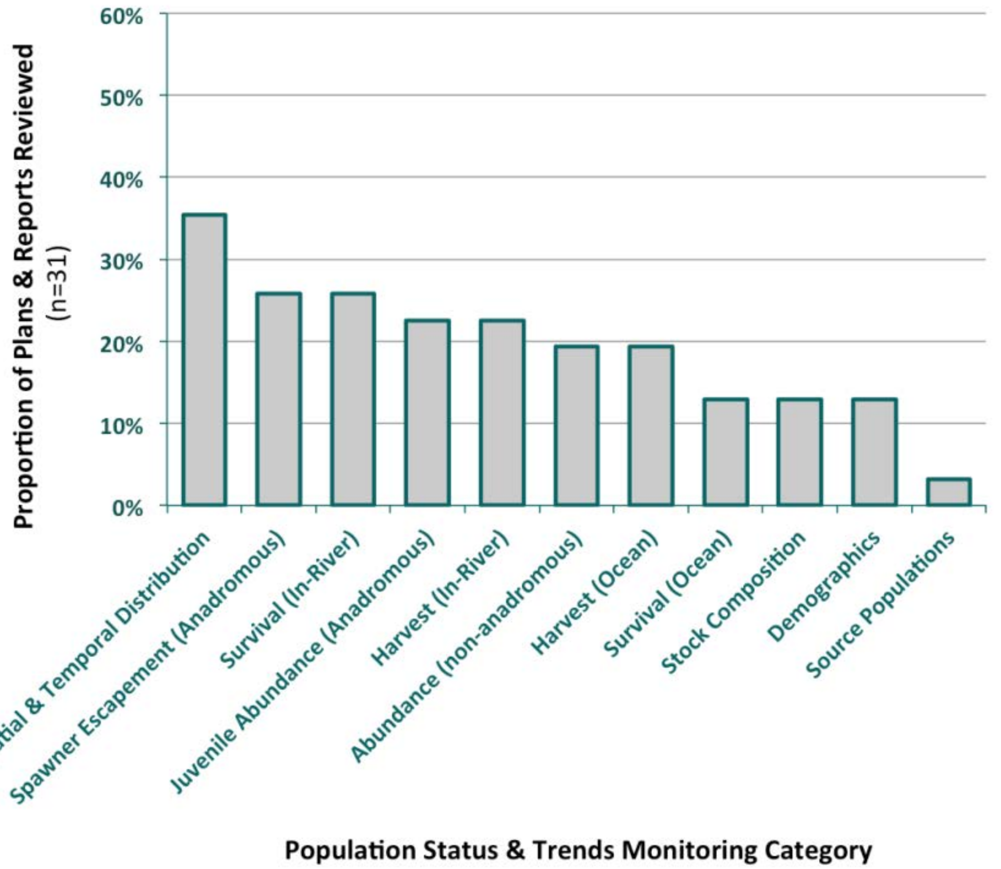


Figure 7-9: Frequency of occurrence of different categories of population monitoring expressed in plan objectives.

Monitoring of spatial and temporal distribution is the most frequent category (35%). Non-anadromous abundance, in-river survival, and in-river and ocean harvest each occur in 20-25% of documents. Relatively infrequent categories of monitoring include ocean survival, stock composition, demographics and source populations.

## Box 7-3: Spotlight on Monitoring in the SONCC Coho Salmon Recovery Plan

The National Marine Fisheries Service's (NMFS) plan for recovery of Southern Oregon/Northern California Coast (SONCC) coho Evolutionarily Significant Units (ESU) focuses on detailed monitoring strategies including sampling standards and data requirements for measuring abundance and distribution over time in each population. The plan incorporates effectiveness monitoring as part of an adaptive management approach where recovery actions can be adjusted based on new information and physical and biological effectiveness metrics (NMFS 2014a). About 32% of the project cost (over 100 years) will be directed at monitoring efforts (approximately $16 million/yr region-wide). Monitoring of adult and juvenile coho takes place in Upper/Mid-Klamath, Salmon, Scott, Shasta, Trinity and South Fork Trinity sub-basins. Upper Klamath, Scott, Shasta and Trinity are identified as good candidates for life cycle monitoring stations.

Monitoring of SONCC coho salmon and habitat is done at the population scale (NMFS 2014a). For coho ESUs NMFS follows monitoring methods detailed in California's Coastal Salmonid Monitoring Program (CMP) and the monitoring components of Oregon's Plan for Salmon and Watersheds (OPSW) paraphrased below (NMFS 2014a):

1. Create a monitoring framework that includes all relevant coho ESUs.
2. Conduct status and trends monitoring for the following:
    - watershed health and water quality;
    - ESU-level population abundance;
    - population productivity;
    - population spatial distribution and structure; and
    - life history and ecological differences across ESUs.
3. Create permanent life cycle monitoring stations.
4. Implement physical and biological effectiveness monitoring (including validation monitoring) of programs and actions.
5. Determine whether goals of effectiveness and validation monitoring can be achieved by measuring a subset of restoration actions. Determine appropriate subset.

Life cycle monitoring stations monitor smolt and adult abundance, and can be used to: (1) estimate abundance of adult coho and downstream migrating juveniles; (2) estimate marine and freshwater survival rates; (3) track abundance of juveniles coincident with habitat modifications; and (4) calibrate spawning ground surveys for estimating adult abundance based on live adult, redd and carcass observations. These stations need to be located and designed for complete counts basin-wide or for sub-portions of the basin and use weirs, fences, traps, live mark/recapture techniques and/or sonar.

## 7.3 Project Effectiveness Monitoring

> *"Evaluation of any habitat manipulation program is needed to determine whether enhancement projects achieve their intended objective and whether or not projects are working. Unfortunately, project expenditures are far ahead of our knowledge of the effectiveness of these 'improvements'. Without evaluation, we cannot recognize our mistakes, innovate appropriate new techniques, or determine if funds have been wisely spent. "*
>
> ***-B. Fontaine (1988)***

The effectiveness of restoration activities should be monitored to ensure they are achieving the desired results. As stated in Section 7.1.1, **Project Effectiveness Monitoring** is 'monitoring to evaluate' and can be used to assess whether project objectives are carried out as planned (implementation monitoring), whether restoration actions are resulting in the expected physical effects (physical effectiveness monitoring), and whether an expected biological response occurred (biological effectiveness monitoring) (see Figure 5-2). All three types of monitoring can occur in conjunction with restoration actions. We focus here on the latter two forms of monitoring. Both types depend on performance measures. **Physical Effectiveness Monitoring** often relies on a Before-After-Control-Impact (BACI) approach that requires pre-treatment and post-treatment monitoring of conditions at both reference sites and treated sties (Porter et al. 2014). When pre-treatment characterization has not occurred, it is also possible to randomly sample from similar habitats and use these as a proxy for the pre-treatment state of the monitoring site (Porter et al. 2014). Example indicators that might be tracked with physical effectiveness monitoring include changes in water quality, flow, stream temperature, riparian plantings status, channel connectivity, reclaimed estuary area and others. **Biological Effectiveness Monitoring** can measure short- or long-term responses to restoration actions (e.g., successful passage through a former barrier to recolonized habitats, population increases from cumulative basin restoration) and requires counts of juvenile and adult fish as well as behavioral data (e.g., via snorkel surveys, electrofishing, PIT tags). Caution is advised for biological effectiveness monitoring, since it is a complex and technically rigorous approach requiring measurement of many parameters (Washington Salmon Recovery Funding Board 2003). Monitoring of long-term responses is easily confounded by other limiting factors or variables not addressed in the restoration action. Responses to restoration actions may also be difficult to detect or interpret at some spatial scales, requiring assumptions that are easily violated (Porter et al. 2014). These challenges may suggest biological effectiveness monitoring is best suited for short-term monitoring of actions with fast response times. However, at the population level, where it is also referred to as validation monitoring, this type of monitoring is the only form that can establish clear causal relationships between fish populations, habitat and management actions (Washington Salmon Recovery Funding Board 2003). Since biological effectiveness monitoring at the *population* scale is rare, in this section we focus primarily on *project* scale physical and biological effectiveness monitoring.

Existing databases and project summaries sometimes do not explicitly state whether a given monitoring program is focused on status and trend monitoring, effectiveness monitoring, or both. In the following summaries, we focus on information where monitoring data had potential benefits for monitoring the independent or cumulative effects of restoration projects. Cumulative effects can sometimes be inferred from status and trend monitoring, provided that there are appropriate contrasts over space and time.

## 7.3.1 Major Project Effectiveness Monitoring Programs

### Federal Organizations and Programs

#### NMFS Pacific Coastal Salmon Recovery Fund (PCSRF) Database – Project Effectiveness Monitoring

After the development of project performance metrics in 2005 and 2010, the NMFS Pacific Coastal Salmon Recovery Fund (PCSRF) launched a project database and interactive web map (https://www.webapps.nwfsc.noaa.gov). This database catalogues PCSRF grant-funded restoration projects in the Klamath Basin from 2000 to 2016, 13 of which had project effectiveness monitoring objectives (NMFS 2016b). This handful of projects was primarily distributed across the Trinity, Salmon, Mid Klamath, and Upper Klamath river sub-basins and generally occurred on an annual or semi-annual basis (Figure 7-10). Spending ranged from about $7,500 to $128,000 per project (average $28,000).

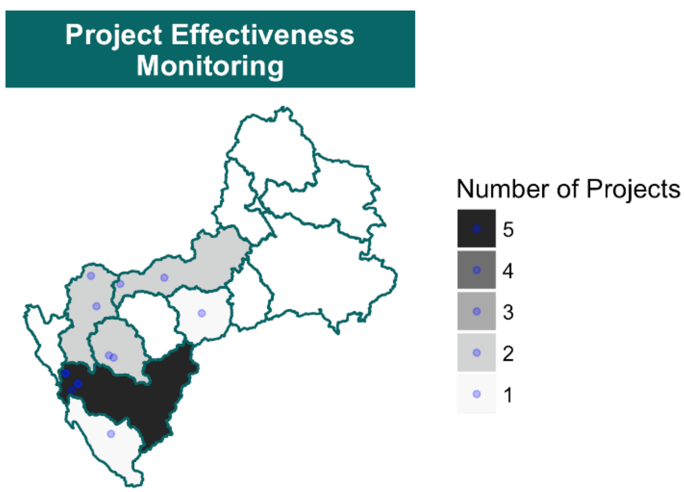


Figure 7-10: Frequency of PCSRF project effectiveness monitoring projects by sub-basin 2000-2016 (n = 13).

#### USGS Effectiveness Monitoring of Sucker Restoration Projects

The US Geological Survey conducts effectiveness monitoring of sucker restoration efforts in the Upper Klamath Basin. Key examples include assessing the effects of Chiloquin Dam removal on restoration of Lost River, shortnose and Klamath largescale sucker populations in the Williamson and Sprague Rivers (Martin et al. 2013b), and evaluation of the impacts on Lost River and shortnose suckers of The Nature Conservancy's Williamson River Delta Restoration Project (Burdick 2012; Wood et al. 2013). In 2015, the USGS conducted an evaluation its juvenile sucker cohort tracking efforts, with consideration of capture efficiency, size selectivity, and assumptions made during survival analyses (Burdick et al. 2016).

#### USFWS Effectiveness Monitoring of Restoration Projects

The USFWS funds Tribal and agency research and monitoring for anadromous fish restoration in the Klamath River Basin. In 2013, the agency contributed more than $2.9 million to these efforts (NMFS 2015), which include monitoring the effectiveness of restoration efforts. Project effectiveness monitoring has included assessment of the effects of coho and Chinook rearing habitat restoration in the Trinity River (Goodman et al. 2016; Goodman et al. 2014; De Juilio et al. 2014).

### State Organizations and Programs

#### ODFW Effectiveness Monitoring of Restoration Projects

The Oregon Department of Fish and Wildlife (ODFW) conducts a large number of fish restoration and monitoring projects in the Oregon portions of the Klamath Basin (ODFW 2016). A majority of these efforts are focused on population monitoring for a variety of listed and unlisted species (see Section 7.2.5), however, ODFW also evaluates the effectiveness of monitoring and restoration actions. Recent examples include a distribution survey in 2014 for redband trout on Deming Creek Ranch to determine if summer distribution is increasing, monitoring of Rock Creek to ensure successful rotenone treatment and removal of brook trout, and monitoring of Miller Lake Lamprey in Evening Creek to determine if reproduction success is increasing (ODFW 2016).

### Tribal Organizations and Programs

#### Yurok Fisheries Lower Klamath River Effectiveness Monitoring

The Yurok Tribe's Lower Klamath Division of Fisheries (YTFP-LKD) conducts performance monitoring to assess effectiveness of implemented restoration actions to guide their adaptive management approach and to ensure knowledge transfer to basin partners. Major programs include off-channel pond effectiveness monitoring, constructed wood jam (CWJ) effectiveness monitoring, and general fish population monitoring.

From 2010-2016, YTFP-LKD (with Fiori GeoSciences) constructed eight off-channel habitat features within priority Lower Klamath tributaries. To help assess the performance of these constructed habitats, YTFP-LKD monitors fish use, water quality, and habitat conditions within each feature. Methods include photographic monitoring and repeat topographic surveys using Real Time Kinematic (RTK) GPS equipment and optical total stations at each site to document baseline and as-built conditions and to help assess habitat changes over time. Water quality data are gathered using hand-held YSI probes and sondes that collect continuous water quality samples. Parameters monitored include water temperature, dissolved oxygen, pH, and specific conductivity. These monitoring efforts have provided valuable insight into how stratigraphy and ground and surface water interactions influence water quality in "blind ended" alcoves. Knowledge gained from initial studies of Terwer Creek alcoves and McGarvey Creek Alcove I, influenced the designs for McGarvey Alcoves II-IV. These features were constructed to receive more ground and/or surface water inputs, which resulted in improved dissolved oxygen and water temperature conditions relative to McGarvey Alcove I, which is sited in a location with minimal hyporheic or surface water exchange.

To assess fish use of constructed off-channel habitats, YTFP-LKD routinely conducts seasonal mark-recapture population estimates using the Chapman modification of the Petersen estimator (Ricker 1975). PIT tag antennas installed in a few Lower Klamath off-channel habitats also help improve our understanding of fish use, primarily coho salmon. Fish monitoring at these sites has documented variable but consistent use of constructed off-channel habitats by juvenile salmonids. Data collected for this program are available via various YTFP-LKD reports. Much of the information collected to-date will be summarized in individual Case Study Reports slated for completion in late 2017 and will be available online via the Yurok Fisheries website (http://www.yuroktribe.org/departments/fisheries/).

To assess the effectiveness of CWJs and other related wood loading activities in Lower Klamath tributaries, the YTFP-LKD also conducts monitoring using similar visual techniques as for off-channel habitats. In some cases, YTFP-LKD has placed individual tree tags on installed wood to help monitor stability and/or track movement of mobile wood. The photo-monitoring and topographic surveys document baseline, as-built, and post-restoration habitat conditions and help assess changes over time. Survey metrics of interest include number of pools, residual pool depth, pool:riffle ratio, width:depth ratio, channel sinuosity, and floodplain connectivity.

Insights gained from these monitoring efforts support generally accepted wood loading principles: (1) more complex structures provide increased ecosystem benefits relative to more simple structures which are common to California; (2) using a combination of whole tree materials (i.e., long stems with rootwads attached, medium – small logs, and slash materials) dramatically increases habitat complexity and structure resiliency; (3) complex and/or post assisted structures are more capable of collecting and retaining mobile wood relative to more simple structure types; and (4) more complex structures are more capable of initiating and maintaining floodplain connectivity. Other points of interest for these monitoring activities include assessing the life span of installed jams in various environmental settings, identifying potential failure mechanisms, and monitoring wood decay.

Recently, YTFP-LKD has been conducting snorkel inventories in conjunction with physical habitat mapping protocols to document juvenile salmonid use of CWJs versus use of untreated habitats and/or reaches (study streams are Terwer, Hunter, and Hoppaw creeks). Protocols employed thus far are similar to those outlined in Pess et al. (2005). Photo-monitoring and topographic survey information is available via various YTFP-LKD reports and databases; however, YTFP-LKD is in the process of collecting, reviewing, and summarizing the fish use information.

Yurok population monitoring of juvenile Chinook salmon abundance and adult fall Chinook age composition (described in Section 7.2.4) also permits evaluation these populations' responses to management actions and environmental conditions. Lastly, the Yurok Juvenile Coho Ecology Project has been critical for guiding and assessing effectiveness of lower Klamath tributary coho restoration efforts (described in Section 7.2.4).

### Karuk Tribe Off-channel Pond Effectiveness Monitoring

The Karuk Tribe has supported effectiveness monitoring by graduate students from Humboldt State University of off-channel pond creation for juvenile coho habitat (Witmore 2014; Krall 2016). Krall's (2016) study found that many constructed ponds were occupied by and supported juvenile coho during periods when mainstem conditions were poor for survival, and that habitat conditions within these ponds are within a suitable range for juvenile coho. Witmore (2014) found no statistically significant difference between the beneficial effects of constructed off-channel ponds, beaver influenced ponds, and small tributaries.

## NGOs and NGO-led Programs

### Williamson River Delta Water Quality and Vegetation Monitoring

From 2007 to 2012 following intentional levee breaches by The Nature Conservancy (TNC), the organization began monitoring water quality and vegetation across the re-inundated portion of Williamson River Delta Preserve (5.5 sq mi/14.2 km$^2$). The program documented effects of restoration on surface water chemistry within and surrounding the delta. Bi-weekly grab sampling and subsequent laboratory analysis was performed annually from March through November to examine nitrogen, phosphorous and carbon constituents. During the same period, continuous multi-probe monitoring was utilized to collect water temperature, dissolved oxygen, pH, and specific conductance data on an hourly basis. Vegetation monitoring involved cataloguing changes in wetland diversity over time. New open water, deep water, wetland, emergent marsh and riparian habitats were created following re-inundation. Most vegetation recruited naturally and established in areas determined by flood duration, water depth and existing seed sources. However, monitoring indicated some supplementary planting was required (Willow, Tule and Wocus lily) to increase diversity, remediate disturbance, and mitigate invasive plant infestations. Additionally, starting in 2005 TNC seeded several native species into former agricultural fields in upland areas of the Preserve (e.g., native bunchgrasses and forbs). The organization has monitored the effectiveness of these re-vegetation efforts annually since 2010. These data collected by TNC help to assess the effectiveness of wide-ranging efforts by multiple agencies and organizations in the upper Klamath Basin to restore and manage wetlands. Overall, the monitoring program suggests positive trends in the delta's water quality since restoration and an increase in plant diversity, including a transition from pioneer species to early/mid-seral species.

### Williamson River Delta Sucker Population Monitoring

Historically, the marshes surrounding Upper Klamath Lake were some of the most important nursery and rearing habitats for several sucker species. The Nature Conservancy's (TNC) Williamson River Delta restoration project was designed to address both water quality and habitat availability to directly benefit sucker populations. Currently, approximately 4 sq mi/10 km$^2$ of emergent wetland habitat have been made available for larval and juvenile sucker rearing, with an additional 4.7 sq mi/12 km$^2$ of open water habitat. Following re-inundation, a monitoring program was implemented to document changes in sucker populations. Suckers were initially studied in pilot restoration areas (2000-2005) before a long-term monitoring program was established in 2006. Program monitoring goals included:

1. Determine the distribution, abundance, and habitat use of endangered larval suckers with a focus on the Tulana and Goose Bay portions of the delta.
2. Determine if other species (native and non-native) are using the restored wetlands.
3. Describe and characterize condition (age, size, growth, gut fullness) of larval suckers.
4. Determine how restoration at the delta changes the distribution and patterns of habitat use by larval suckers along Upper Klamath Lake shorelines and in South Marsh.

A number of sampling methods were applied throughout the 2000-2011 monitoring period. Pop-nets were used to collect fish samples for analysis. When sucker monitoring was completed, the results were promising. Larval suckers inhabited the restored wetlands and were exhibiting greater body lengths and fuller guts in the vegetated areas.

#### Community Organizations and Programs

**Mid-Klamath Watershed Council Off-channel Pond and Thermal Refugia Effectiveness Monitoring**

Since 2001, the Mid-Klamath Watershed Council has participated in restoration projects in the Mid-Klamath subbasin. Effectiveness monitoring efforts include tracking recovery of restored off-channel pond habitat and monitoring use of restored thermal refugia by juvenile fishes (www.mkwc.org).

**Salmon River Restoration Council Habitat Restoration Effectiveness Monitoring**

The Salmon River Restoration Council (SRRC) with assistance from Stillwater Sciences and Sweet River Sciences, is conducting a comprehensive Salmon River floodplain and mine tailing assessment, which is now entering an implementation phase for in-stream habitat restoration. That phase will be accompanied by project effectiveness monitoring. In addition, during the summer of 2017, SRRC will implement the South Fork Tributary Habitat Improvement Project, which increases wood loading in two key tributaries. This project will be followed by two years of intensive post-project monitoring to assess the effects of the increased structure on geomorphology of the reaches and spawning and rearing habitat.

### 7.3.2 Project Effectiveness Monitoring in Key Plans

Figure 7-11 indicates that both types of effectiveness monitoring occur infrequently in the plans/documents reviewed compared to status and trend monitoring.

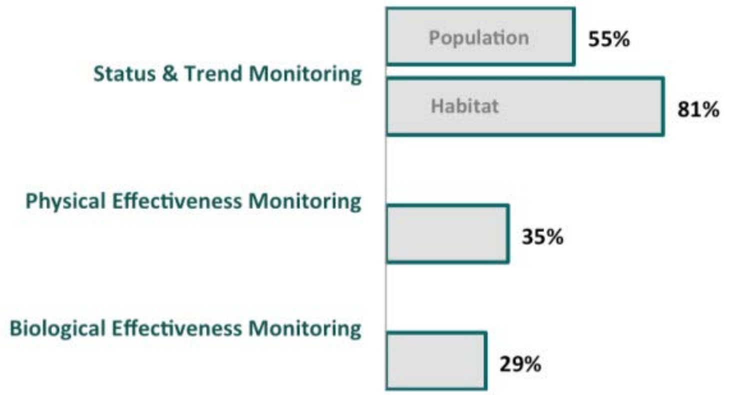


Figure 7-11. Frequency of monitoring types in key Klamath Basin monitoring plans and related documents.

For the purposes of this synthesis we use the same categories for Physical Effectiveness Monitoring as those listed in the Habitat Status and Trends Monitoring section (see Table 7-1). We consider only one category ('fish population') for Biological Effectiveness Monitoring.

Figure 7-12 shows that fish population monitoring was the most frequent type of effectiveness monitoring in our sample of studies (29%). Of the habitat categories listed, physical effectiveness of riparian & landscape (26%) and water quality (23%) actions are most frequently specified. Marine/estuary and groundwater actions are not targeted for Physical Effectiveness Monitoring in any of the documents.

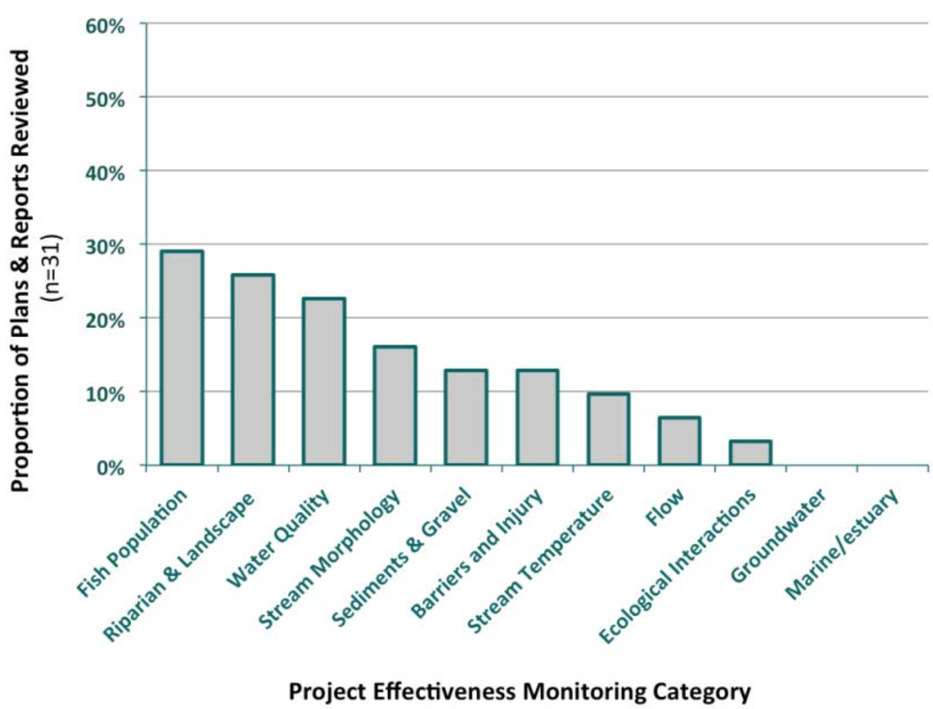


Figure 7-12: Frequency of occurrence of different categories of project effectiveness monitoring expressed in plan objectives.

# 8 Where to From Here?

The purpose of this section is to outline suggestions for the major steps that should be completed in the iterative development of the Integrated Fisheries Restoration and Monitoring Plan for the Klamath Basin.

## 8.1 Synthesis Report is Just a Beginning

**This Synthesis Report was a first step towards development of the full Plan, "a conversation refresher"** to invite and expand cooperative engagement of all interested participants through inclusive workshops, interviews and peer review. The ultimate product – an Integrated Fisheries Restoration and Monitoring Plan (IFRMP) for the Klamath Basin – is intended to help agencies and Tribes with fisheries management jurisdiction to **wisely allocate funds in a coordinated manner to support the most effective restoration and monitoring work in the Klamath Basin**. A **key** principle underpinning this Plan is that native fish species will be able to return to the upper basin *either* through removal of the four lower Klamath River dams (USDI et al. 2012) *or* by adding extensive new and enhanced fish passage infrastructure that will allow native fishes to effectively migrate past the dams. This includes providing a science framework and decision-making processes, data and tools that allow agencies to: (1) determine how to logically sequence and prioritize the implementation of actions for restoring fisheries and fish habitat; (2) design monitoring and evaluation activities to assess the effectiveness of restoration actions; and (3) adjust restoration actions and monitoring approaches based on what is learned through time. The IFRMP is expected to describe a comprehensive approach based on systematic and iterative methodology that emphasizes learning from the outcomes of carefully designed restoration and monitoring actions.

Although it was beyond the scope of this synthesis to conduct a census of *every* monitoring and restoration effort to date, **we have applied multiple complementary approaches to capture information on major stressors, restoration and monitoring organizations, programs, and projects across the Klamath Basin** (Section 5.5). Our approach also helped to identify major stressor categories and link the classes of restoration actions that alleviate these stresses. The level of detail is sufficient to provide broad insights into the scope, scale, distribution, and nature of these activities and how they have changed through time. This enables us to present general patterns in the relative distribution of restoration projects across restoration and monitoring types or sub-basins (knowing that *precise* numbers of projects, dollars, etc. are not *exactly* right). Our status and trend summaries (e.g., Section 6.4) are further supported by broader discussions of restoration and monitoring techniques, their effectiveness, as well as case studies of recent projects in the Klamath Basin that provide greater context around how these activities are implemented on the ground.

The synthesis step is merely a beginning, designed to lay the groundwork for the broader Plan. By providing interested parties with a consolidated repository of useful information on restoration activities with supporting data, case studies and tools, it will be possible to more efficiently and objectively move towards iterative development of the full IFRMP. The underlying data and information assembled can be further iteratively polished for 'completeness' and leveraged in future steps to rigorously identify gaps and needs. While an important step forward, this Synthesis Report was not intended to present a unified, comprehensive conceptual model for "the way things work" in different parts of the Klamath Basin, or to identify the most effective restoration strategies that have been completed so far. Those tasks are for later in the process of developing the IFRMP.

*How do we move from the vast array of restoration and monitoring activities in the Klamath Basin conducted by dozens of actors towards a common vision and direction for a comprehensive, integrated IFRMP, a focused, practical and rigorous Plan to restore self-sustaining natural production of fish populations, and eventually allow for the resumption of Tribal, recreational and commercial fisheries with enhanced harvest opportunities?* As advised by the National Research Council (NRC 2004, 2008) and others, **the most important first step involves embracing an adaptive management mindset and the associated best practices** to guide the collaborative design and prioritization of restoration work, and to promote iterative learning and adjustment. NRC (2004, 2008) encouraged the broad community of organizations and interested participants pursuing Klamath River restoration to organize assessments around the principles of adaptive management, and to use adaptive management to rigorously assess the river's response to restoration actions and ultimately the response of fish populations that depend on the river. A solid adaptive management framework is essential for defensible science in support of dam removal or extensive improvements to fish passage facilities and related fisheries goals and objectives. To elaborate on NRC's advice, **Section 8.2 outlines important best practices for what adaptive management entails when practiced in a rigorous manner**.

Adaptive management practice in the Klamath River Basin will also benefit from **adopting elements of organizational and technical approaches used successfully elsewhere** to enhance effectiveness and efficiencies. While not an exhaustive list, Section 8.3 provides lessons and insights from programs in four river basins that have wrestled with complex aquatic ecosystem and fish recovery efforts: (1) the Trinity River Restoration Program; (2) the Dry Creek Adaptive Management Plan; (3) Elwha Adaptive Management Guidelines; and (4) the Columbia River Basin.

The Pacific States Marine Fisheries Commission has recognized the need for adaptive management to achieve restoration and monitoring goals in the Klamath River Basin and provide and synthesize reliable scientific information to decision-makers. The *process* of developing the IFRMP using an adaptive management paradigm (Section 8.4) requires a highly specialized set of steps, knowledge, skills and abilities. These include: technical scientific facilitation to forge interdisciplinary strategies; conceptual and quantitative model development; experimental design; statistical insights on sampling techniques; application of quantitative tools and methods to support decision-making; science communication; experience with complex information management systems; and applied adaptive management techniques to monitor, evaluate and adjust restoration actions through a systematic collaborative process. **Recommended steps to develop the IFRMP over the next two years are outlined in Section 8.4.**

## 8.2 Embrace the Adaptive Management Mindset

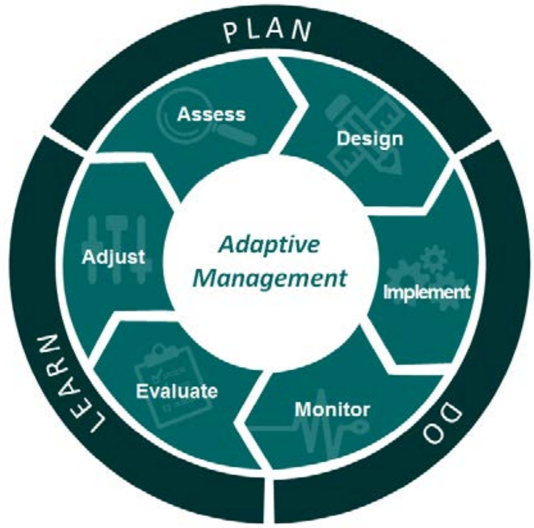


Figure 8-1: Adaptive management cycle.

Thirteen years ago the National Research Council's Committee on Endangered and Threatened Fishes in the Klamath River Basin (NRC 2004) noted numerous challenges with ecosystem management in the Klamath Basin, and identified the need for using adaptive management (Figure 8-1) as an organizing framework for restoration. One of the issues they highlighted pertains to the weight given to professional judgement rather than direct empirical evidence, and a reticence to abandon initial judgements even when they are not supported by empirical tests. The Committee stated that the adaptive management approach "*is both ecologically and socially responsible, given that ultimately all agencies and other stakeholders have limited resources with which to operate*", and that recovery of endangered fishes in the Klamath Basin "*cannot succeed without aggressive pursuit of adaptive management principles, which in turn require continuity, master planning, flexibility, and conscientious evaluation of the outcomes of management*". Four years later, a Committee on Hydrology, Ecology and Fishes of the Klamath River (NRC 2008) reaffirmed this need, noting the continued lack of integration of individual studies in the Klamath Basin, calling for an impartial body to define an overall vision for science and restoration, and reiterating the importance of connecting effective science with successful decision-making.

Other practitioners, such as Bennett et al. (2016) and Bouwes et al. (2016a), with experience in the intensively monitored watersheds in the Pacific Northwest, believe that adaptive management is the best approach for learning and prioritizing actions for effective stream restoration. As in the Pacific Northwest, adaptive management is being increasingly used in habitat restoration and species recovery in other large river basins including the Trinity River, Missouri River, Platte River, and Russian River. From our experience in some of these programs and elsewhere, we agree that adaptive management can indeed help as outlined in the two NRC studies (NRC 2004, 2008).

> **Box 8-1: What is Adaptive Management?**
>
> "Adaptive management is a formal, systematic, and rigorous program of learning from the outcomes of management actions, accommodating change, and improving management (Holling 1978). Its primary purpose is to establish a continuous, iterative process for increasing the probability that a plan for environmental restoration will be successful. In practice, adaptive management uses conceptual and numerical models and the scientific method to develop and test management options. It requires the explicit recognition that management policies can, with appropriate precautions, be applied as experimental treatments (Walters 1997). Decision makers use the results as a basis for improving knowledge of the system and adjusting management accordingly."
>
> Excerpt from NRC (2004), p.332.

Adaptive management has a variety of definitions, whether those of NRC (pg. 332;

2004, previous box) or others. Another helpful way to think about adaptive management is as **a 'mindset' focused on more rigorously defining uncertainties and approaches to learning, and building knowledge to assist decision-making**. Adaptive management is not needed in all environmental management situations but can be very useful *where there is significant uncertainty about the effectiveness of policies and practices*. Applying the rigor of adaptive management often requires an additional commitment of effort and resources, but *can lead to better decisions more quickly than the status quo* (Figure 8-2). Without a formal structured learning process, discoveries of what might work better will be serendipitous and slow, leading, at best, to very gradual improvements in the 'quality of the decision' (the effectiveness of the outcomes when compared against objectives). By applying a systematic, coordinated, structured approach to decision making, the community of co-managers, restoration practitioners, interested participants and decision makers more rapidly learn and reduce critical uncertainties affecting decisions (Figure 8-2).

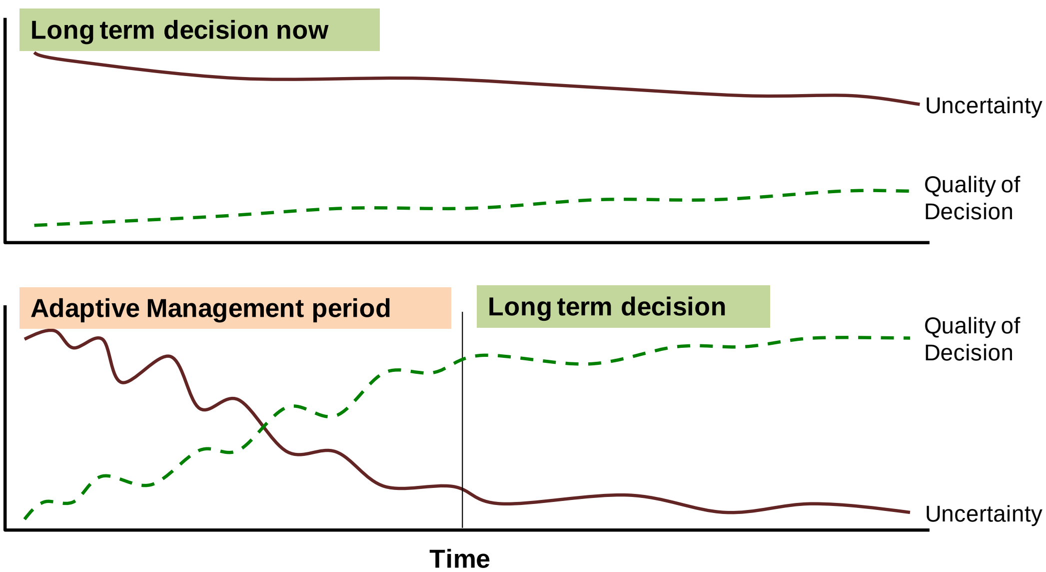


Figure 8-2: Illustration of how adaptive management (AM) can lead to better decisions. The graph on the top illustrates status quo management, where decisions are made without a formal mechanism to explicitly learn and reduce uncertainties. The graph on the bottom shows an alternative approach where by AM is used to actively probe the system and test competing hypotheses for the explicit purpose of quickly learning what works best.

Another advantage to thinking about adaptive management as a **mindset** (rather than a "recipe" of steps) is that even if all steps of the adaptive management loop (Figure 8-1) are not completed, applying best practices within the steps can still yield a variety of benefits (Figure 8-3). In the subsections below we expand upon lessons about best practices we have learned from other adaptive management programs and recommend the next steps to develop the complete IFRMP.

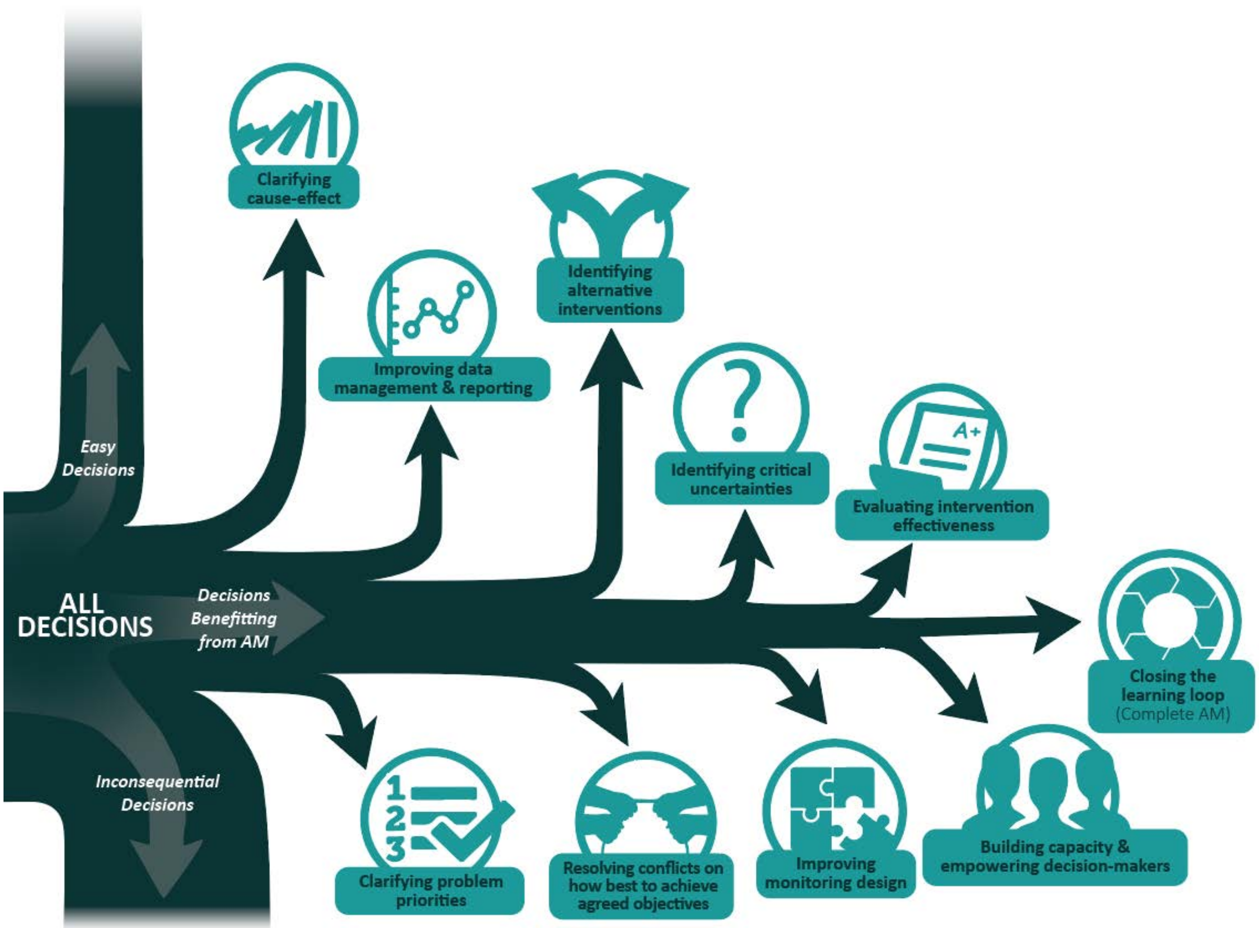


Figure 8-3: Benefits of approaching decisions using an adaptive management mindset.

Adaptive management comes with its own challenges, requiring awareness and preparation by prospective practitioners. The first challenge is that of simply “getting started” when there are so many entities involved in restoration of Klamath Basin fisheries (Figure 8-4 and Appendix I) and so many plans and programs underway. This provides both an opportunity and a challenge. The opportunity is for adaptive management to serve as a framework for coordinating restoration and monitoring efforts to support more efficient and effective learning. The challenge is to successfully implement adaptive management in such a complex setting.

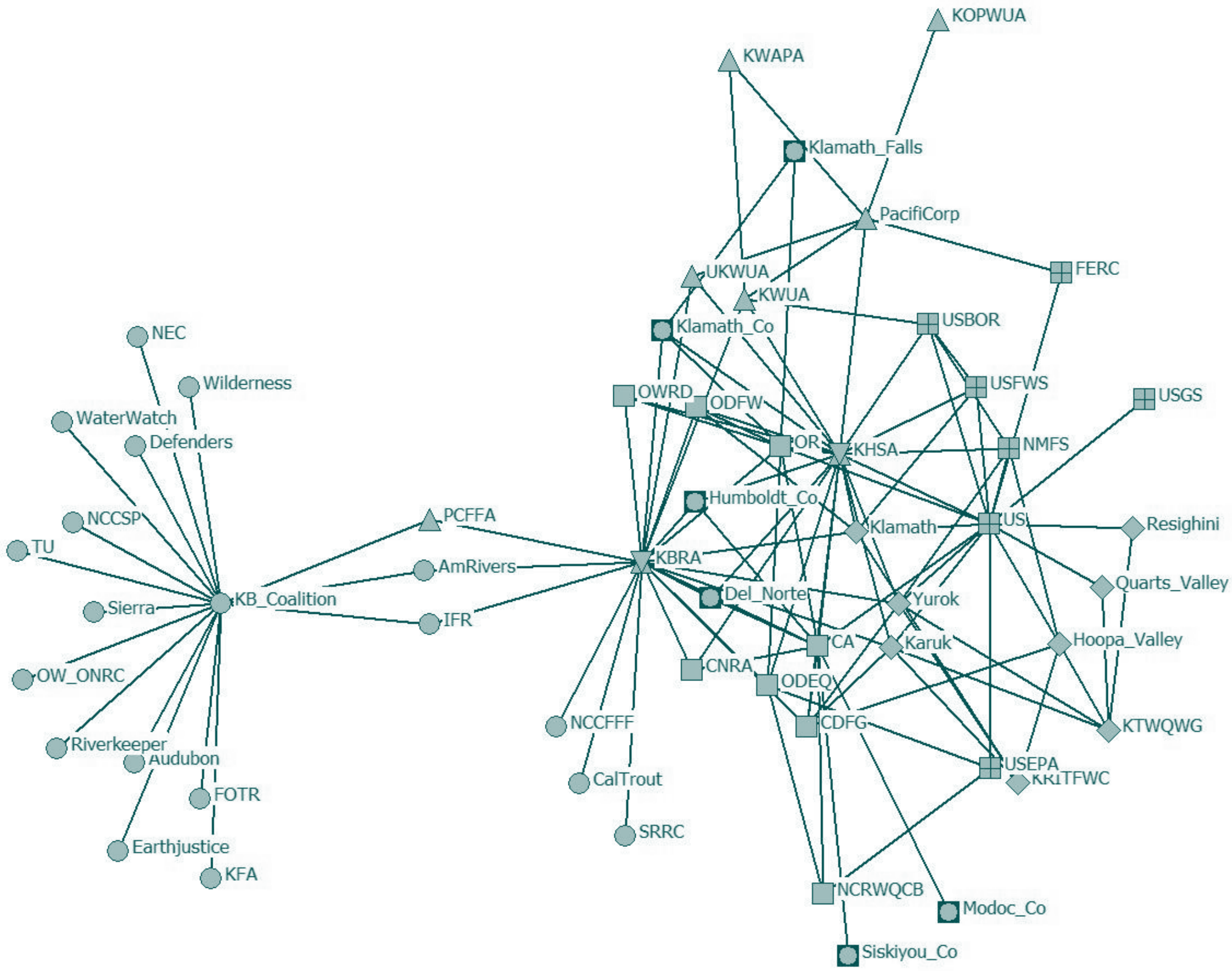


Figure 8-4: Network diagram of collaborating relationships in 2009-2010 between entities involved in Klamath Basin management and restoration. Based on the work described in Chaffin et al. 2015, pre-publication figure version used with permission of B. Chaffin.

What enables or inhibits adaptive management? Ten years ago ESSA engaged a group of leading adaptive management practitioners in a study for the National Commission on Science for Sustainable Forestry on factors that enable adaptive management (Greig et al. 2013). Figure 8-5 shows a hierarchical list of situation attributes that, if favourable, enable adaptive management (or conversely, if not favorable, can be inhibiting). While much discussion in the literature about adaptive management focuses on technical aspects, many of these attributes pertain to governance. This highlights the importance of sound technical practices *and* good governance towards enabling a successful adaptive management program.

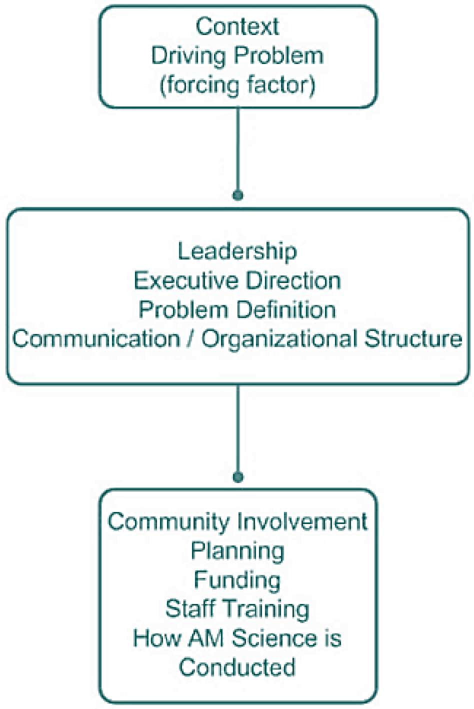


Figure 8-5: Hierarchy of factors that enable adaptive management (Greig et al. 2013). Once the factors in the middle box are well established, those in the lower box are likely to follow.

### 8.2.1 Technical Best Practices

There are widely varying uses of the term adaptive management, many of which fall far short of what is described in Box 8-1 and stray outside of what we refer to as 'real' adaptive management. Rather than get bogged down in lengthy debates about where the boundary lies, we find it more constructive to focus on what adaptive management entails when being practiced in a rigorous manner (Table 8-1). We typically use a simple six-step iterative process to describe adaptive management. While others sometimes use four or five steps, **the number of steps is less important than adaptive management's iterative, cyclical nature, and the specific work that should occur through the cycle (Table 8-1).**

Table 8-1. Summary of technical best practices for adaptive management (from Marmorek et al. 2006). [DQO] refers to practices which overlap with the Data Quality Objectives process (EPA 2006).

| | Best Practices within each Step |
|---|---|
| Step 1. Assess and define the problem | a. Clearly stated management goals and quantitative objectives (i.e., restoration and recovery goals and objectives for Klamath)<br>• State the problem based on overall conceptual model [DQO]<br>• ID the decisions that you want to make annually, episodically [DQO]<br>b. Build conceptual models (of system, of limiting factors, of restoration actions)<br>c. Articulate unknowns, ID key uncertainties (e.g., how restoration actions should affect focal species indicators, hypotheses to be tested)<br>d. ID alternative restoration actions (including existing restoration plans for Klamath)<br>e. ID focal species and measurable indicators<br>f. ID spatial / temporal bounds (representative study locations)<br>• ID the boundaries of the study [DQO]<br>g. Explicitly state assumptions<br>h. State up front how what is learned will be used<br>i. Involve interested participants, scientists and managers |
| Step 2. Design | a. Active AM - have documented AM designs for implementing actions in a systematic way (contrasting treatments, replications, controls where feasible at smaller scales)<br>b. Obtain statistical advice and generate a statistical design for implementation of restoration actions to provide information of sufficient statistical power and reliability for future decisions [DQO]<br>c. Consider range of possible outcomes (prediction, use of models), and have draft If/Then decision criteria or triggers for steps to follow under alternative states of nature and/or outcomes of restoration actions<br>d. Monitoring plan (existing monitoring plans)<br>• Develop "if-then" decision rules; triggers for what to monitor [DQO]<br>• Specify tolerable limits on decision errors [DQO]<br>e. Develop a data management plan (existing data management plans; tools)<br>f. Formal AM plan (for all steps, not just monitoring)<br>• Plan to revise full plan on a 5-yr timeframe (otherwise will become irrelevant)<br>g. Peer review of design<br>h. Draw up multi-year plans and obtain multi-year budget commitments<br>i. Involve interested participants, scientists and managers |
| Step 3. Implementation | a. Perform contrasting restoration actions as designed (contrasts over space, or over time; won't be possible for some large scale actions like dam removal)<br>b. Document any unavoidable changes from what was designed<br>c. Monitor the implementation |
| Step 4. Monitoring | a. Implement monitoring plan as designed<br>b. Baseline ("before") monitoring<br>c. Undertake status and trends monitoring<br>d. Concurrently undertake physical and biological effectiveness monitoring (incl. short-term pilot programs)<br>e. Implement the Data Management Plan as it was designed |
| Step 5. Evaluation of results | a. Compare monitoring results against restoration objectives [moving towards or away from goals?]<br>b. Compare monitoring results against assumptions, uncertainties, hypotheses, models [e.g., model predictions; existing analytical methods]<br>c. Receive further statistical or analysis advice – review adequacy of monitoring<br>d. Ensure data analysis keeps up with data generation from monitoring activities |
| Step 6. Adjustment / revision of hypotheses, monitoring and management | a. Document meaningful learning and how it has / will be used to change priority restoration and monitoring actions<br>b. Communicate learning to decision makers, all other participants, and the broader community<br>• Deliver at annual or bi-annual science symposiums (what has been learned, including surprises)<br>• Conduct parallel public outreach effort to communicate simplified science, lessons and obtain impressions of public/interested participants<br>c. Update decision criteria / triggers that will be used to evaluate whether restoration actions are working / need adjusting in future<br>d. Return to Step 1 and adjust the list of critical uncertainties, hypotheses, models, and monitoring approaches based on what has been learned; continue the next iteration of the cycle |

A key characteristic of adaptive management is **explicitly identifying and then reducing uncertainties that are hampering confident management decisions.** Often conflict can indicate uncertainty, although not all conflict can be resolved by adaptive management. For example, if there is disagreement over goals and objectives, conflict resolution approaches may be needed. Adaptive management is most likely to be helpful in situations where there is agreement regarding goals and objectives, but disagreement about how best to achieve them. Using adaptive management to resolve this type of disagreement essentially means applying the scientific method for learning (identifying and testing hypotheses) that is commonly used in research, and applying it to testing hypotheses that are relevant to environmental management decisions at an operational scale (Figure 8-6).

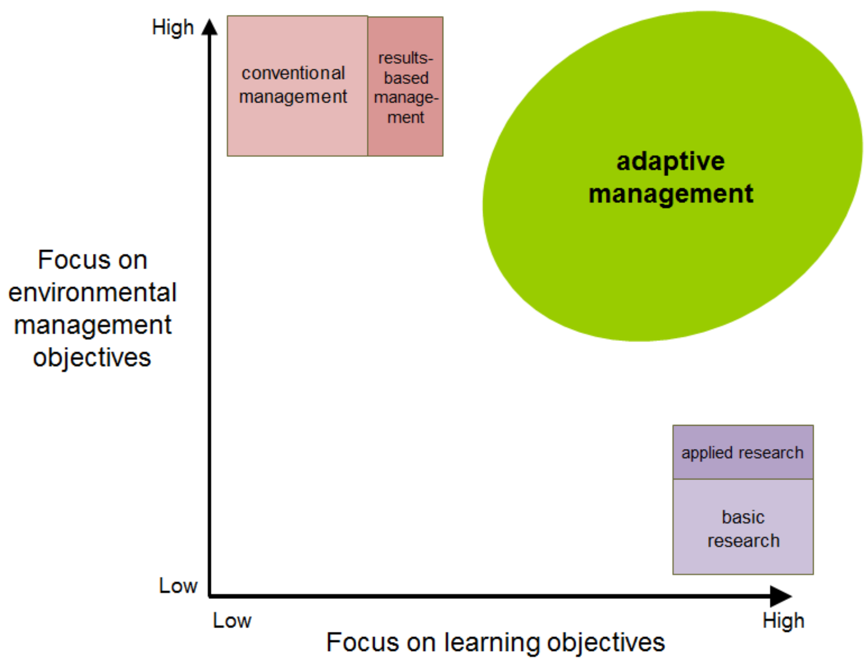


Figure 8-6: Characterization of how adaptive management differs from conventional management and basic research (adapted from Marmorek et al. 2006).

If there is considerable ecological uncertainty, other learning approaches such as smaller scale research may be required to improve understanding of the characteristics of the ecological system, *and are often included in adaptive management programs as precursors to larger scale management treatments.* For example, the Science and Adaptive Management Plan for the Missouri River Recovery Program is using a four-level approach to reducing uncertainties regarding pallid sturgeon that range from laboratory or field research studies through to implementation-scale actions expected to have a population-level response (Table 8-2).

Table 8-2: Pallid sturgeon framework for the Lower Missouri River (Fischenich et al. 2016).

| | | |
|---|---|---|
| Level 1: Research | Population Level Biological Response IS NOT Expected | Studies without changes to the system (laboratory studies or field studies under ambient conditions) |
| Level 2: In-river Testing | | Implementation of actions at a level sufficient to expect a measurable biological, behavioral, or physiological response in pallid sturgeon, surrogate species, or related habitat response. |
| Level 3: Scaled Implementation | Population Level Biological Response IS Expected | In terms of reproduction, numbers, or distribution, initial implementation should occur at a level sufficient to expect a meaningful population response progressing to implementation at levels that result in improvements in the population. The range of actions within this level is not expected to achieve full success (i.e., Level 4). |
| Level 4: Ultimate Required Scale of Implementation | | Implementation to the ultimate level required to remove as a limiting factor. |

In a system as large and complex as the Klamath Basin it will probably be impossible to eliminate all of the identified uncertainties – and it will certainly not be possible to reduce them all at once. Agreeing on which to tackle first is easier if participants can agree on a set of **objective, neutral prioritization criteria**. For example, the **Missouri River Recovery Program lists six criteria** in their Science and Adaptive Management Plan (Fischenich et al. 2016) **for prioritizing Level 1 and Level 2 science components** for pallid sturgeon:

- *Relevance to current decisions/actions*: whether the work would contribute to thorough effectiveness evaluations of actions that are expected to be implemented.
- *Biological value of information*: whether the work would provide strong evidence to inform decisions on actions in terms of either their biological benefit or feasibility (i.e., high information value relative to cost).
- *Minimize risk to species*: whether the information gained would help to avoid taking actions that pose a high risk to species.
- *Progress towards compliance*: whether the work would contribute to an evaluation of the status and trend of fish populations and progress towards objectives.
- *Timeliness of learning*: whether the work would provide faster answers than would otherwise occur, or in time to meet mandated deadlines.
- *Cost feasibility*: whether the varied benefits outweigh the costs.

Another effective approach is to **sequence** the uncertainties, key questions, hypotheses and indicators as restoration advances. For example:

1. Can spawning fish get past barriers and access new habitat? (Example indicator: changes in fish distribution – eDNA may be helpful as a cost-effective means of mapping distribution.)
2. Is that newly accessed habitat good for spawning and rearing? Are there places to spawn? Is water quality good enough for survival? (Example indicators: quantity and quality of spawning and rearing habitat, estimated juvenile survival.)

3. Can the offspring of fish that spawned in newly accessible habitats rear effectively and go out to sea as healthy smolts? (Example indicators: survival estimates through PIT-tagging, smolt size, condition and number, parr to smolt survival estimates.)
4. How many fish are coming back? Are they healthy? (Example indicators: smolt to adult survival rates, disease levels, fish condition.)

Adaptive management requires **sound experimental design**, and **contrast**. In river systems, the opportunities for contrast among actions that affect the whole system (e.g., testing changes in volume or timing of flow releases) are often temporal. Different actions need to be compared across multiple water years. In larger river systems such as the Klamath there will also be some opportunities for creating spatial contrasts among sub-basins or tributaries for actions with a smaller footprint (e.g., site-specific habitat restoration). Some may be sufficiently pristine to serve as 'untreated' controls; and others already dramatically altered could serve as a 'worst case' contrast. It is always a challenge to allocate money for monitoring control areas, but it is essential.

A retrospective analysis of habitat restoration actions in the Columbia River Basin and their effects on fish populations (Marmorek et al. 2004) also offer some important lessons that can inform adaptive management in the Klamath Basin:

- *Develop common and scalable indices of habitat restoration actions, to allow inferences at multiple scales.* Historical data rarely allowed inferences at multiple spatial scales (i.e., project, tributary, population, and sub-basin scales). Effects of restoration actions are diluted as the spatial and temporal scale increases by such factors as hydrosystem passage, variable climatic and ocean conditions, and different ecoregions. Noise from these factors can be filtered out (e.g., by using covariates), but project signals become weaker at larger scales.
- *Pay attention to where restoration projects and reference areas are located.* Most habitat actions occurred where habitat conditions were bad, with no systematic attempt to maintain and monitor control sites in areas with poor habitat conditions. As a result the areas with few to no habitat actions tended to be in wilderness areas. Even if restoration actions had increased fish survival, it would be difficult to detect without monitored controls in areas with poor habitat (i.e., more precise monitoring would not reduce this confounding).
- *Pay attention to the timing of restoration projects*. The apparent responses to treatments depend strongly on when the treatment is applied. Staggered implementation of restoration treatments would reduce the risk that treatment effects are masked by common year effects. Formal staircase designs (e.g., Walters et al. 1988) for treatment implementation could reduce this problem.
- *Use structured analysis tools and decision tools.* When managing large ecosystems where there are many competing demands for a limited budget, explicitly consider trade-offs between scientific objectives (e.g., high statistical power) and management objectives (e.g., work within budgets, achieve environmental improvements quickly). Decision analysis can help evaluate such trade-offs and is a powerful tool for designing large-scale monitoring and experimental programs (Walters and Green 1997).

### 8.2.2 Governance Best Practices

Setting up adequate governance structures and processes is essential for successful adaptive management. It is important to **clearly distinguish technical roles and responsibilities from management roles and responsibilities**. Table 8-3 summarizes how technical and management roles would differ in each of the six adaptive management steps. Figure 8-7 and Figure 8-8 illustrate this separation of roles in three other adaptive management programs. All three visual aids include the important role of **independent peer review**.

Learning is foundational to adaptive management. **Entities involved in adaptive management need to have strongly embedded learning processes** (looking back at what has been done, and learned) and **planning processes** (looking ahead to what needs to happen based on what's been learned). It is absolutely critical to share **updates to the state of knowledge** with all interested participants, in products such as summary reports, fact sheets, and more detailed technical reports. This includes efforts to simplify science and lessons learned for public outreach. Without such updates, there is a risk that valuable insights gained through adaptive management remain confined to a small technical group intensively involved in the work, while other participants retain their old paradigms (Marmorek and Peters 2001). This phenomenon can cause major setbacks when key staff change roles and move on; it's very important that departing staff convey to new staff the lessons they've learned (e.g., "I used to think that…").

Table 8-3: Differences between management and technical responsibilities, for each of the six steps of adaptive management (adapted from Murray et al. 2011).

| Step in AM Cycle | Management Role (includes Decision Makers and Interested Participants) | Technical Role |
|---|---|---|
| | Responsibilities are numbered in approximate sequence within each step, although frequent iteration will occur within and amongst steps. | |
| 1. Assess | 1.2 Raise issues and concerns.<br>1.3 Develop fundamental objectives (what is desired, not how to get there).<br>1.4 Explain to technical scientists why each fundamental objective matters (i.e., keep scientists focused on what matters to the decision makers).<br>1.5 Ask questions about efficacy of different management approaches and cause-effect relationships. | 1.1 Summarize existing knowledge about the ecosystem, and its history.<br>1.6 Develop performance measures/indicators associated with each fundamental objective, so that managers can use these to evaluate options.<br>1.7 Develop formal sets of alternative hypotheses that would inform critical uncertainties and are tied to fundamental Program objectives.<br>1.8 Filter these hypotheses down by summarizing what is known, what is not known, and what is unknowable. Focus in on critical uncertainties affecting resource management decisions.<br>1.9 Explain to decision makers and interested participants results of the filtering process (i.e., keep decision makers realistic about known / unknown). |
| 2. Design | 2.1 Develop broad strategies and alternatives to achieve the fundamental objectives, and resolve critical uncertainties concurrently.<br>2.4 Evaluate the alternative sets of management actions under consideration, and trade-offs among objectives (including learning as an | 2.2 Convert broad strategies and alternatives into hypotheses to be tested based on Step 1. Translate into specific sets of management actions that can be conducted in an AM experiment.<br>2.3 Simulate alternatives in a suite of models to evaluate expected outcomes of proposed alternatives, help |

| Step in AM Cycle | Management Role (includes Decision Makers and Interested Participants) | Technical Role |
|---|---|---|
| | Responsibilities are numbered in approximate sequence within each step, although frequent iteration will occur within and amongst steps. | |
| | objective).<br>2.6 Assess what level of investment is acceptable in monitoring and evaluation (depends on both funding and the risks of incorrect decisions based on faulty inferences).<br>2.7 Assess what management responses would be depending upon the outcome of the AM experiment.<br>2.9 Provide input on politically acceptable experimental designs, and approve the design of the AM experiment. | design the AM experiment, and assess rates of learning.<br>2.5 Use models to assess the likely level of certainty in conclusions with different levels of investment in monitoring and evaluation, and with different designs of the AM experiment.<br>2.8 Through dialogue with managers and interested parties, converge to a design for the AM experiment which best meets both policy considerations and statistically reliability. |
| 3. Implement | 3.1 Ensure that the implementation planned in Version 2 of the AM Plan is followed.<br>3.4 Review and approve annual implementation plans. | 3.2 Work through all of the technical details of implementation consistent with the Plan and annual decisions.<br>3.3 Suggest annual revisions to implementation plan (if required) to managers, and revise as required. |
| 4. Monitor | 4.1 Ensure that the monitoring planned in Version 2 of the AM Plan is followed.<br>4.6 Review and approve annual monitoring plans. | 4.2 Carry out field monitoring consistent with the Plan and annual decisions.<br>4.3 Enter data into databases.<br>4.4 Conduct research necessary to support monitoring methods, including analyses of costs and benefits.<br>4.5 Present proposed annual monitoring plan (if required) to managers, and revise as required. |
| 5. Evaluate | 5.4 Provide feedback to technical group on presentations of interim results from evaluations, and presentations from peer reviews.<br>5.5 Request additional evaluations to help in decision making. | 5.1 Perform analyses and evaluations as described in the Plan and annual data analysis plans.<br>5.2 Compare monitoring results against Program objectives, hypotheses, model predictions.<br>5.3 Synthesize evaluations for managers and interested parties; provide summaries and presentations at annual symposia.<br>5.6 Respond to peer reviews and requests from managers for additional evaluations. |
| 6. Adjust | 6.2 Decide if adjustments to actions are warranted based on information from technical scientists, and other factors affecting decisions. | 6.1 Clarify implications of evaluations for possible adjustments to actions and hypotheses, including risks and benefits of alternative decisions. |

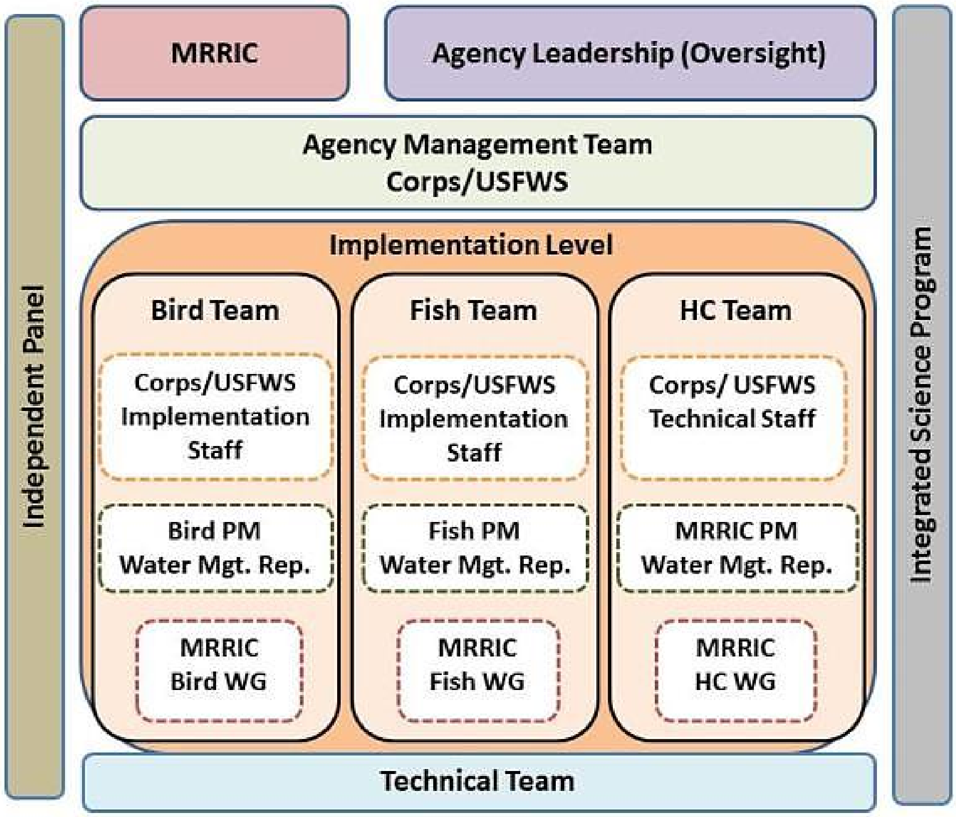


Figure 8-7: Proposed governance structure of the Adaptive Management Plan for the Missouri River Recovery Program (Fischenich et al. 2016). See Appendix O for explanations of the roles and responsibilities of each entity. [Abbreviations: MRRIC, Missouri River Recovery Implementation Committee; Corps, U.S. Army Corps of Engineers; USFWS, U.S. Fish and Wildlife Service; HC, human considerations; PM, Project Manager; Water Mgt. Rep., Water Management Representative; WG, work group.]

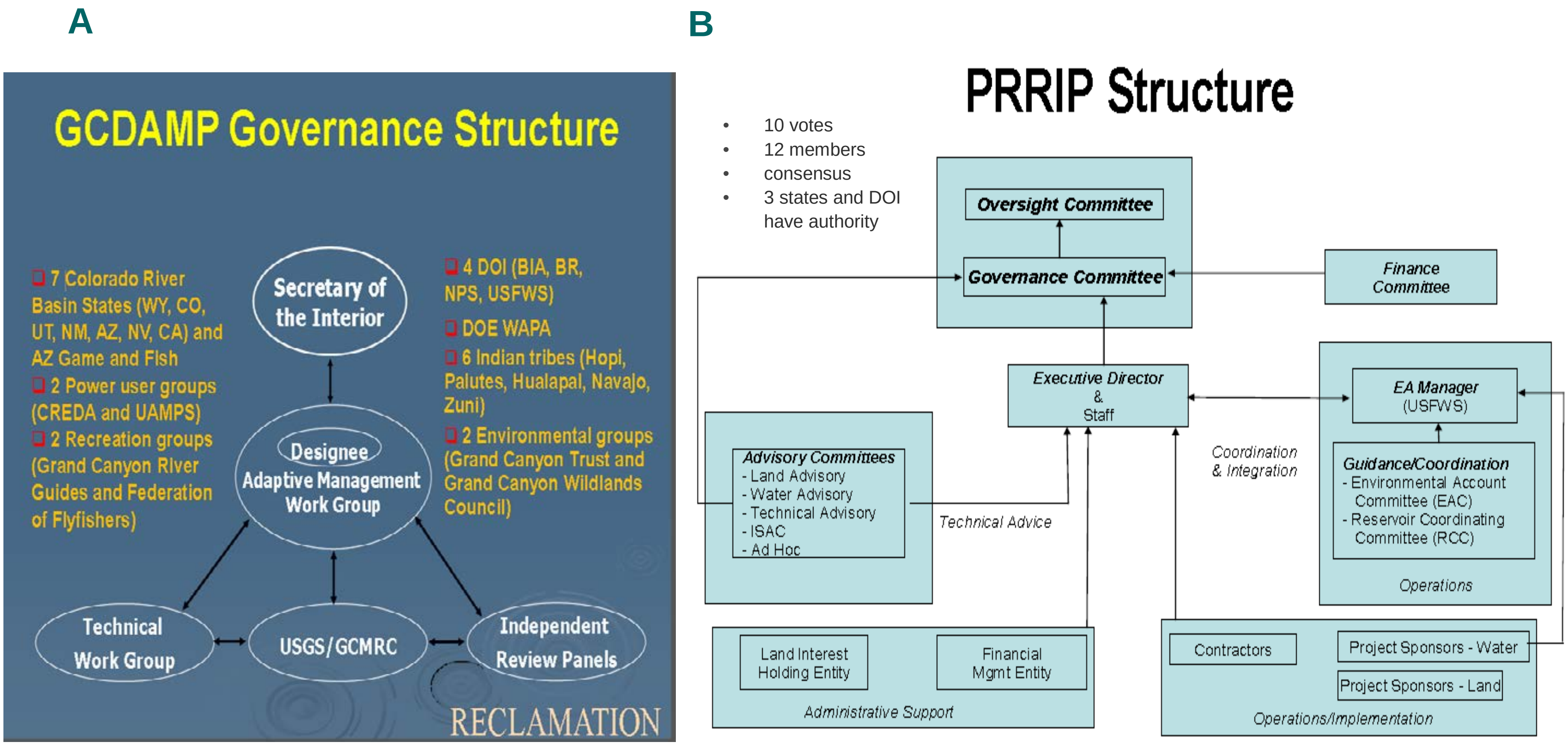


Figure 8-8: Governance structures of the (A) Glen Canyon Adaptive Management Program and (B) Platte River Recovery Implementation Program (Marmorek et al. 2015). [In the Platte Program, ISAC is the Independent Science Advisory Committee.]

We recently prepared a discussion paper for an adaptive management program we are working on in the Missouri River (Marmorek et al. 2015) which examined some of the main governance attributes of four large-scale adaptive management programs (U.S. Columbia Basin Fish and Wildlife Program, Trinity River Restoration Program, Glen Canyon Dam Adaptive Management Program, and the Platte River Recovery Implementation Program). Some general observations about the governance characteristics of these programs are listed below:

- Each program has a clear executive authority for adaptive management. Statutory decision-making tends to rest with the individuals holding responsibility for this executive authority and these individuals are informed of the decisions at other levels of governance.
- Each program has a unique structure for policy, management, and technical levels of governance.
- Governance at the senior management and policy level (involving decisions related to the adaptive management program) involves either a narrower oversight team/committee or a consultative group with more diverse perspectives, generally requiring consensus or a strong majority of support of the group to pass a motion.
- Governance at the management level (involving decisions related to management actions) tends to involve a broad base of stakeholder perspectives.
- Governance at the technical level (involving decisions related to knowledge generation) leads to the generation of policy-neutral, technical information across various technical working groups (by subject or domain).
- All programs involve some form of independent science review.
- Input from interested participants (stakeholders) is consistently provided at the management level, and in some cases provided at the policy level. This input is purely consultative in some programs (e.g., Trinity Adaptive Management Working Group (TAMWG), Missouri River Recovery Implementation Committee (MRRIC)), but has decision making authority in other programs (e.g., Glen Canyon Adaptive Management Work Group, Platte Governance Committee).
- Processes to generate technical information are separated from processes to explore preferences and make decisions.
- The synthesis of scientific information to inform decision making tends to be completed independently by technical organizations/agencies, although a coordinating group can facilitate synthesis of science across diverse entities.

## 8.3 Lessons from Other Large-Scale Fisheries Restoration Efforts

Development of the Klamath Basin IFRMP can benefit from lessons and insights from other river basins that have wrestled with complex aquatic ecosystem and fish recovery efforts. Four case studies are provided in this section. The first two illustrate some of the technical and governance aspects of adaptive management programs for the Trinity River and for Dry Creek, which is part of the Russian River system. The third describes the guidelines for monitoring and adaptively managing restoration in the Elwha River framed in terms of indicator triggers, decision rules for biologically-based restoration phases. The fourth describes the governance landscape in the Columbia River Basin, which has a similar history and complexity to the Klamath Basin (characterized in Chaffin et al. 2015).

### 8.3.1 Trinity River Restoration Program

Section 2 of this report provided a snapshot overview of the Trinity River Restoration Program. This section provides a more in-depth summary.

The Trinity River is an important resource for people, fish, and wildlife. Management of water and fisheries in the Trinity River is closely tied to management of water and fisheries in the Klamath. The construction of the Trinity River and Lewiston dams in the early 1960s diverted the majority of the river's water to provide electrical power and water for farming, industry, and human consumption. This reduced the flow which altered natural geomorphological processes and ultimately changed the quality and quantity of available habitat for fish and wildlife. This, combined with historical mining impacts and logging, reduced salmon populations to roughly 20 percent of pre-dam abundances (USFWS and HVT 1999). A Record of Decision in 2000 resulted in the creation of the Trinity River Restoration Program.

The Trinity River Restoration Program (TRRP) is a large-scale, adaptive management program that intends to restore the geomorphic processes required to create and maintain salmonid habitat in the 40 miles below Lewiston Dam. It began with analyses of changes that occurred since construction of the Lewiston and Trinity dams in the early 1960s, and diagnoses of the best approaches to reverse these changes (USFWS and HVT 1999). This work was followed by the development of a scientific framework (conceptual model, monitoring strategy, and adaptive management plan) in support of implementing watershed restoration actions designed to restore the Trinity River (TRRP 2009, TRRP and ESSA 2009). Scientists collaboratively developed an integrated conceptual model of the Trinity River system, identified appropriate assessment criteria, and devised reliable designs for monitoring habitat and populations of Trinity River fish, birds, amphibians and reptiles.

A rigorous adaptive management approach was developed to monitor and improve the effectiveness of a range of Trinity restoration projects. The Program has been implementing many types of projects including in-channel habitat actions (e.g., removing berms, creating side-channels, and placing large woody debris), watershed restoration activities to reduce the load of fine sediment, coarse sediment management, erosion control, and replacement of bridges and structures within the floodplain. One of the challenges in this project was to navigate the diverse priorities and varying views of interested participants which need to be considered in program decisions (e.g., what in-channel projects to build, where to build them, how much water to release when, how much coarse sediment to add where, how actions should be monitored and evaluated, and which assessments should be prioritized). Participants included the U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, Hoopa Valley Tribe, Yurok Tribe, California Department of Fish and Wildlife, U.S. Forest Service, California Trout, and California Department of Water Resources.

A number of techniques were used to overcome these challenges. A collaborative, workshop-based approach was used to help the Program develop an Integrated Assessment Plan. Trinity scientists were led through iterative scientific workshops and report-writing sessions to develop conceptual models (TRRP 2009), an integrated assessment plan (TRRP and ESSA 2009) and an online data portal to support hypothesis-testing (http://odp.trrp.net/). One-on-one conversations were held with i on important issues prior to the workshops, which helped foster more effective dialogue during the workshops.

To address challenges of integration across space, time and disciplines, and the challenge of prioritizing monitoring and assessments, program decisions were organized across three important temporal and spatial scales: (1) annual decisions on a system scale (e.g., flow scheduling, sediment augmentation); (2) short-term feedback on the effectiveness of rehabilitation projects during 2009-2013 (site scale) to inform the construction of remaining sites; and (3) long-term feedback (system, decadal scale) to evaluate the overall effectiveness of the suite of Program actions and progress towards long-term objectives. Program scientists clearly articulated uncertainties and detailed hypotheses for each of the Program's objectives, and then collaboratively developed experimental designs, performance measures and analytical approaches to test these hypotheses and reduce the uncertainties. Looking-outward matrices were used to identify linkages between actions and disciplines, which formed a foundation for the design of an integrated sampling framework. The sampling framework enabled implementation of consistent monitoring protocols and evaluation methods, and facilitated interdisciplinary synthesis by co-locating sites in common spatial units. This was essential for evaluating the Program's overall restoration strategy (which involves coordinated actions supporting multiple ecosystem processes and components).

Scientists and managers developed an adaptive management and decision analysis framework using a phased approach. Phase 1 involved a series of facilitated workshops to elicit key information from Program and partner scientists. This provided the building blocks for the decision analysis and adaptive management framework. Phase 2 involved working with the Program and partners to organize these building blocks, looking for opportunities for efficiency and integration, culminating in the Integrated Assessment Plan. This Plan is designed to provide detailed guidance on how to assess the effectiveness of prescribed management actions in achieving Program goals and objectives. A direct outcome of Phase 2 was the implementation of a pilot monitoring and evaluation program in 2010 based on designs described in the Integrated Assessment Plan.

Having quick access to rigorously documented data is crucial for rapidly evaluating the effectiveness of restoration, and adjusting management actions. The Trinity River Restoration Program developed and maintains an integrated information management system, called the Online Data Portal to consolidate and organize assessment plans and data, and to support interdisciplinary syntheses of information.

The adaptive management framework formed a robust foundation for iterative improvements to the Program. Long-term, system-scale hypotheses have been tested, and revisions to the hypotheses proposed based on the results (Pickard 2012). A multi-disciplinary working group developed an analytical framework to inform Program-scale decisions about which projects to build and where to build them (Pickard 2013). The Program is ongoing, and prepares annual reports that are available online.

In line with the best practices described in Sections 8.2.1 and 8.2.2, the governance of the TRRP is structured to separate technical and management roles, and includes independent peer review (Figure 8-9).

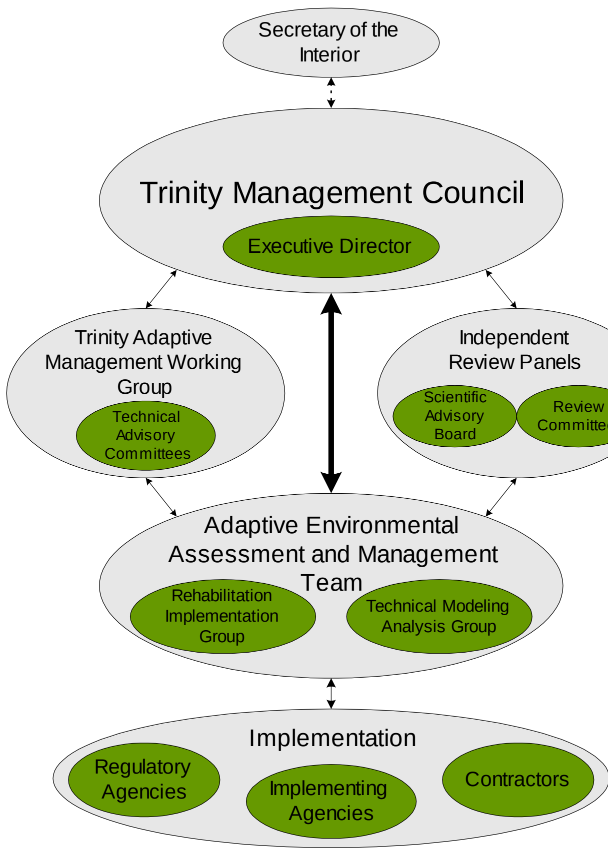


Figure 8-9: Trinity River Restoration Program Governance structure (from Marmorek et al. 2015).

## 8.3.2 Dry Creek Adaptive Management Plan

The Russian River flows into the Pacific Ocean 70 miles north of San Francisco, California, and provides habitat for threatened and endangered coho salmon (*Oncorhynchus kisutch*), Chinook salmon (*Oncorhynchus tshawytscha*), and steelhead (*Oncorhynchus mykiss irideus*). The Sonoma County Water Agency (SCWA) and U.S. Army Corps of Engineers (USACE) regulate flow from Warm Springs Dam/Lake Sonoma along 14 miles of Dry Creek, a major tributary of the Russian River. This flow regulation provides water and flood control for 600,000 residents. The National Marine Fisheries Service issued a 15 year Biological Opinion in September 2008 mandating large-scale enhancement of six miles of Dry Creek summer and winter rearing habitat, to improve stream flow and habitat conditions for coho and steelhead.

The Biological Opinion raised a question about whether Dry Creek habitat enhancements will have the desired benefits, and called for an adaptive management, monitoring and evaluation plan to identify project goals, objectives and success criteria. The SCWA engaged an external independent group to facilitate collaborative development of an Adaptive Management Plan (Porter et al. 2014).

Multi-agency workshops were convened to identify performance measures, develop success criteria for each performance measure, select approaches for evaluating performance measures relative to success criteria, and agree on decision rules for determining quantitative progress toward the total amount of habitat enhancements required in the Biological Opinion. Challenges included: strongly held beliefs by interested participants (NOAA Fisheries, CDFW, USACE, SCWA); different opinions on what constitutes project success, the preferred form of fish habitat, and appropriate scales and types of effectiveness monitoring (feature scale versus site / reach scale); complexities in validation monitoring due to very low densities of coho and difficult sampling conditions; and variable levels of landowner participation. Progress in achieving interagency consensus was catalyzed by: independent technical facilitation; joint field trips to develop a common, realistic understanding of geomorphic opportunities, constraints, and logistical sampling difficulties; agreement on various organizing frameworks (conceptual model, objectives hierarchy, decision rules); adapting the restoration designs, success criteria, and effectiveness monitoring protocols to the geomorphic attributes of each reach; developing effective experimental designs; and novel approaches to validation monitoring using tagged fish. Figure 8-10 illustrates how progress towards the required amount of habitat enhancement will be first assessed in 2018.

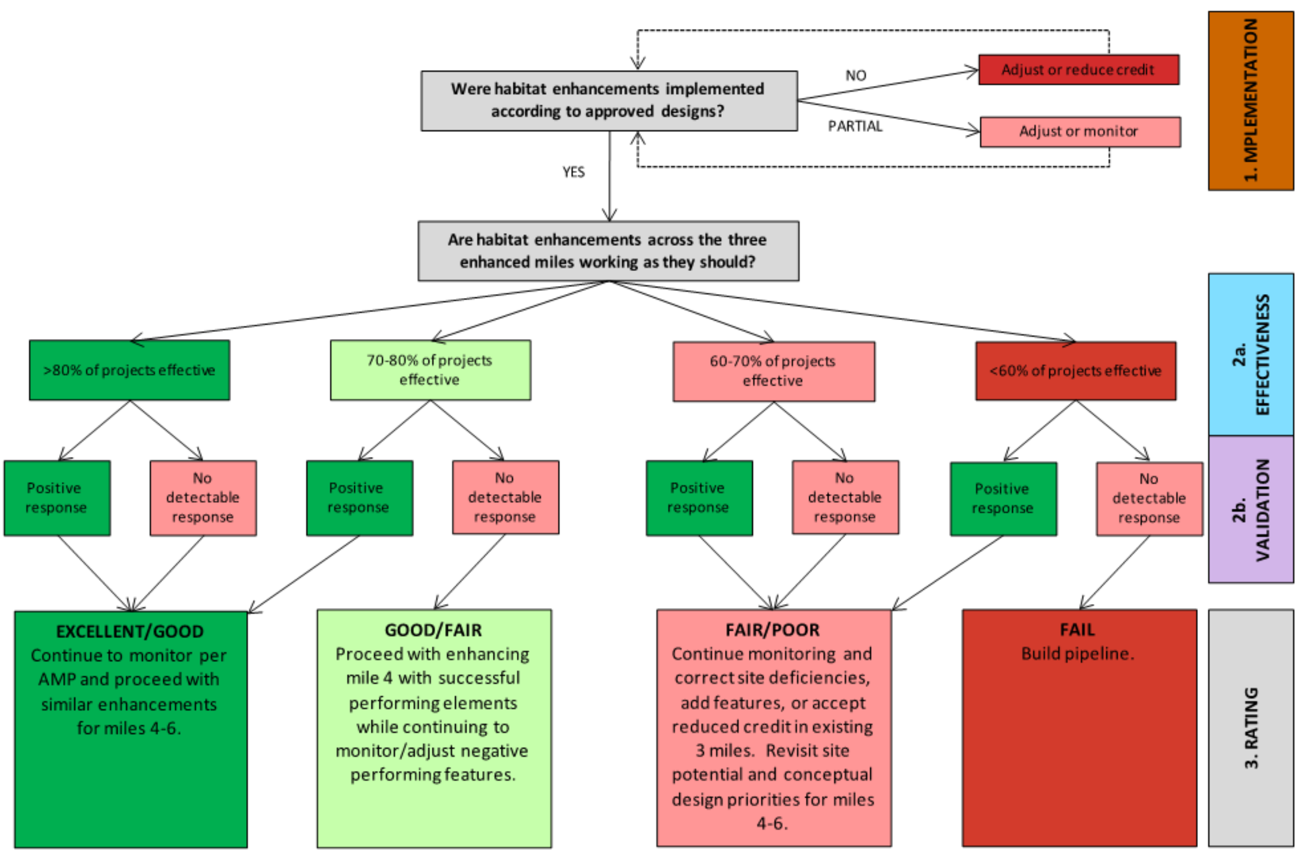


Figure 8-10: Process for determining the course of action in Dry Creek in 2018 (Porter et al. 2014).

### 8.3.3 Elwha Monitoring and Adaptive Management Guidelines

The Elwha and Glines Canyon dams, which were built in the early 1900s, limited access for salmonid species to most of the Elwha River. Three of these salmonid species – Puget Sound Chinook salmon (*Oncorhynchus tshawytscha*), Puget Sound steelhead (*Oncorhynchus mykiss irideus*), and bull trout (*Salvelinus confluentus*) – as well as Pacific eulachon (*Thaleichthys pacificus*) are listed under the Endangered Species Act. These dams were recently removed. Peters et al. (2014) propose a structured adaptive management approach to reduce uncertainty about how to achieve full restoration of the ecosystem and its native anadromous fisheries.

Peters et al. (2014) propose guidelines for monitoring and adaptively managing restoration of Chinook salmon and steelhead on the Elwha River. The guidelines provide a framework that follows the typical steps in the adaptive management cycle: setting restoration goals and objectives; recognizing uncertainty; identifying and monitoring performance indicators that measure progress of restoration actions towards the objectives; evaluating outcomes; and using decision rules to make adjustments if needed. They also recognize the importance of a good data management strategy for supporting and documenting decisions about changes to restoration actions, particularly given the number of participants and the long restoration timeframe.

Under the proposed guidelines, the goals, objectives, performance indicators, decision rules and decisions are specific to each Elwha River species. Decision rules are based on indicator trigger values for four biologically-based restoration phases: (1) preservation; (2) recolonization; (3) local adaptation; and (4) viable natural population. Restoration would move from one phase to the next when trigger values for all performance indicators are all met for the prior phase (Figure 8-11).

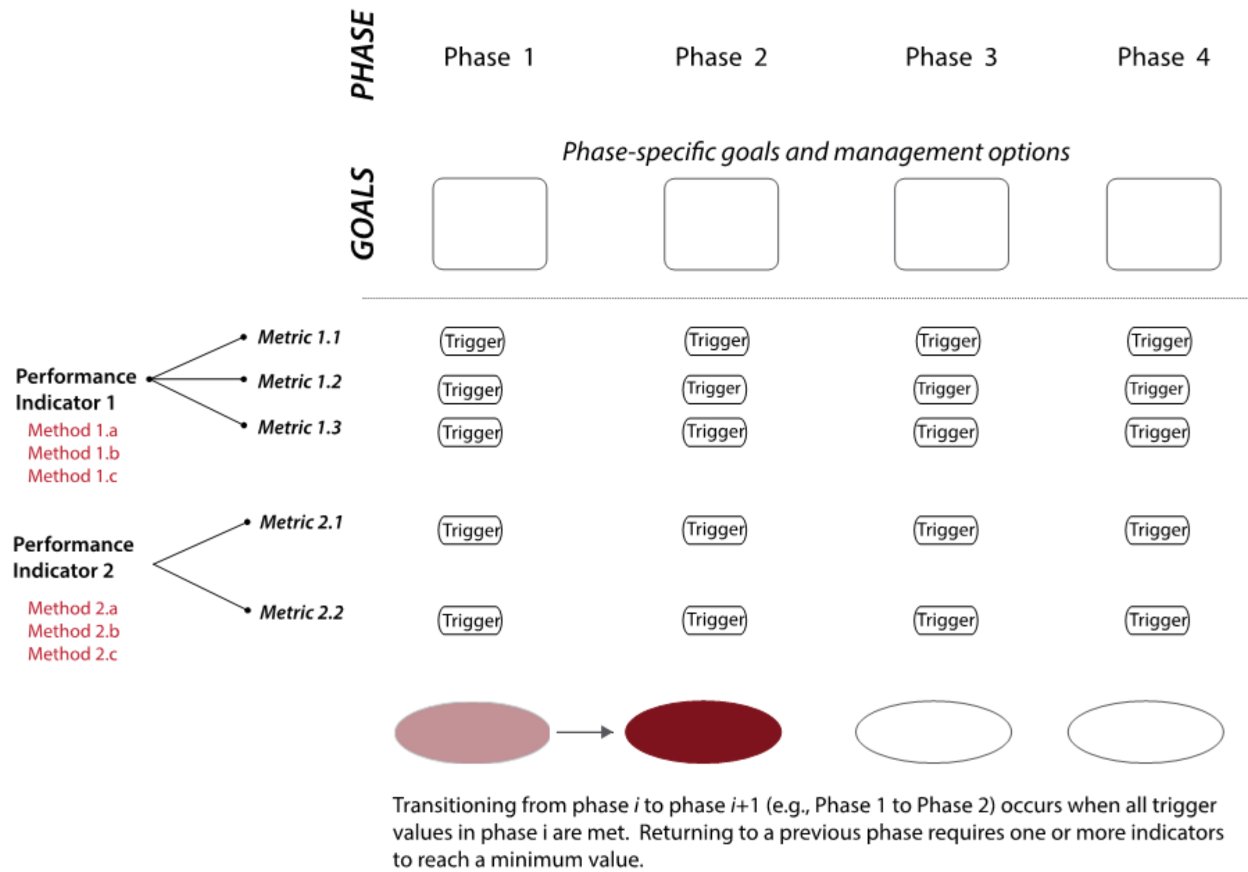


Figure 8-11: Conceptual example of how performance indicators (rows) will be used to evaluate whether objectives have been achieved for each restoration phase (columns) for the Elwha River. The adaptive management approach will evaluate performance indicators for each phase and move to the next restoration phase once all trigger levels for the current phase have been achieved. Source: Peters et al. 2014, Figure 1.

There is a temporal element to the decision rules; if the trigger value for one or more indicators is not reached within the specified timeframe, further investigation ensues to determine why. Is it because the wrong trigger value was chosen or because of unforeseen conditions affecting the rate of recovery (for example, ocean harvest)? Adjustments to triggers or restoration management actions may be needed – including a return to a previous phase. If the trigger values are not met and the specified length of time has not expired, actions within the current phase continue. This decision process is characterized in Figure 8-12.

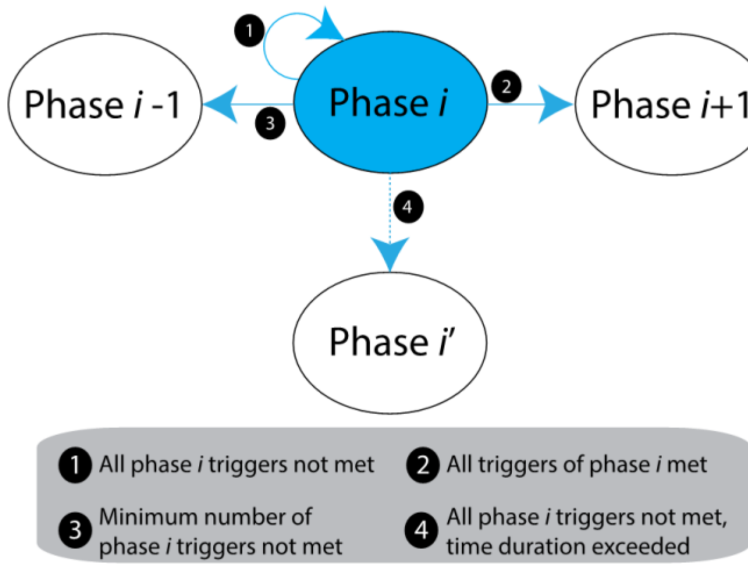


Figure 8-12: Conceptual model showing four different management outcomes (1-4) to be evaluated on an annual basis. The oval in blue is the current management phase (i). When evaluating status, the management decision could be to remain in the current phase (1), move to the next phase (2), return to a previous phase (3), or adjust the trigger values within a phase, resulting in a new set of performance indicators (denoted i') for that phase (4). Source: Peters et al. 2014, Figure 2.

## 8.3.4 Columbia River Basin

### *History and Background*

Attempts to restore, protect, or enhance fisheries in the Columbia have led to programs and governance structures that may be useful as a case study for the Klamath. The Columbia is the fourth largest river basin in North America by volume, covers 259,000 square miles, and drains portions of two countries and seven states. The Columbia basin is home to numerous tribes, and its rich fisheries resources have supported humans since time immemorial. Historical estimates for salmon range from 10 to 16 million adult fish returning annually. These salmon runs, once amongst the world's largest, have declined by over 90 percent. Intensive commercial fishing, human development, and the construction of more than 450 dams throughout the basin led to concerns over fisheries resources, beginning in the late 1800s.

As Europeans moved into the Basin, conflicts with native peoples escalated. Treaties between settlers and tribes were negotiated and then often abrogated during this period. The 1855 treaties between the United States and the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes of the Warm Springs Reservation of Oregon, the Confederated Tribes and Bands of the Yakama Nation, and the Nez Perce Tribe (as well as those with other tribes) reserved and guaranteed fishing and hunting rights for these tribes. In 1977, these four treaty tribes joined together to form the Columbia River Inter-Tribal Fish Commission (CRITFC), established to ensure coordination and technical assistance to protect treaty fishing rights and ensure the continuation and restoration of tribal fisheries.

The lower Columbia River forms the boundary between the states of Oregon and Washington, and conflicts between regulations imposed by the two states created enough difficulties that in 1918 the U.S. Congress created the Columbia River Compact to govern commercial fisheries, considering their effects on escapement, treaty rights, and species listed under the Endangered Species Act (ESA), and to allocate limited resources between recreational, commercial, and treaty Indian fishers.

Congress created the Bonneville Power Authority (BPA) in 1937 to deliver and sell the power from Bonneville Dam. Continuing dam construction from the 1940s through the 1960s created dams throughout the region, impacting salmon and steelhead runs significantly. Attempts to mitigate fisheries impacts from federal dam construction began early, and to date have resulted in one of the largest fisheries mitigation programs in the world, including fish hatcheries, juvenile fish diversion screens at irrigation water withdrawals, restoration of tributary and mainstem habitats, fish transportation programs, predator control programs in reservoirs, fish passage facilities at major dams, and fish monitoring.

BPA works to conserve and enhance fish and wildlife, including species that are listed as threatened or endangered under the ESA. BPA's fish and wildlife program supports the federal government's treaty and trust obligations to Northwest tribes, including fishing rights and cultural traditions. Known as the "All-H" approach, the program strives to make improvements in four key areas: habitat, hatchery, harvest and hydro (the dams and reservoirs). Since 2008, negotiated long-term agreements termed "Columbia Basin Fish Accords" among BPA, the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, three states and six tribes have governed and funded these commitments and partnerships. The Accords are up for renewal in the next few years.

The cumulative effect of these mitigation agreements has been a series of federal financial obligations to states and tribes to pay for mitigation activities throughout the basin. These mitigation, monitoring, and restoration programs are now funded more than $250 million per year, and include substantial funding to states and tribes to implement various fisheries programs.

In the 1960s and 70s, a variety of court cases and legislative actions began to reaffirm the tribes' treaty fishing rights. One of these court decisions - U.S. versus Oregon, included development of a management agreement involving all parties in a structured fisheries management and allocation regime. The U.S. versus Oregon Technical Advisory Committee has prepared Biological Assessments for combined fisheries based on relevant U.S. versus Oregon management plans and agreements for ESA-listed stocks for all mainstem Columbia River fisheries since January 1992. The current management agreement specifically outlines allocations and shares between sport, commercial and tribal fisheries by stock, run, and fishery over a 10-year period. Several Technical and Policy Committees established under this agreement serve to make decisions and resolve conflicts that may arise regarding these issues.

On December 5, 1980, Congress passed the Pacific Northwest Electric Power Planning and Conservation Act, which authorized the four states of Idaho, Montana, Oregon, and Washington to form the Northwest Power and Conservation Council (Council). The Act directs the Council to prepare a plan to protect, mitigate and enhance fish and wildlife of the Columbia River Basin that have been affected by the construction and operation of hydroelectric dams, while also assuring the Pacific Northwest an adequate, efficient, economical and reliable electric power supply. (The Act resulted in a more coordinated fish and wildlife mitigation program in the Columbia, largely directing the expenditure of BPA funding, including periodic reviews and revisions of the plan.) Proposals to the Council for fish and wildlife projects are reviewed annually by the Independent Scientific Review Panel. Additionally, an Independent Science Advisory Board provides independent scientific advice and recommendations regarding scientific issues that relate to agency fish and wildlife programs.

To improve restoration planning and adaptive management, the Council has funded a comprehensive sub-basin planning process, as well as a collaborative, system-wide project to improve the consistency of population and habitat monitoring. The program is reviewed and adapted every five years. The Council's 2014 Fish and Wildlife Program is committed to an adaptive management approach that uses research and monitoring data to understand, at multiple scales, how program projects and measures are performing, and to assess the status of focal species and their habitat. This information is evaluated to determine if projects and measures are having the intended measurable benefits to fish, wildlife and their habitat, within the context of their status and trends, which are mitigated, enhanced and protected through the program. This information enables the Council to determine whether progress is being made toward program goals and objectives, and provides guidance on monitoring, effectiveness, research, data management and reporting.

In 1991, NOAA Fisheries listed Snake River sockeye as endangered under the Endangered Species Act. Status reviews occurring since 1991 have resulted in most Columbia Basin salmon and steelhead stocks being listed under the ESA. The implementation of the ESA has resulted in numerous consultations between NOAA, the USFWS, and the “action agencies” that operate the federal hydrosystem in the Columbia. Decisions have been subject to near constant litigation and review. From 1995 to 2000, federal, state and tribal fish agencies participated in a collaborative process called PATH (Plan for Analyzing and Testing Hypotheses), which used decision analysis and other approaches to evaluate the effects of the hydrosystem on listed stocks of spring-summer and fall Chinook in the Snake River Basin (Marmorek and Peters 2001; Peters et al. 2001). The PATH process provided a brief respite from litigation. An Adaptive Management Implementation Plan (AMIP) was developed to infuse the implementation of the 2008 Reasonable and Prudent Alternative (RPA) with the best science currently available.

Under the 2008-2018 Federal Columbia River Power System (FCRPS) Biological Opinion Adaptive Management Implementation Plan, federal dams are operated by the Action Agencies through 2018 for multiple purposes, subject to several fish conservation actions set out in the RPA. The dams are configured and operated under the RPA to meet objective performance standards for fish passage survival. Their management is subject to modification in response to new fish survival information. Additionally, the RPA requires mitigation actions for the benefit of all ESA-protected salmonid species adversely affected by the FCRPS: projects to improve tributary and estuarine salmon and steelhead habitat; to reduce fish and bird predation; and to use hatcheries to help protect wild stocks. These programs are informed by ongoing research, monitoring and evaluation (RM&E) about the status of the listed species and the effects of the RPA on them. The Action Agencies and NOAA Fisheries are managing the RPA actions adaptively, through 2018, to insure they incorporate the best available science and are informed by the status of listed salmonids. These actions have been, and continue to be, subject to review by federal courts under litigation. Much of the work done to collect data and inform these status reviews is conducted by states, tribes, and federal agencies funded by BPA under the auspices of the Northwest Power and Conservation Council (NPCC) fish and wildlife program.


Figure 8-13: Overview of salmon and steelhead recovery related processes. Source: Columbia River Basin Salmon and Steelhead Long-term Recovery Situation Assessment (see: http://ruckelshauscenter.wsu.edu/wp-content/uploads/2013/06/ ColumbiaRiverBasinSalmonandSteelheadLong-TermRecoverySituationAssessment-FinalReport.pdf).

The tributary habitat-based, off-site mitigation strategy of the Federal Columbia River Power System Biological Opinion (FCRPS BiOp) has led to recent efforts to monitor habitat and response such as Columbia River Habitat Monitoring Program (CHaMP) and the Integrated Status and Effectiveness Monitoring Program (ISEMP). These include: status and trend monitoring of fish and habitat to track and evaluate fish-habitat relationships at the levels of Evolutionarily Significant Units (ESUs), sub-basins and populations; Action Effectiveness monitoring to evaluate the effect of habitat actions; and an Analytical Framework. ISEMP includes monitoring fish and habitat status and trends monitoring efforts in selected watersheds, while CHaMP implements a standard set of fish habitat monitoring (status and trend) methods in up to 26 watersheds across the Columbia River Basin. The watersheds were chosen to maximize the contrast in current habitat conditions and also represent a temporal gradient of expected change in condition through planned habitat actions.

The large investments in habitat restoration and conservation in the Pacific Northwest have led to calls for evaluation of the effectiveness of these actions. One such attempt is the concept of Intensively Monitored Watersheds (IMW) for Salmon Restoration. (The basic premise of IMWs is that the complex relationships controlling salmon response to habitat conditions can best be understood by concentrating monitoring and research efforts at a few locations, studying how various management actions interact to affect habitat conditions, how system biology responds to these habitat changes, and the concurrent year-to-year effects of variations in weather, flow, and other factors.

Working with its federal, state, tribal, and local partners, NOAA Fisheries published recovery plans for lower Columbia River salmon and steelhead and upper Columbia spring Chinook and steelhead in 2013. The plans provide road maps to recover salmon and steelhead species. During the listing process, the states of Oregon, Washington, and Idaho also took pro-active steps to address many of the issues that had led to the listings, coordinating and implementing habitat restoration and monitoring activities (e.g., Oregon's Watershed Enhancement Board, Washington's Salmon Recovery Funding Board). Through a program of intensively monitored watersheds, NOAA Fisheries and its partners have made considerable advances in the experimental design and monitoring of habitat restoration programs, and the application of adaptive management (Bennett et al. 2016; Bouwes et al. 2016a).

NOAA has also produced guidance for monitoring efforts to determine the status and trends of listed salmonids in the Pacific Northwest. (This guidance is designed to prioritize the efforts of the many organizations that participate in monitoring across the region.) Recommendations include monitoring that addresses all of the viable salmonid population (VSP) criteria, listing factors, and threats. The document recommends regional coordination, levels of precision, long-term analysis, and a stratified habitat status and trend monitoring program. The document also suggests at least one IMW for each "recovery domain". Regional guidance has led to coordinated efforts to manage data and prioritize data collection, in projects such as Coordinated Assessments for Salmon and Steelhead (efficient, interagency sharing of consistent, transparent data), and the Columbia Basin Partnership (combining tribal treaty trust responsibilities, sustainable fisheries goals, and ESA recovery actions into one public process.

## Governance and Decision-making Structures in the Columbia

The Columbia is a large, complex, international basin with a 150± year history of fish and wildlife restoration and recovery efforts. Restoration and monitoring have evolved through numerous treaty, program, and court-adjudicated ramifications to the present system of federal oversight, litigation, and co-management through multiple technical forums. The program is supported by very significant levels of funding, which include ratepayer dollars from the electricity customers of BPA, federal agency allocations, and numerous State, Tribal, Local, and private sources of revenue. Much of the spending, particularly that funded by the BPA, is guided regionally by the NPC C, with scientific review by independent boards. However, additional federal, state, local, and tribal programs operate independently without such regional oversight.

Watershed Boards, Soil and Water Conservation Districts, and local and state agencies work collaboratively on restoration and monitoring projects. These projects are guided by decisions made by state-level conservation organizations (Recovery Boards, local Parks and Conservation agencies, Fish and Wildlife Agencies, other natural resource agencies) which develop plans for various sections of the landscape. Monitoring is conducted at local level. Funding and reporting, including voluntary participation, is primarily state and local. Local utilities fund mitigation hatcheries.

State agencies attempt to coordinate restoration and monitoring activities and prioritize for effectiveness via watershed/salmon recovery boards. Sport and commercial fisheries for non-listed species are managed by fish and wildlife agencies. Tribal fisheries are recognized and implemented by the tribes with state coordination, often formalized by court-imposed direction and cooperative technical teams. Sharing of harvestable surpluses and/or allocation of allowed ESA impacts are implemented through ESA consultation with federal agencies. Monitoring is reported at the state and tribal levels. Funding and reporting at state level involves primarily state and federal funds.

Tribal treaty rights are recognized and established through a recorded history of treaties and court decisions. Tribal Councils, fish and wildlife departments, and inter-tribal consortia establish rules for tribal fishers. Tribes participate as co-managers in allocation and regulation forums, which are often formally adopted by courts. Funding involves primarily federal and tribal dollars. The existence of CRITFC ensures coordination amongst the four tribal treaty members, though other tribes are not part of CRITFC.

Federal agencies provide ESA oversight of harvest and habitat decisions. They participate in and support of recovery efforts, including development of recovery plans. They review and consult on harvest, hatcheries, and other issues. Federal agencies also carry the primary mitigation responsibilities, including significant federal funding, and provide oversight of overall programs through NPCC, federal caucus, litigation and review of program by courts.

Successes in restoration and monitoring in the Columbia can be partially attributed to well-established governance structures that were often hard-won and borne out of seemingly intractable disagreements, as described above. Challenges to success in the Columbia include continued fragmentation of fisheries restoration and monitoring efforts, even with the existence of a multi-state Council empowered by the U.S. Congress. The existence of extensive federal funding has enabled substantial restoration and monitoring efforts to persist over decades, but continuing policy differences regarding dam removal, recovery efforts for listed species, the use of hatcheries, fishery allocation, and other issues have resulted in substantial litigation and disagreement that remains an impediment to progress. The listing process has resulted in substantial review and questioning of the impacts of the federal hydropower system on species status, which is as yet unresolved and calls into question the long-term efficacy of recovery efforts in the continuing presence of the system. Regional coordination and oversight of funding, restoration, monitoring, and data management has been necessitated by multiple listings under ESA, but continues to be a work in progress. NOAA's Columbia Basin Partnership approach is the most recent attempt to combine multiple and often conflicting demands into one process.

## 8.4 Outline of Major Tasks to Complete Entire Plan

*This section provides an outline of the recommended tasks to iteratively complete the overall Integrated Fisheries Restoration and Monitoring Plan for the Klamath River Basin. Providing specific details at the sub-task level, time-line estimates, etc. is beyond the scope of this document.*

The sections that follow outline the major steps that should be followed to develop the full IFRMP for the Klamath Basin. These steps are consistent with NRC (2004) recommendations and related adaptive management best practices (Section 8.2), including:

- establishing clear goals and objectives;
- developing conceptual models of cause-effect linkages among stressors, habitats, focal species and restoration decisions;
- working out alternative hypotheses for restoration actions that can be experimentally tested and monitored for effectiveness;
- identifying key uncertainties;
- determining criteria and procedures to set priorities for, and sequence, restoration actions;
- implementing thoughtful assessments coupled with rigorous monitoring that will reveal responses to management actions;
- comparing forecasted responses to management actions (expected outcomes) with observed outcomes; and
- conducting systematic, regular re-assessment of findings and necessary revisions to conceptual models, hypotheses, models, monitoring programs and priority restoration actions.

While the steps in this section are listed in sequence, in practice many will be **highly iterative and require several rounds of revision prior to finalization and Plan adoption in the fall of 2019**. Section 8.4.10 describes cross-cutting the task-process elements that will be required to complete these steps and sustain dialogue amongst managers, scientists and interested participants.

### 8.4.1 Define the Problem

#### *Plan Vision*

The overall vision for restoration of the Klamath River Basin is to **return the entire river from Keno Dam to the Pacific Ocean to a well-connected river in support of fish migration to and from the Upper Basin while improving flows, water quality, habitat and ecosystem processes.** Restoration of connectivity and ecosystem processes is essential to increasing the size and diversity of fish populations, repatriating these populations to their historic habitats, improving harvest opportunities, and adding future protection against existing and ongoing effects of climate change. Evidence for this vision is provided by the numerous studies summarized in this Synthesis Report. Numerous scientific bodies and agencies, including the Pacific States Marine Fisheries Commission, have recognized the need for adaptive management to achieve restoration and monitoring goals in the Klamath River Basin and provide and synthesize reliable scientific information to decision-makers.

Authority for this vision derives from the U.S. Department of Interior Klamath Facilities Removal EIS/R (USDI et al. 2012a), developed in accordance with the requirements of NEPA and CEQA. The EIS/R analyzed proposals in the Klamath Hydroelectric Settlement Agreement (KHSA) and found that **the status quo was the *least* environmentally preferable** alternative to removal of the four lower Klamath River dams (or by extension, adding extensive new and enhanced fish passage infrastructure). Considering the best science and peer reviewed findings, **the Secretary of the Interior determined that removal of the four mainstem dams was in the broad public interest including being the most appropriate means of advancing fisheries restoration objectives** (USDI et al. 2012a, USDI 2016). The Secretarial Statement of Support reminded all that the final authority for approving or denying dam removal now resides with **the Federal Energy Regulatory Commission (FERC).** Both PacifiCorp and the newly formed Klamath River Renewal Corporation (KRRC) filed their joint application for dam license surrender, transfer and dam removal with FERC on September 23, 2016. It was at the time the former Secretary of the Interior's expectation (in October 2016) that FERC will support the KRRC's detailed decommissioning and removal plan once these detailed plans are further fine-tuned (USDI 2016).

#### *Develop Broad Phase-Specific Goals*

With tens of millions of tonnes of sediment deposited in several reservoirs, the magnitude of geomorphic and other habitat changes in the Klamath River and estuary following the recommended dam removal will be *dramatic and highly dynamic*. Clues as to what to expect can be gleaned from ongoing restoration in the Elwha River, the largest completed dam removal to date. The Elwha dam removal and adaptive management and monitoring approach (Peters et al. 2014) provides a valuable reference for managers in the Klamath Basin. Restoration co-managers in the Elwha organized the definition of goals, performance indicators and associated decision rules and monitoring into <u>four ecologically-based restoration phases</u> (Peters et al. 2014). This phased approach (see Section 8.3.3) offers significant communication benefits as it organizes the problem into logical units that have distinct concerns and priorities. **A fundamental step in clearly defining the problem in the Klamath Basin is to articulate and**

**agree on broad statements of what restoration co-managers hope to achieve during each phase of restoration.**

Klamath River restoration co-managers may wish to adopt and refine the restoration phases used in the Elwha (Peters et al. 2014) given the overarching similarities between the two systems. For example, this *might* resemble:

- **Reference conditions and planning:** the present phase where goals, objectives and restoration and baseline data collection plans are being formalized before any substantive actions are taken. In addition to completing the IFRMP, the focus during the reference and planning phase is filling gaps in datasets documenting the reference, pre-removal conditions, so that the magnitude of future restoration improvements can be assessed. For example, it will be important to ensure that estimates of fish habitat, distribution and abundance, bathymetry maps, remotely sensed data, aerial photos and LiDAR imagery are accurate and carefully reviewed, so that restoration co-managers and practitioners can generate comparisons with baseline performance indicators and key indicators in future phases (e.g., to track evolution of sediment deposition and erosion). For example, during the planning of the removal of the Elwha Dam, it was discovered that errors in 1917 bathymetry maps of Lake Mills had led to a considerable underestimate of the amount of stored sediment (24 million $yd^3$, instead of the actual 34 million $yd^3$)[52].
- **Preservation and mitigation [or capability enhancement] phase:** the period during and shortly after dam removal, when elevated concentrations of suspended sediment could potentially affect fish survival, and genetic / life history diversity, unless protective mitigation measures are implemented. If Klamath dams are not removed, this is the period when fish passage infrastructure is added, which may/may not temporarily reduce fish passage opportunities or create other risks. If the dams are not removed (i.e., regulators instead choose to invest in extensive improvements of passage facilities), this phase may morph into a phase in which the capability for restoration and monitoring is enhanced, including such domains as fish passage, as well as trap and transport.
- **Recolonization and range expansion phase:** the period after passage is restored and fish have access to historic habitats above dams, and begin to successfully spawn and produce smolts in these habitats. During this phase, restoration co-managers and practitioners may attempt a variety of temporary interventions to accelerate recolonization (e.g., transporting fish to accelerate recolonization of historic habitats).
- **Local adaptation and growth phase:** the period when all aspects of the previous stages are met, sufficient numbers of fish are spawning volitionally with minimal human intervention, using newly accessible habitats, and populations are on a sustained growth trajectory, with expansion of life history diversity and evidence of other local adaptations to the Klamath ecosystem.

[52] http://www.seattletimes.com/seattle-news/elwha-dam-removal-project-held-back-as-silt-estimate-too-low/

- **Restored ecosystem functions and harvestable populations phase:** the period when all aspects of previous stages are met, and viable natural populations exist that can withstand exploitation by fisheries without heavy reliance on hatcheries (i.e., hatchery supplementation levels substantially reduced relative to reference condition).

During the problem definition stage of Plan development, **restoration co-managers will be required to "deal" with the fundamental planning assumption related to dam removal versus provision of extensively enhanced fish passage.** "Not knowing" which of these two paths is the *de facto* planning assumption adds **significant inefficiencies**[53] to the tasks that follow.

Table 8-4 summarizes the main products that would be generated from these early steps (articulating Plan vision, phases of restoration and their broad goals) in clearly defining the restoration problem.

Table 8-4: Summary of potential task-process tools and techniques to generate main product(s) from early steps in clearly defining the restoration problem.

| Task-Process Tools | Suggested Main Product(s) |
|---|---|
| 1. Backgrounder memo on Plan vision | Short brochure describing the vision of the Plan and intended phases:<br>• Reach agreement on and define phases of restoration. |
| 2. Technical meetings with appropriate Plan cooperating partners, co-managers, experts and interested participants | • Reach agreement and document broad statements of what restoration co-managers hope to achieve during each phase of restoration.<br>• Make working assumptions of the Plan explicit (e.g., dam removal or provision of extensively enhanced fish passage). |
| 3. Graphic design | This document would be written for general audiences, would be suitable for both public outreach and technical audiences, and would contain hyperlinks to more technical documents supporting the intended approach. |
| 4.Technical documents supporting the Plan. | |

## *Develop Early Annotated Outline for the Plan by Phase of Restoration and Subregion*

Nearing completion of the development of the Plan Vision, we recommend creating a formal "search image" for agencies, cooperating partners and interested participants for what the final Integrated Fisheries Restoration and Monitoring Plan will include. The detailed annotated outline created during this task will then provide the framework or "home" for rigorous and collaborative development of the content that is to emerge from the iterative tasks that follow.

[53] Proceeding to develop the IFRMP with "both" actions in mind is *possible*, but will add additional time, effort and cost to Plan development.

While the structure of the final Plan outline will certainly evolve the intent is to make the Plan very focused on **phase and subregion decisions** and the key uncertainties associated with each of those decisions. Though the precise structure remains to be determined, a **possible** structure for the Plan could be as follows (below), with templates of tables and figures included for each section to guide development of the Plan.

A. Overall vision of the restoration
    a. Goals for each phase of the restoration (e.g, preservation & mitigation; recolonization & range expansion; local adaptation & growth; and restored ecosystem functions & harvestable populations phase)
    b. Overall conceptual model (expansion of 4-box model used in first workshop, but still very simple; (stressors and potential actions to reduce stressors) for overall basin, with companion simple conceptual models for three major subregions)

*B. Summary of habitat and population factors limiting achievement of the restoration vision (by 3 subregions)*
    a. Upper Klamath Lake (incl. Williamson, Sprague and Lost subbasins)
    b. Upper Klamath River (incl. Butte, Shasta and Scott sub-basins)
    c. Mid and Lower Klamath River (incl. Salmon, Trinity and S. Fork Trinity sub-basins)

C. Reference conditions and planning phase
    a. Upper Klamath Lake
        *i. Overall goal for this phase*
        *ii. Key gaps in datasets that should be filled to document reference conditions*
    b. Upper Klamath River [same subsections as Upper Klamath Lake]
    c. Mid and Lower Klamath River [same subsections as Upper Klamath Lake]

D. Preservation and mitigation phase
    a. Upper Klamath Lake
        *i. Overall goal for this phase*
        *ii. Fine tuning of conceptual model for this subregion and phase [if required]*
        *iii. Hierarchy of objectives to achieve goal for this phase*
        *iv. Key actions to protect and restore habitat and fish populations in this phase*
        *v. Define decision criteria and triggers for this phase*
        *vi. Critical uncertainties in protection and restoration decisions in this phase*
            1. Within this subregion
            2. In other subregions but affecting this one
        vii. Methods of reducing critical uncertainties in this phase
            1. Research and Assessments
            2. AM Experiments
            3. Monitoring and Evaluation (Key Performance Indicators (KPIs), decision rules/criteria and trigger values. KPI Effect Sizes affecting decisions / triggers, sampling design, monitoring protocols, analysis plan)
                a. M&E for status and trend (progress towards goals and objectives)
                b. M&E to assess action effectiveness (adjust actions)

viii. Alternative decisions based on outcomes of this phase (adjust step of AM cycle; IF THEN statements associated with decision criteria and triggers)

b. Upper Klamath River [same subsections as for Upper Klamath Lake]

c. Mid and Lower Klamath River [same subsections as for Upper Klamath Lake]

E. Recolonization and Range Expansion Phase [same structure as above for Preservation Phase]

F. Local Adaptation and Growth Phase [same structure as above for Preservation Phase]

G. Restored Ecosystem Functions and Harvestable Populations Phase [same structure as above for Preservation Phase]

H. Appendices for Assessment and Monitoring Protocols [these will be very limited under minimal/low options]

I. Other TBD Appendices [these will be very limited/non-existent under minimal/low options]

To generate the draft annotated Plan outline, we recommend determing then working collaboratively with **three Subregional Workgroups**:

- **Upper Klamath Lake**, including Williamson, Sprague and Lost sub-basins
- **Upper Klamath River**, including Butte, Shasta and Scott sub-basins
- **Mid and lower Klamath River**, including Salmon, Trinity and South Fork Trinity sub-basins.

Past examples of past Adaptive Management Plans ESSA have developed are listed in the Klamath Basin Integrated Fisheries Restoration and Monitoring web-based Document Library (accessible at http://kbifrm.psmfc.org/document-library/). In addition to prior Klamath efforts, these examples may help assist the Technical Working Group and Subregional Workgroups make choices about elements to include/exclude.

## *Develop Suite of Conceptual Models for each Phase of Restoration*

The use of conceptual models is a key element of problem definition in adaptive management. **Conceptual models are meant to provide a concise visual statement of our current understanding of physical-biological cause-effect linkages through which a valued ecosystem component responds to restoration/management actions** (and other exogenous or indirect effects). **Development of conceptual models occurs iteratively with defining formal objectives and supports identification of key performance indicators**. Developing conceptual models helps to formally consolidate current scientific understanding, as well as provide a venue to identify key questions, areas of uncertainty, identify potential restoration actions, develop expectations, assess the likelihood of success, begin to define needed assessments and monitoring and start to elucidate possible trade-offs associated with different restoration actions.

Development of the Synthesis Report used a simple organizing framework (Figure 3-1) for *identification* of historical stressors and interactions amongst watershed inputs, water quality, fluvial geomorphic processes, physical habitat and focal species of the Klamath Basin aquatic ecosystem (i.e., watershed, mainstem, tributaries). This was a simple and useful tool for organizing vast amounts of information, but it intentionally did not detail specific cause-effect chains that predict system responses and effects of management actions on the status of specific habitats and fish populations.

During the problem definition stage of Plan development, **we recommend developing an overall conceptual model for the Klamath Basin and exploration of options to develop a suite of regional conceptual submodels for the different phases of restoration.** There are many possibilities and levels of granularity that are possible: conceptual models of historic conditions; conceptual models of current conditions; and conceptual models of desired future (restored) conditions. Depending on preferences, these conceptual models can be developed at a regional "topic" level by phase of restoration and there will be conceptual models for individual priority focal species. This process should and will occur *iteratively* and *hierarchically*, helping to inform the definition of formal objectives and performance indicators. As the conceptual submodel development unfolds and the desired level of granularity emerges, there will be an opportunity to "look outward" and ensure linkages amongst conceptual submodels have been made explicit. However, caution is needed to avoid over-elaboration on topics and process detail (i.e., the path of endless questions and derivations, vast spaghetti diagrams that add complexity rather than reducing it). To both keep the conceptual model development effort tractable and to ensure value in restoration applications, the conceptual models should strive to include at least one or more restoration actions that affect state variables and focal species performance indicators.

Conceptual models come in many different forms and styles and include varying levels of detail (simple drawings, statistical relationships, process models); (see examples: Figure 8-14 to Figure 8-17). Major components typically include box and arrow diagrams of cause-effect chains linking management actions and other driving variables that directly affect the subsystem through to key performance indicators for a valued ecosystem component. Arrows in the cause-effect chains are usually associated with text statements about mechanisms and hypotheses (including alternative hypotheses).

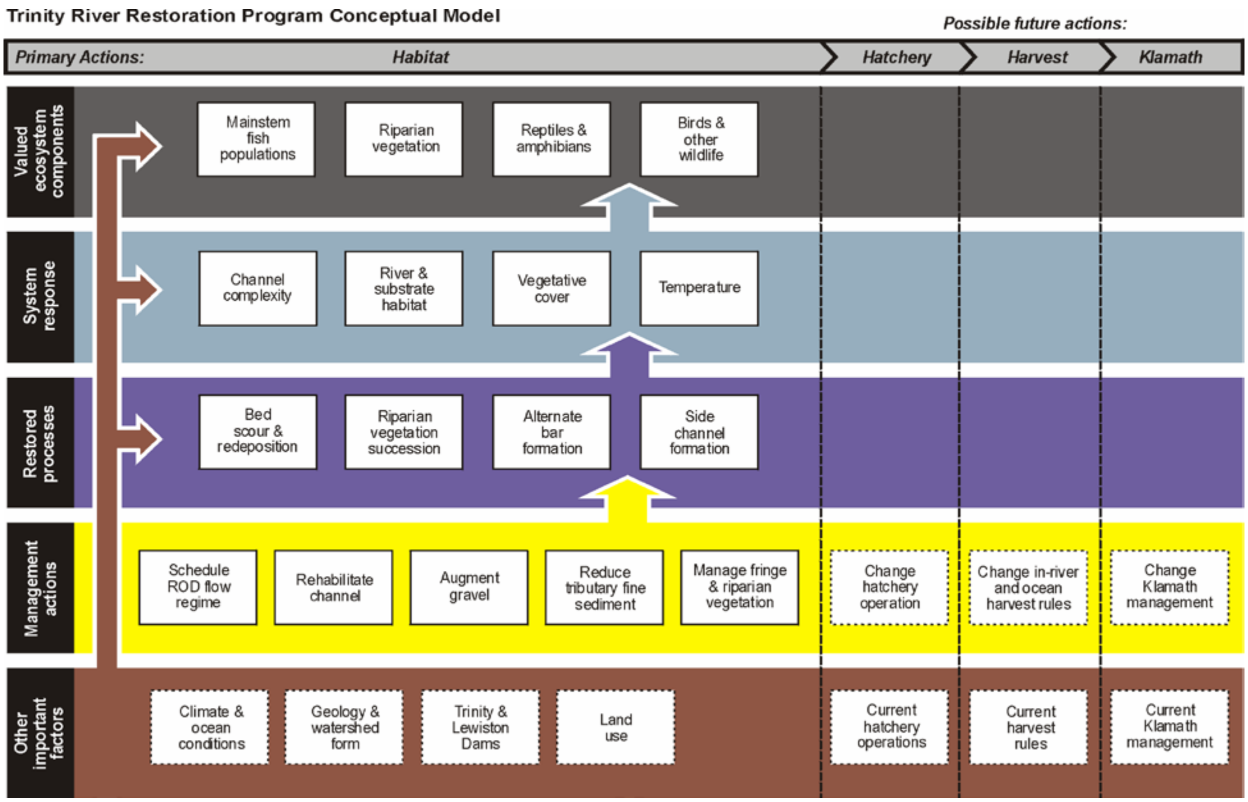


Figure 8-14: Example - Trinity River Restoration Program conceptual model. Source: TRRP and ESSA 2009.

In our experience, every decision support exercise must include assumptions about what is included and excluded to keep the effort tractable. This involves seeking a balance of representative species and indicators given the state of scientific knowledge, the types of decisions the effort is meant to support, and budgetary resources. One of the functions of a representative focal species approach is to facilitate the organization and synthesis of a suite of broadly representative ecological indicators. However, there is a practical need to constrain such efforts to avoid the paralysis that comes with trying to “cover everything”. As knowledge and restoration priorities continue to evolve in the Klamath, the suite of focal species, habitats and indicators that are ultimately identified should be broadly representative of a very large number of ecosystem needs. **A representative set of focal species that considers stressors at all life-history stages, many locations, and a multitude physio-chemical impact pathways will be robust in reflecting broad ecosystem needs**. The suggested focal species have been identified in this Synthesis Report (Section 4.3).

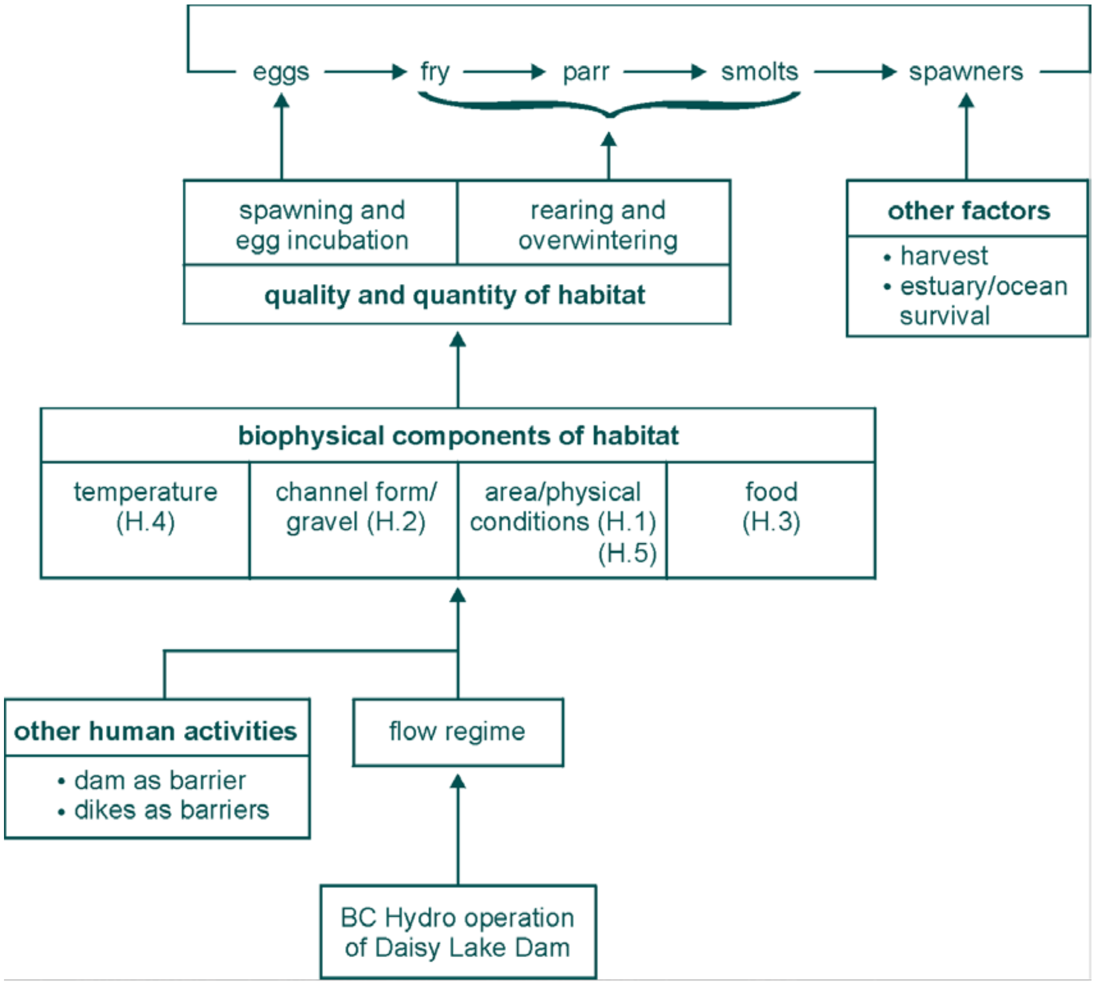


Figure 8-15: Example – overall salmon conceptual model for operation of Daisy Lake Dam, Cheakamus River British Columbia, Canada. This is the highest level conceptual model in a hierarchy. Each of the numbered boxes relating to habitat (H.1 to H.5) have more detailed conceptual sub-models. Source: Consultative Committee for the Cheakamus River Water Use Plan 2002.

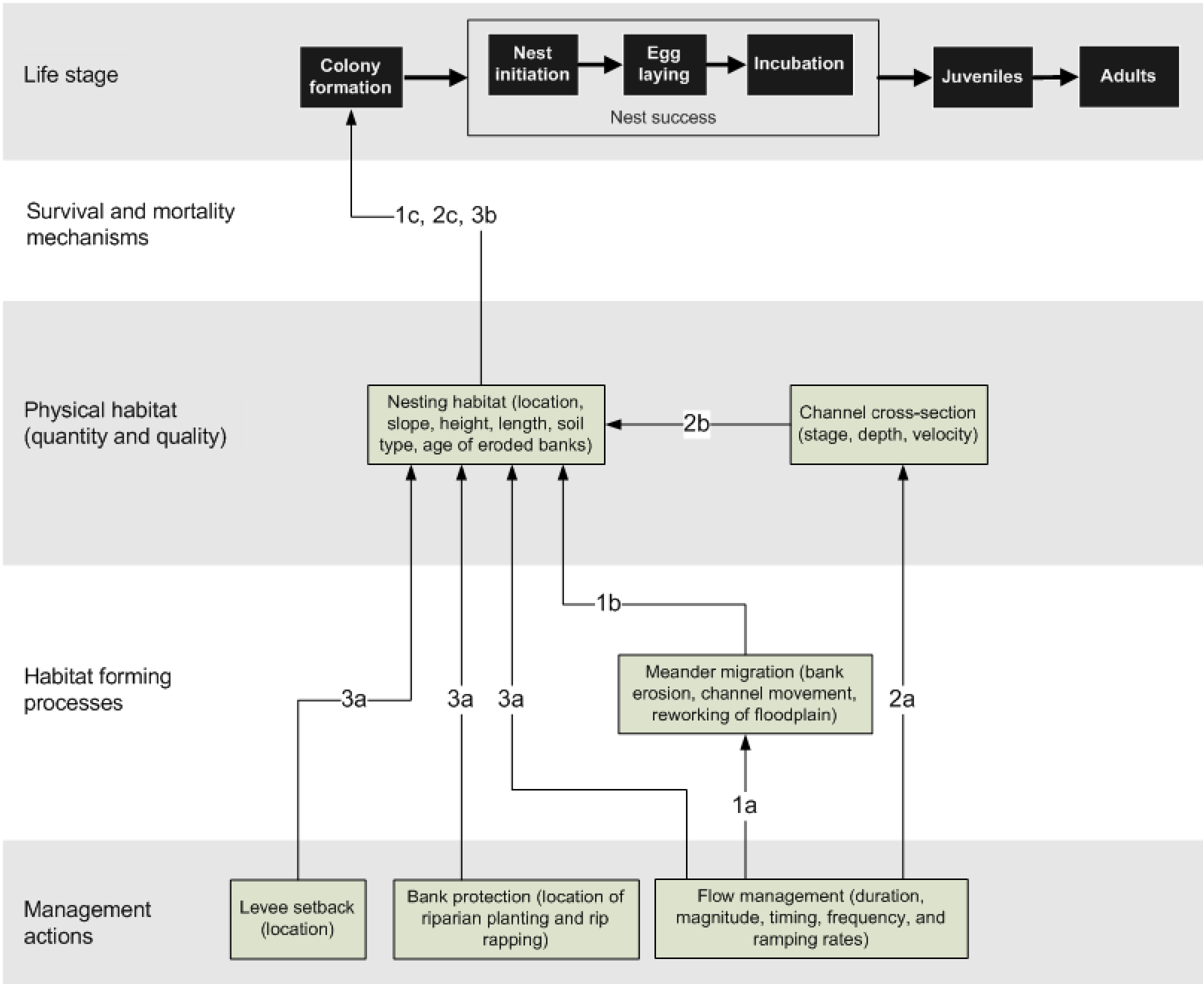


Figure 8-16: Example – conceptual diagram representing links between management actions and important life stages for bank swallows, Sacramento River, CA. Source: EFT Record of Design, ESSA 2011.

It is important to develop statements of linkages about cause-and-effect relationships of the interacting variables with early statements of expected responses to restoration actions, e.g., see Table 8-5. This step will occur iteratively during initial conceptual model development. As conceptual models and objectives stabilize with iteration, prioritization activities are then conducted, and these cause-and-effect linkage statements become increasingly important.

Table 8-5: Summary of the pathways linking management actions to performance measures, the individual links that may be quantified, and the models, functional relationship, and/or data that may be used to quantify the links presented in Figure 8-16.

| Pathway and Link | Link | | Proposed model, functional relationship, or data source |
|---|---|---|---|
| | From | To | |
| 1a | Flow | Meander migration | DOM / historical flow data -> Meander migration model |
| 1b | Meander migration | Quality of nesting habitat | Data related to important covariates (soils, bank height, bank slope)<br>Literature review or expert elicitation of habitat preferences?? |
| 1c | Quality of nesting habitat | PM for colony formation | |
| 2a | Flow | Channel cross-section | DOM / historical flow data -> cross-sections assumed constant |
| 2b | Channel cross-section | Quality of nesting habitat | Data related to important covariates (soils, bank slope)<br>Literature review or expert elicitation of habitat preferences?? |
| 2c | Quality of nesting habitat | PM for colony formation | |
| 3a | Flow, levee setbacks and bank protection | Channel cross-section | DOM / historical flow data -> cross-sections assumed constant or input as an action (e.g., levee setback), |
| 3b | Channel cross-section | Area of accessible nesting habitats | Data related to important covariates (levees, bank protection, soils, bank height, bank slope)<br>Literature review or expert elicitation of habitat preferences?? |
| 3c | Area of accessible nesting habitat | PM for colony formation | |

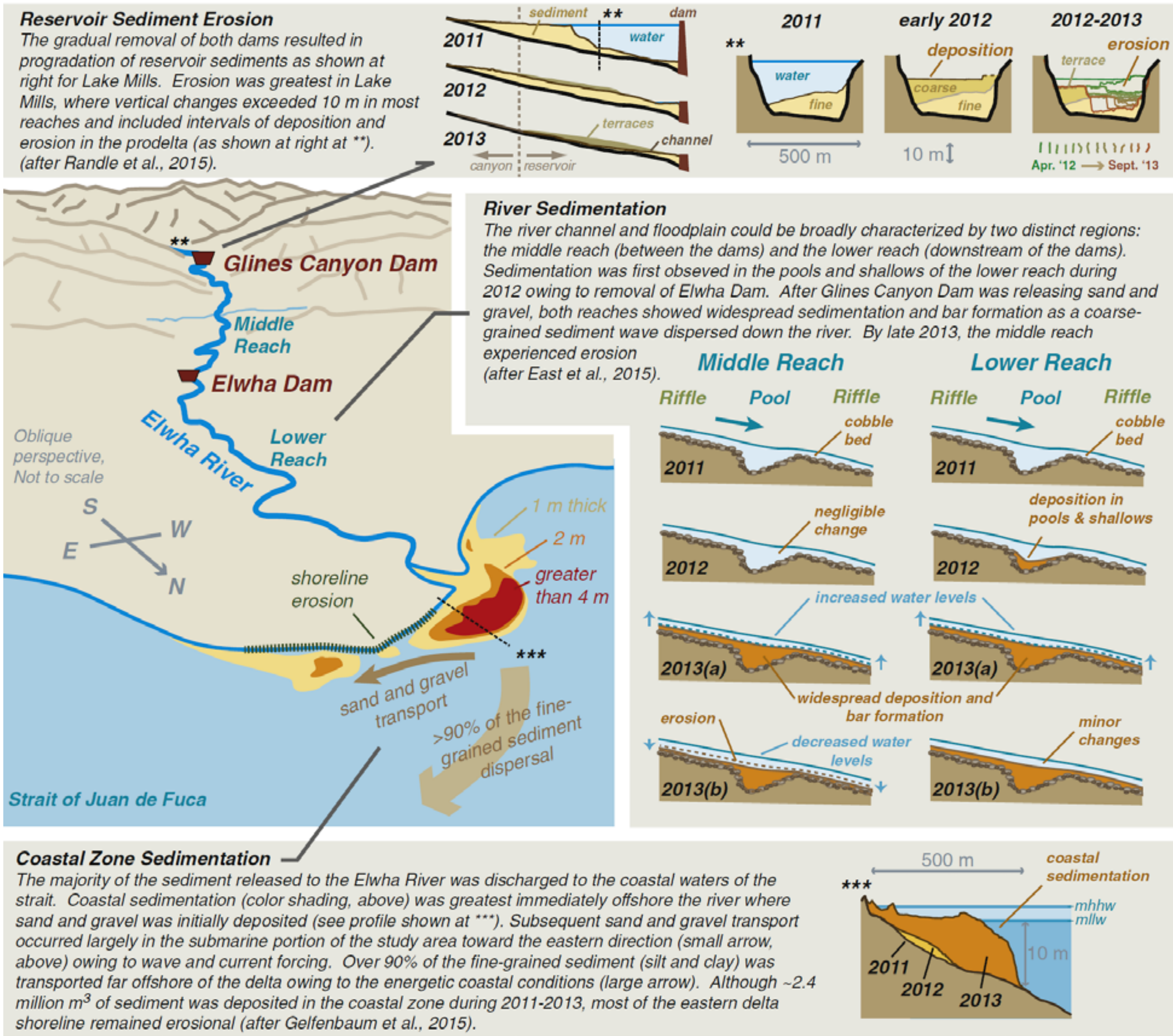


Figure 8-17: Example – Integrated conceptual model of geomorphic processes and change during dam removals on the Elwha River, Washington. Source: Figure 13, Warrick et al. 2015.

Developing the IFRMP presents a complex and technically challenging undertaking. The effort to formalize Plan conceptual models will be assisted by review of synthesis information collected to date which will help enable preparation of straw conceptual models including presentations of existing models (e.g., S3). We recommend the following steps:

- agreement on a set of principles to guide the development of conceptual models;
- technical meetings and interviews;
- review of existing conceptual models;
- preparation of a straw integrated conceptual model linking multiple submodels;
- review of the straw integrated model at a workshop; and
- further refinement and finalization of the conceptual model through technical meetings.

Participants will work through issues of conceptual model scope, bounds and integration amongst submodels within the Plan (Table 8-6). These submodels need to accommodate at least three dimensions: (1) the phases of restoration described above; (2) the differences among sub-basins; and (3) different system processes (e.g., the four components of the organizing framework presented in Figure 3-1, the rows in Figure 8-14 and Figure 8-16). After the conceptual model workshop, cooperating submodel design teams will have reinforced and established links with other researchers and obtained enough information to proceed with the development of the technical details in subsequent steps. **As subsequent steps of Plan development are completed, these early conceptual models will be periodically reviewed and updated.**

### Additional Problem Definition & Bounding Steps

As agreement is reached on the number of submodels, and sufficient understanding is built during their development, submodel design teams must begin to address several critical bounding questions. Table 8-6 summarizes important bounding and filtering steps that are completed iteratively during conceptual model development and integration.

Table 8-6: Common steps in problem bounding. As agreement is reached on the number of conceptual elements, and sufficient understanding is built during their development, disciplinary teams must begin to address several critical bounding questions.

| Problem definition and bounding steps | Description |
|---|---|
| 1. Articulate initial restoration objectives and initial performance indicators | • Begin with priority focal species (and valued ecosystem components closely tied to these focal species) to bound problem.<br>• Prepare statements for potentially relevant restoration objectives, building on information in the Synthesis (section 6.3).<br>• Identify candidate list of quantifiable performance indicators for objectives. Work initially to focus on the “top 3-5” indicators for each conceptual submodel and then iteratively add additional candidate performance indicators once all conceptual submodels considered.<br>• These preliminary indicators will be screened and prioritized in subsequent Plan development steps. |
| 2. Spatial and temporal horizon of interest | • <u>Spatial horizon (def.):</u> The geographic scope and boundary limits of the study area that will be included in the Plan. Areas outside of these bounds will not be considered.<br>• There are three common ways to describe the spatial horizon/extent or geographic scope of the Plan:<br>  o Overall area of interest — What is the overall study area that people care about?<br>  o Areas where some management actions are likely to occur<br>  o Areas which can effect outcomes (e.g., this would include some representation of rates of marine survival of anadromous fish)<br>• <u>Temporal horizon (def.):</u> The retrospective and/or prospective temporal limits of |

| Problem definition and bounding steps | Description |
|---|---|
| | conducting, evaluating and concluding restoration and monitoring under the Plan. For example, whether the Plan will be implemented for 10, 20 or 50 years.<br>• Decisions on the temporal horizon of the Plan involve answering the following questions:<br>  o How long into the future do we need to conduct restoration and monitoring to understand the consequences of a particular management action?<br>  o What is the likely duration of monitoring for each major phase subsystem to be used in evaluating the effectiveness of restoration actions and assist in species recovery recognizing there will be natural environmental (process) variation?<br>  o For focal species monitoring, life-history periodicity information is a fundamental consideration |
| 3. Spatial and temporal resolution of interest | • Spatial resolution (def.): The most appropriate discrete spatial reporting unit for a performance indicator or physical variable (e.g., reach segment, cross-section, specific gage location). Typically, this involves making decisions about suitable levels of aggregation for specific variables, as well as choices about subsets of index locations to include to show representative trends and patterns of variation.<br>  o Where would managers most like to know about a particular performance indicator?<br>  o What subdivision of space is most helpful for understanding physical processes (e.g., hydrological sub-basins)?<br>  o What subdivision of space is most helpful for understanding biological processes (e.g., key habitats for different phases of the life history of focal species)?<br>  o For what portions of the area of interest (Figure 3.8) does relevant input data needed to calculate the performance indicator exist?<br>  o What representative sites can be simulated in the quantitative models that are used to make predictions on physical and biological indicators?<br>  o Are there particularly important sites which need to be monitored going forward (e.g., existing flow gages, rotary screw tap site, dam facilities)?<br>• While statistical considerations play an essential role once more rigorous design takes place, during the initial bounding stage, it can be helpful to focus on identifying the finite set of specific, representative index sites within “hotspots”.<br>• Temporal resolution (def.): The temporal frequency that is to be associated with each incremental estimate or prediction for a performance indicator, at a specific location. In modelling, this is also commonly referred to as model “time-step” (e.g., hourly, daily, weekly, monthly, annually).<br>  o Requires asking: Should we monitor various processes on an annual, monthly, weekly, or daily time step, given both the rates of change of system components, and the current state of knowledge? |
| 4. Statements on functional relationships (linkages) and articulation of unknowns, alternative hypotheses | • Statement of linkages about cause-and-effect relationships of the interacting variables with early statements of expected responses to restoration actions (the “words” that are associated with the arrows in conceptual models). |

| Problem definition and bounding steps | Description |
|---|---|
| | • Identify priority stressors / limiting factors<br>• Clear articulation of unknowns, and beliefs about key uncertainties about how restoration actions will affect focal species.<br>• Whether there are feasible techniques for testing hypotheses and monitoring outcomes. |
| 5. Conceptual Submodel looking outward | As the number of subsystem and phase conceptual increase in number or complexity, it is critical to have clear flows of information among the components. One helpful technique that can be used in workshops is the development of a **Looking Outward Matrix** (Holling 1978). Each element in an LOM represents a potential transfer of information between components, and also explicitly recognizes the management actions and driving variables that are relevant to each submodel. Experts in the domain of an individual submodel will focus on understanding what is required from all the other submodels to predict how their submodel will behave, also considering spatial and temporal resolution and units of measure. |

Table 8-7 summarizes the main products that would be generated during the definition of the initial conceptual model.

Table 8-7: Summary of potential task-process tools and techniques to generate Plan conceptual submodels used in each phase of restoration.

| Task-Process Tools | Suggested Main Product(s) |
|---|---|
| 1. Conceptual model backgrounder, leveraging existing models identified during the Synthesis. | Consolidated document of Plan conceptual (sub)models used in each phase restoration:<br>• Draft/Final<br>• Further updated in subsequent steps |
| 2. A workshop to review the draft conceptual model, with pre- and post-workshop technical meetings and as-needed interviews | Update Klamath Basin IFRMP Document Library |
| 3. Expert peer review of draft conceptual submodels prior to finalization | |

## 8.4.2 Formal Hierarchy of Objectives and Performance Indicators

A *hierarchy* of goals and objectives, aligned with major restoration phases, is an **essential roadmap for restoration**. Building on the problem definition and conceptual model, **the next step of Plan development is to develop an objectives hierarchy and associated key performance indicators for Klamath River restoration.** To make this process more tractable and efficient, *the goals and objectives hierarchy can further be stratified per the agreed upon restoration phases.* The ordered levels of increasing specificity (Figure 8-18) enable co-managers, restoration practitioners and interested participants to relate broad goals to quantifiable objectives and link specific performance indicators, hypotheses and other features within the overall discernable hierarchy. During this step, the initial performance indicators that emerged from conceptual model development are mapped to the hierarchy, and missing indicators **iteratively** developed for all core and sub-objectives.

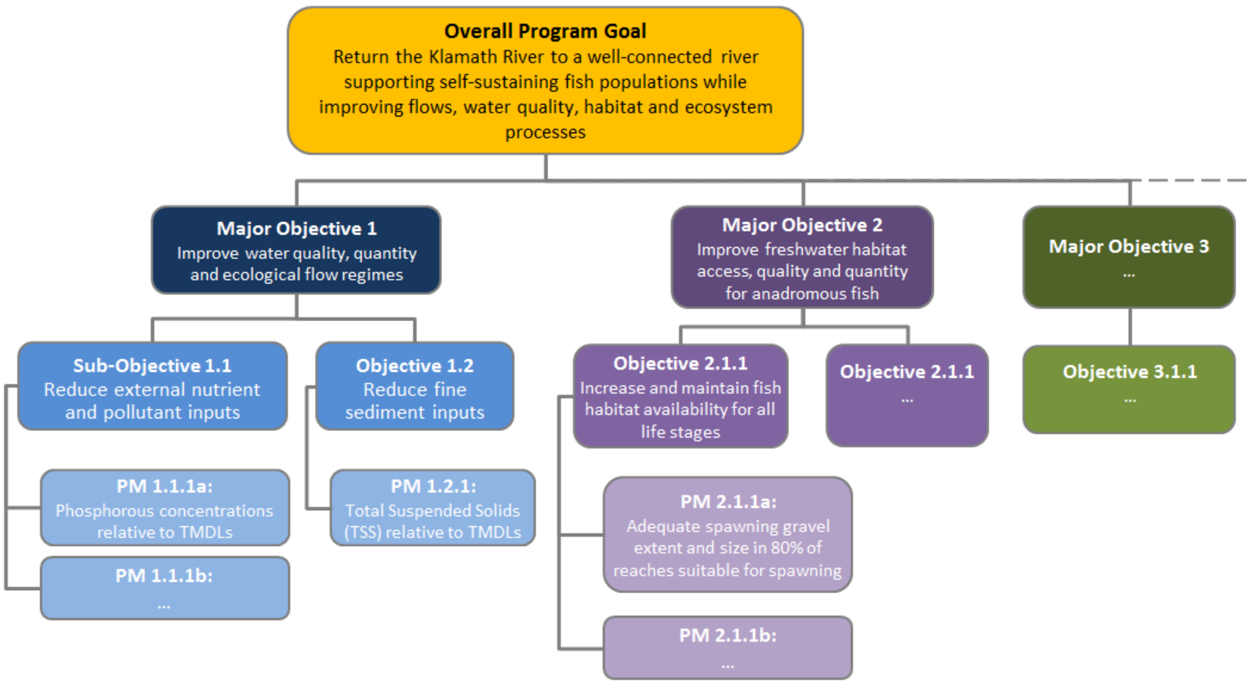


Figure 8-18: Objectives hierarchy, moving from broad restoration program goals to major objectives, through to sub-objectives that become successively more measurable and allow linkage to specific assessments and monitoring indicators. PM = Performance Measure (= Performance Indicator).

As described in **Section 6.3 and presented in detail in Table 6-1**, we selected a representative subset of these plans for purposes of generating an initial starting point for common goals and objectives in the Klamath River Basin. **This initial hierarchy of objectives** was assembled following review of at least 72 publicly available strategic plans (species specific recovery plans; fisheries restoration plans; watershed and habitat restoration plans; water quality plans) that span a timeframe from 1991 to 2017, and encompasses 28 federal, state, tribal, and other agencies, and includes a representative mix of plans pertaining to the lower, upper, mid, and whole Klamath Basin as well as national scale species recovery plans (see Section 6.3; full list of plans provided in Appendix K). Considerably more work is required to develop a simple hierarchy of tangible objectives and sub-objectives that effectively guides development of monitoring plans and performance measures in the IFRMP.

A frequent comment from interview participants related to the fragmented nature of restoration and monitoring activities in the basin. Table 8-8 shows that **most of the plans we reviewed contained general/broad or vague monitoring objectives**. An effective IFRMP will need a clear objectives hierarchy to map restoration and monitoring objectives from the myriad small projects to decisions and goals at the basin-scale, and link these to the triggers that guide progression through restoration phases.

Table 8-8: Clarity of monitoring objectives and strategies in reviewed plans.

| Category | Definition | Proportion |
|---|---|---|
| General/Broad | Broadly defined monitoring objectives & general principles | 48% |
| Not Clear | Supplementary monitoring plan(s) required ('plans to plan'); no monitoring objectives stated | 35% |
| Clear/Specific | Clearly defined monitoring objectives and strategies (time-bound; indicators; thresholds; specific actions) | 26% |

Effective monitoring plans require **clear, measurable objectives** and strategies that are defined at the appropriate scale (e.g., site, stream reach, sub-basin). Harris (2005) provides an example of a clear and measurable objective:

> "Installation of 10 boulder weirs within the 800 foot long project reach is expected to result in the creation of four pools in addition to the three currently in the reach and increase reach level average residual pool depth by one foot. These changes may take 1-2 years to occur and will persist at least until 2015."

Key features of this objective include explicit identification of actions and measurable expected results as well as time-boundedness indicating the period over which monitoring would be required.

**The process of articulating objectives requires expressly identifying one or more key performance indicators for each sub-objective**. Additionally, as performance indicators are defined, statements related to key uncertainties should be updated and revised as needed. As shown in our Synthesis, fisheries agency biological opinions and other restoration plans contain a variety of recommended performance indicators that should be considered in this framework. Some performance indicators are more critical than others for evaluating progress towards defined objectives and sub-objectives.

A more granular effort is needed to isolate critical performance indicators that are key inputs to identified decisions in specific locations and for particular species. This will help to control what can easily become a "laundry list" of metrics. During iterative refinement of the objectives hierarchy and performance indicators, facilitators will work to discern **primary performance indicators**—those ready to go, or with limited controversy from **candidate indicators** that are interesting, but still in the feasibility stage (need to be pilot tested before they could be routinely calculated) or controversial in terms of their evaluation and decision-making value. *Subsequent steps in Plan development, namely gap analysis and prioritization, are used to further structure the hierarchy of objectives, and identify which assessments and monitoring activities are truly core.* At this stage, the focus is on restoration phases and sequencing of decisions.

## *Define Desired Suitability Thresholds & Benchmarks*

As the objectives hierarchy and associated key / primary performance indicators are articulated, we recommend asking disciplinary experts for their opinions on **suitability thresholds** and benchmarks. Multiple restoration objectives, focal species, life-history stages and associated indicators create a very complex solution space. Even if approximate, identification of two suitability thresholds for all performance indicators (a good/fair and a fair/poor threshold) allow co-managers and interested participants to more readily understand as restoration proceeds whether conditions are improving, worsening or flat. Note, *these are similar but not the same as phase-based decision triggers* for shifting restoration decisions (discussed in Section 8.4.3). Suitability thresholds/triggers are statements about where managers would like to see performance indicator values. Decision criteria and triggers relate to when to adopt / stop / modify restoration actions and potentially move to/fall back to different restoration phases. <u>Suitability thresholds and ranges provide non-specialist resource managers and interested participants with a rapid status assessment of whether a performance indicator is in a preferred state, regardless of whether a specific decision trigger has been reached.</u>

Table 8-9 summarizes the main products that would be generated from a formal hierarchy of objectives and performance indicators.

Table 8-9: Summary of potential task-process tools and techniques to generate a formal hierarchy of objectives and performance indicators.

| Task-Process Tools | Suggested Main Product(s) |
|---|---|
| 1. Draft goals and objectives hierarchy with example performance indicators ('something to shoot at')<br><br>2. Technical meetings with appropriate Plan cooperating partners, co-managers, experts and interested participants on No.1 (what do they like; what was missed)<br><br>3. Goals and objectives workshop to review revised hierarchy, obtain final input | Draft / Final goals and objectives hierarchy:<br>• Stratify per agreed upon restoration phases, if helpful. "Enter" the conversation on objectives and performance indicators by focusing on phases and sequencing of decisions<br>• *Resist* tendency to generate "laundry lists"; focus on "need to know", not "nice to know".<br>• Development iterative including through to future steps where gap analysis and prioritization activities are completed<br>Identify primary and candidate performance indicators<br><br>Update preceding Plan elements (conceptual models, critical uncertainties, etc.)<br><br>Update Klamath Basin IFRMP Document Library |
| 4. Survey / interviews to elicit desired suitability thresholds | Desired suitability thresholds for all primary/key performance indicators.<br>• Suitability thresholds and ranges provide non-specialist resource managers and interested participants with a rapid status assessment of whether a performance indicator is in a preferred state regardless of whether a specific decision trigger has been reached.<br>Final goals and objectives hierarchy with performance indicators and suitability thresholds |

### 8.4.3 Candidate Restoration Actions & Assessments for each Phase of Restoration

With agreement on problem definition and objectives from the preceding steps, restoration co-managers, practitioners and interested participants can now **begin to map candidate restoration actions and assessments (management responses) that need to be made annually and periodically in each phase of restoration (including baseline data collection priorities).** This requires being diligent to focus on management interventions that are *under human control*, and continuing to apply best available scientific knowledge to reduce priority stressors (limiting factors). During the initial iteration, the focus is on identifying initial beliefs of the best restoration strategies and actions for the **phases** of restoration. **Participants will be guided to identify the *major* substantive phase-specific actions, and the limiting factor(s) / sub-objectives addressed by these actions.** For example, a key area to review will likely include the balance of natural recolonization and artificial supplementation using hatchery outplants. The critical inputs to the decision should be identified, and expected responses to the proposed actions stated.

In addition to the phases of restoration, this work could be divided (e.g., working groups) according to the categories presented in Section 6.5 of the Synthesis:

- Fish passage improvements
- Hatchery rearing and reintroduction
- Instream flow management
- Instream and wetland habitat restoration
- Riparian habitat restoration
- Upland habitat and sediment management
- Water treatment and wetland

*Note: depending on preferences of cooperating partners, structured gap analysis may be helpful in parallel with this step.*

This process typically leads to revisions / additions to statements of restoration hypotheses, critical uncertainties and the cause-effect linkages in conceptual models. Later steps are used to assess gaps, and to dive deeper into the major assessments and necessary monitoring design (outlined below). Initially, the phased framework will assist with organizing the discussion of options and initial beliefs about priorities.

In the Klamath River Basin, the ability to select and implement restoration and monitoring actions will hinge critically on distinguishing whether managers are moving forward with dam removal or the addition of significantly enhanced fish passage capabilities. For example, under dam removal, the high turbidity, fine silts and sand during and immediately following dam removal will potentially increase mortality rates of fish in the river (USDI et al. 2012a,b). The actions necessary to mitigate this risk under dam removal (e.g., creating side channels as refugia, safeguarding broodstock in the hatchery environment, transporting fish to upstream refugia) are quite different from the actions required if fish passage facilities were to be completed.

## *Define Decision Criteria and Triggers*

**For each substantive action, decision criteria and triggers will be iteratively developed.** A decision rule is a logical statement of the type "if [criteria], then [decision]." **Triggers are defined *for each key performance indicator, or for multiple performance indicators in a combined decision rule*.** Triggers are the specific criteria that are used to determine if the decision rule has been met and leads to implementing the appropriate management action (see Peters et al. 2014). Decision rules involve judgments about the number of triggers and other criteria that need to be satisfied to move from one restoration phase to the next. If a trigger is not met within the defined limit (e.g., four years), then the assumptions used to develop the trigger value are re-evaluated (e.g., Peters et al. 2014). This may result in developing new trigger values or identifying other factors that are preventing the trigger value from being exceeded (e.g., a previously unrecognized limiting factor).

An example of a trigger would be a threshold number of natural spawning adult Chinook salmon, which if all the other triggers are met, would result in advancing to the next restoration phase and begin a sequence of new actions such as beginning to reduce hatchery production of Chinook salmon based on future returns (e.g., Peters et al. 2014).

Triggers are different from suitability thresholds for performance indicators. Decision criteria and triggers relate to when to adopt / stop / modify restoration actions and potentially move to/fall back to different restoration phases. Suitability thresholds/benchmarks are statements about where managers would like to see values for performance indicators (*regardless* of the restoration phase) that enable clear communications on the current status of focal species and other ecosystem components.

Table 8-10 summarizes the main products that would be generated from this step of Plan development. This step may be further informed by, and could occur in parallel with, a structured analysis of gaps (see Section 8.4.4).

Table 8-10: Summary of potential task-process tools to generate candidate list of priority restoration actions, and to articulate decision rules and triggers for advancing from one restoration phase to the other.

| Task-Process Tools | Suggested Main Product(s) |
|---|---|
| 1. Backgrounder technical memo/document (building on Synthesis material)<br><br>2. Structured gap analysis (see Section 8.4.4)<br><br>3. Technical workshop on restoration actions, triggers and gaps<br><br>4. Workshop summary document | Draft (candidate) and Final chapter (for full IFRMP) on phase-specific restoration actions and performance indicator triggers:<br>• Substantive phase-specific actions, linked to the limiting factor(s) and objectives the action will change if/when implemented.<br>• Triggers for major performance indicators.<br>• Critical inputs to the decision should be identified, with expected responses.<br>• Stratify per agreed upon restoration phases.<br>Update preceding Plan elements (conceptual models, critical uncertainties, etc.) |

| Task-Process Tools | Suggested Main Product(s) |
|---|---|
| 5. Peer review of workshop summary (w comment/ response) | Gap analysis (see Section 8.4.4)<br><br>Update Klamath Basin IFRMP Document Library |

## 8.4.4 Conduct Structured Gap Analysis & Develop Prioritization Framework

**Gap Analysis**

Beginning to prioritize restoration actions, assessments and associated monitoring is a difficult and necessarily iterative process for a Plan of this scale. Because this process tends to be highly influenced by opinion, more data-driven assessments of gaps in how priority stressors are being targeted by restoration are helpful (Barnas et al. 2015). With priority stressors (limiting factors) identified earlier through conceptual modeling, it is possible to address the degree to which existing restoration and monitoring projects target these concerns throughout the Klamath River Basin. This process will inevitably identify projects that have not yet been included in our database. If the Oversight Group believes a missing restoration and monitoring projects can be identified efficiently, **the first step in the gap analysis is to further update the project database developed for the Synthesis Report, filling gaps in the coverage of restoration and monitoring activities** (Appendix H).

A more complete database is necessary to conduct a structured gap analysis, where we compare the number, type, magnitude, form and effectiveness of projects in different regions to the stressors of greatest concern in those regions. In addition to updating the database and analyzing information in it, dialogue with local experts will be required to understand where more attention is needed (e.g., projects to reduce inputs of phosphorus have worked well in sub-basin X, but only deal with 15% of the area of concern). For example, work by Trout Unlimited on the California Freshwater Conservation Success Index enables an overlay of stressors with restoration efforts to reveal the degree of match between need and action. Various summary metrics (e.g., percent of ecological concerns matched to restoration actions that are intended to reduce these concerns) are an important step, together with local expertise, in determining where additional restoration funding should be directed. An example of this type of analytical approach is provided in Barnas et al. (2015). In some areas further diagnoses may be required to determine which factors are most limiting, and therefore which gaps in existing restoration projects are the most critical.

For example, while not yet focused on specific limiting factors, our initial review of databases and plan documents suggested several species-specific data gaps. Figure 8-19 shows the frequency with which focal species are addressed in the reviewed plans, revealing a prioritization of salmonids in these documents. Restoration monitoring actions are less frequently specified for sucker, lamprey, eulachon, green sturgeon, bull trout and redband trout (*O. mykiss newberrii*).

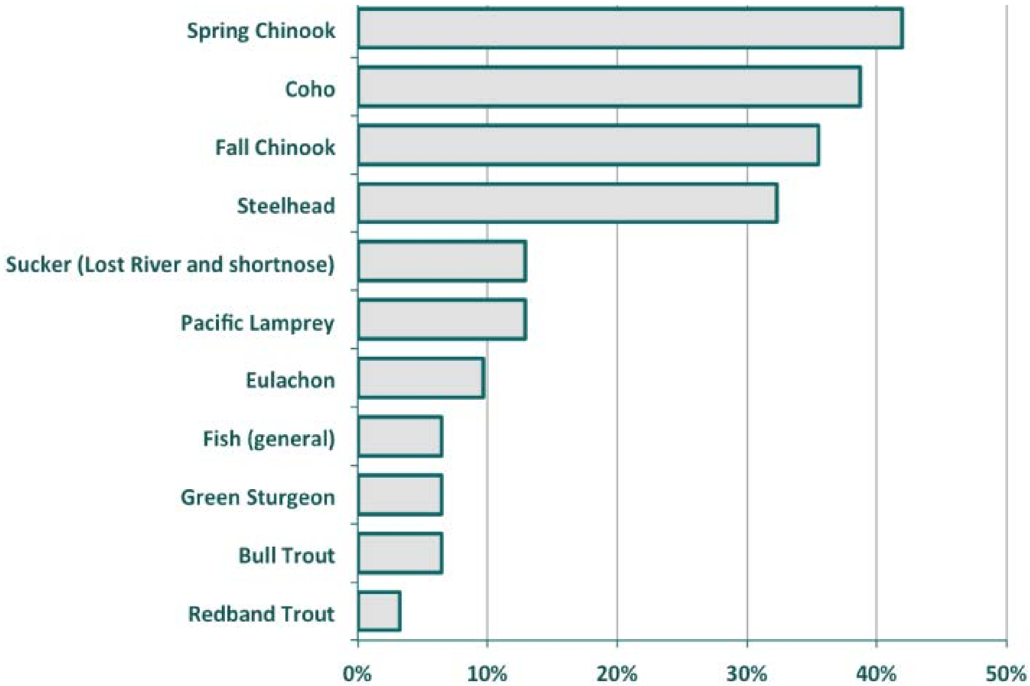


Figure 8-19: Frequency of species targeted for monitoring in reviewed plans.

Table 8-11 provides an example of how information on gaps could be summarized. With overlays of priority stressors, this type of gap assessment will help to inform priorities for additional restoration actions and associated monitoring activities.

Table 8-11: Example summary presentation of monitoring gaps.

| | Water Quality & Fish Habitat Metrics | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Temperature | Dissolved $O^2$ | pH | Nutrients | Turbidity | Algae/Periphyton | E-coli/Bacteria | Ammonia | Chlorophyll-a | Microcystin/anatoxin | Sediment/VSS/TSS | Invertebrates | Atmospheric | Phytoplankton Interaction |
| Sub-basin1 | | | | | | | | | | | | | | |
| Sub-basin2 | X (orange) | X (orange) | X (orange) | (red) | | (red) | (red) | X (green) | | | | | | |
| Sub-basin3 | X (green) | X (green) | | X (green) | | (red) | (red) | | | X (green) | X (orange) | | (red) | |
| Sub-basin4 | X (orange) | X (orange) | (red) | X (orange) | X (green) | (red) | (red) | | (red) | X (green) | X (orange) | (red) | | |
| Sub-basin5 | X (green) | (green) | | | | (red) | (red) | | | | (red) | (red) | | |
| Sub-basin6 | X (orange) | X (orange) | (red) | | X (green) | (red) | X (orange) | | | | | | | |
| Sub-basin7 | X (green) | X (green) | | | X (green) | | (red) | | | X (green) | (red) | | | |
| Sub-basin8 | X (green) | | | | | (red) | (red) | | | | (red) | (red) | | |
| Sub-basin9 | X (green) | X (green) | X (green) | X (orange) | | | | | | | | | | (red) |
| Sub-basin10 | X (green) | | | | X (green) | (red) | (red) | | | | (red) | (red) | | |
| Sub-basin11 | X (green) | X (green) | | X (green) | X (green) | | | | | X (green) | X (green) | | | |
| Sub-basin12 | X (green) | X (green) | X (green) | X (orange) | | | | | X (green) | | | | | (red) |
| Sub-basin13 | X (green) | X (green) | X (green) | X (orange) | | | | | | | | | | (red) |

Source: synthesized from (Royer, 2011; Royer & Stubblefield, 2016)

X (green) No gap; (red) Gap (if variable is linked to known limiting factor); X (orange) Monitoring present but more needed (if variable is linked to known limiting factor)

Identifying species-specific limiting factors and gaps such as those shown above will assist in directing dialogue on **prioritization of limited funds**. Moreover, this activity will inform discussions about additional prioritization criteria in the next step, helping co-managers and interested participants iteratively winnow in on specific priorities for restoration, assessments and monitoring.

**Prioritization Framework**

Comments about funding were the most frequently stated concerns from interview participants. A great deal of uncertainty about funding arose due to the termination of the KBRA. The KBRA envisioned $117.5 million in spending on monitoring projects from 2012-2021 ramping up to an annual expenditure of ~$13 million/yr (Figure 8-20). Given finite funding resources that will be available to restoration and monitoring in the Klamath Basin, clear priorities are essential.


Figure 8-20: Projected annual spending on monitoring under KBRA (KBRA 2010).

In other settings, external peer reviews frequently advise converging to a manageable set of core restoration actions and related assessments which are done well (e.g., advice from the Trinity River Science Advisory Board during the development of the Integrated Assessment Plan, TRRP and ESSA 2009). To exercise this kind of advice in the Klamath IFRMP, it will be **essential to develop specific prioritization criteria and/or questions**. This is especially true in longer-term restoration endeavours where there are inevitably changing physical conditions, new learning, surprises and changes in policies and budgets.

Following identification of gaps, and leveraging the guiding conceptual model framework, **additional "check-list" questions should be developed and applied to assessments that are intended to inform sub-objectives and related performance indicators**. These questions will help further sequence and prioritize assessments and monitoring. Examples of prioritization questions that could be further tailored during development of the Plan might include:

1. *Relevance to goals/decisions*: is an assessment critical for evaluating whether restoration goals and objectives are being achieved? Is it essential to inform key performance indicators and their triggers? How likely is it that restoration actions would change if an outcome of this assessment indicates we are not achieving trigger values? What are the consequences of not assessing this sub-objective? Why and how would these consequences occur?
2. *Value of information, ability to detect change:* whether the work would provide strong evidence to inform decisions on restoration actions in terms of either their biological benefit/effectiveness or feasibility (i.e., high information value relative to cost). Will the assessment provide sufficient accuracy and/or precision to determine appropriate changes to management actions? Do rigorous analyses (e.g., statistical power analyses

to consider natural variability, measurement error, and confounding factors) support the assessment? Has associated literature been reviewed?

3. *Critical baseline information:* does the assessment provide unique baseline data for the objective / key performance indicator / trigger that will be pivotal in assessing change and progress?
4. *Timeliness of learning & clarifying effectiveness:* whether the work would provide faster answers than would otherwise occur, or in time to meet mandated deadlines. Can the assessment measure systemic change in a timely manner for key decisions? Have analyses been completed which quantify what percent change in this ecosystem component could be reliably detected over 10, 15 and 20-year periods (e.g., power analyses which consider measurement error, natural variability, effect size and confounding factors)? Does the assessment provide unique insight to evaluate / test the validity of key hypotheses and/or resolve critical uncertainties?
5. *Minimize risk to species*: whether the information gained would uniquely help to avoid taking actions that pose a high risk to species.
6. *The assessment is essential to supporting other priority assessments*: does the assessment provide required input information to one or more high priority assessments? Or, is this assessment *contingent* upon certain conditions occurring, and therefore can be postponed (e.g., only assess abundance of benthic organisms if fish length distributions show that juvenile salmon are under-sized for their age).
7. *Cost and technical feasibility*: whether the varied benefits from earlier questions/criteria outweigh the costs. Is the assessment financially feasible? Will the budgeted resources enable adequate monitoring of the outcomes of management actions, and determine appropriate changes to management actions?

Check-list questions such as these are typically used to create a qualitative ranking / sequencing of assessment and monitoring plan priorities (e.g., Excluded, Low, Medium, High, Core, Pilot Test).

Table 8-12 summarizes the potential main products that would be generated from this step of Plan development.

Table 8-12: Summary of potential task-process tools and techniques to generate main products for structured gap analysis and prioritization criteria.

| Task-Process Tools | Suggested Main Product(s) |
|---|---|
| 1. Additional engagement / inquiries by PSMFC, Cooperating Partners, Plan consultant, potentially including additional interviews and inquiries to obtain missing project datasets.<br><br>2. Structured gap analysis (see Section 8.4.4); adapt analytical approach provided in Barnas et al. (2015), supplemented by conversations with local experts.<br><br>3. Tools for workshop prioritization activities.<br><br>4. Peer review of gap analysis and prioritization framework. | Comprehensively updated project synthesis database<br><br>Gap analysis infographics and communication materials<br><br>Prioritization check-list / framework<br><br>Elements documented in full IFRMP<br><br>Update preceding Plan elements (conceptual models, critical uncertainties, etc.) |

### 8.4.5 Establish Priority Sequence of Restoration & Assessment Actions

**The detailed sequencing of restoration actions and associated monitoring activities for each phase of restoration** would build from products developed in previous steps: phase-specific goals and objectives, conceptual models, the prioritization framework, and the results of the gap analysis**.** This would initially emphasize the priorities for the initial baseline phase. It is essential to **document *why* each assessment is required and *what* it involves.** Assessments described in this section of the Plan will fulfill at least one of the following purposes: (1) tracking progress toward Klamath ecosystem and fisheries restoration objectives (Section 8.4.2) that contribute to the Plan goals; and/or (2) assessing the effectiveness of specific management actions so as to contribute towards adjustments in restoration plans, restoration actions and/or monitoring in a cycle of adaptive management.

Another important feature involves identifying how different assessments relate to one another, including contingent relationships. If an assessment is contingent, describe what objective and assessment it is contingent upon.

#### *Obtain Statistical & Analysis Advice*

**Adaptive management requires sound experimental design, and contrast**. In river systems, the opportunities for contrast among actions that affect the whole system (e.g., testing changes in volume or timing of flow releases) are primarily temporal (i.e., before-after comparisons). Different actions need to be compared across a range of water years. In larger river systems such as the Klamath there will also be some opportunities for creating spatial contrasts among sub-basins or tributaries for actions with a smaller footprint (e.g., Before-After-Control-Impact comparisons of channel rehabilitation projects). Some areas may be sufficiently pristine to serve as ‘untreated’ controls; others already dramatically altered could serve as a ‘worst case’ contrast. It is always a challenge to allocate money for monitoring control areas, but it is essential.

Some of the criteria/questions in the prioritization framework involve statistical matters (e.g., spatial/temporal sampling frame, statistical power analysis, precision requirements, and basic experimental design) that will involve obtaining statistical advice and documenting specific protocols.

Receipt of statistical advice should occur periodically, especially during major peer reviews.

## *Make Predictions*

**The development of the plan should consider selecting a "core" set of linked models and, where feasible, scientists should use the models to predict the expected performance of focal species and other ecosystem components on which these species depend.** The 2008 NRC committee devoted considerable attention to the numerous ways that models (including hydrologic, hydraulic, water quality, habitat, biological, and management models) can assist in ecosystem management. Likewise, the Trinity River Restoration IAP (TRRP and ESSA 2009) recognized the independent and mutually reinforcing roles of models and empirical data collection (Figure 8-21).

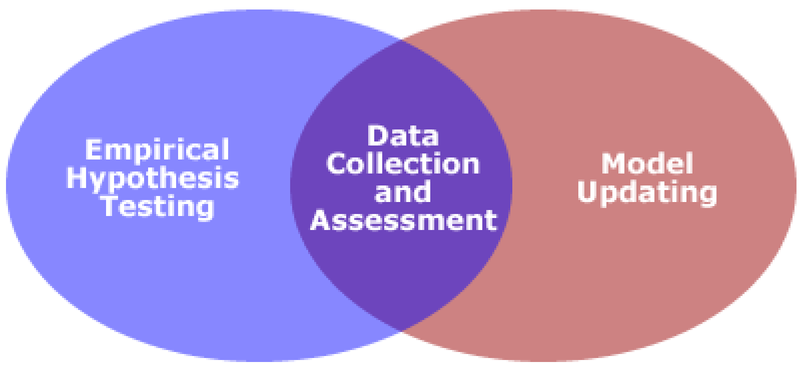


Figure 8-21: Assessments aimed at evaluating management actions and reducing critical uncertainties often require a combination of empirical hypothesis testing and model updating. Source: TRRP and ESSA (2009).

One of the founding fathers of adaptive management, Holling (1978), described "shared vision modeling" and gaming approaches to represent knowledge, identify uncertainties, and illustrate trade-offs among objectives. Here, computer models form the central venue and technical arbiter for negotiations, constituting an agreed-on technical basis for discussions and comparison of performance for proposed alternatives (Figure 8-22). The development of suites of interacting models can help to address many technical concerns, including issues of scale, and should follow a systematic process of development and application, including testing (NRC 2008).

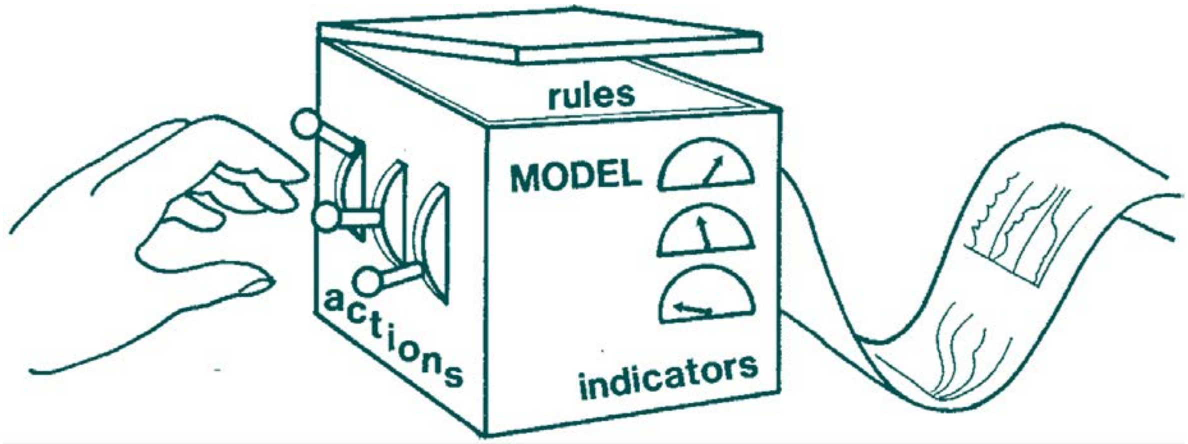


Figure 8-22: Quantitative simulation models help managers predict and evaluate alternatives and trade-offs in parallel with empirical data collection and hypothesis testing.

Restoration in the Klamath River Basin will be informed by both simulation models and empirical analyses to clarify the cause-effect chains by which management actions affect watershed inputs, fluvial processes, habitat quantity and diversity, and population responses (Figure 3-1).

## *Document Assessment Protocols*

Once the IFRMP team has determined the priority assessments, and obtained necessary statistical advice, they need to **document the monitoring protocols to be used for each assessment.** Methodological assumptions and limitations should be incorporated, including technical issues that may still need to be resolved through pilot testing, etc. Table 8-13 summarizes the main products that would be generated from this step of Plan development.

Table 8-13: Summary of potential task-process tools and techniques to generate main products for establishing priority restoration assessment actions.

| Task-Process Tools | Suggested Main Product(s) |
|---|---|
| 1. Facilitated technical meetings or workshop(s), applying prioritization framework.<br><br>2. Identify how different assessments relate to one another.<br><br>3. Obtain statistical analysis advice.<br><br>4. Identification of candidate predictive models.<br><br>5. Peer review of outcome of applying prioritization framework.<br><br>**This process will be highly iterative** | Document why each assessment is required and what it involves. If an assessment is contingent, describe what objective and assessment it is contingent upon (including major restoration phases, decision rules and triggers).<br><br>Document qualitative ranking / sequencing of assessment and monitoring plan priorities (e.g., Excluded, Low, Medium, High, Core, Pilot Test).<br><br>Document key statistical advice.<br><br>Documentation for “core” models and their appropriate applications.<br><br>Update preceding Plan elements (conceptual models, critical uncertainties, etc.). |

### 8.4.6 Design Monitoring and Evaluation Framework

Monitoring plays a key role in understanding whether restoration actions are successful at recovering fish populations. Monitoring also helps to inform co-managers when it is time to move from one phase to the next, based on assessments of key triggers. **Each key performance indicator will require one or more monitoring approaches** to compare the status and trends of focal fish species and other ecosystem components versus established triggers, as well as to gauge the effectiveness of priority restoration actions (Section 7). As there are various reasons why a project may not meet the originally conceived goals and/or objectives, a well-designed monitoring program will contribute to promote learning.

Table 8-14 lists some of the approaches used for monitoring design, as well as field methods for habitat and population monitoring, as specified in the Klamath plans and documents that we reviewed (Section 7).

Table 8-14: Methods of monitoring design, field monitoring, and assessment that were identified in plans we reviewed.

| Habitat Monitoring | Population Monitoring |
|---|---|
| Aerial Surveys | Acoustic Camera (e.g., DIDSON) |
| Before-After Photo Documentation | Capture-Recapture |
| Buoy Arrays (ocean productivity) | Carcass Counts |
| Channel Dimensions Assessment | Direct Observation Surveys |
| Collaboration with other Agencies for Data | Fish Weirs |
| Flow Gages | Permanent Fish Sampling Reaches |
| Habitat Condition Inventory | Genetic Sampling |
| Habitat Typing | Life Cycle Monitoring Stations |
| Large Woody Debris Assessment | Net Harvest Numbers |
| Macroinvertebrate Sampling | Outmigrant Trapping (e.g., rotary screw traps) |
| Meteorological Gages | PIT-tagging |
| Net Surveys (ocean productivity) | Power Analysis (site selection) |
| Stream Gaging Stations (discharge; continuous) | Radio Telemetry |
| Water Quality Monitoring Stations | Redd Counts (tape, GPS) |
| Power Analysis (site selection) | Regional Population Estimation (survey) |
| Radius of Curvature | Smolt Production Surveys |
| Riparian Berm Heights | Snorkel Survey |
| Riparian Condition & Vegetation | Spatially Balanced Probabilistic Sampling Design - GRTS |
| Satellite (ocean productivity) | Spawning Surveys |
| Site Visits | Video Counting Stations |
| Spatially Balanced Probabilistic Sampling Design - GRTS | |
| Stream Habitat | |
| Stream Temperature Gages | |
| Turbine Venting Tests (DO) | |

Some performance indicators chosen from the list above are currently tracked as trends over time (e.g., time is the independent variable, and radius of curvature is the dependent variable), and some will be used to assess physical responses to a particular management action (e.g., peak flow magnitude as the independent variable and riparian berm heights as the dependent variable).

In the context of the IFRMP, we recommend **a common monitoring framework to provide a foundation for monitoring sampling designs and protocols**. This general design for the IFRMP monitoring framework should be compatible with most sampling needs for the key assessments identified to date. This means informing where and when sampling should occur, **including how to roll-up and integrate information at different spatial scales**. The intention behind creating this common monitoring framework and a recommended sampling design is to provide an accepted base structure around which future assessments and data collection can be coordinated, and through which data can be combined across disciplines to elucidate cause-effect relations at a system scale. It should also be recognized that, in terms of budgeting and maintaining trained field technicians, there are some obvious advantages to having consistent methods of annual monitoring.

In the case of the TRRP, once the highest priority assessments were identified, they were used to inform the creation of a sampling design capable of accommodating and integrating the majority of the assessments (Figure 8-23).

Rather than trying to identify the optimal stratification variables for each assessment, the Trinity River IAP recommended starting with a very simple set of strata expected to be important for many priority assessments.

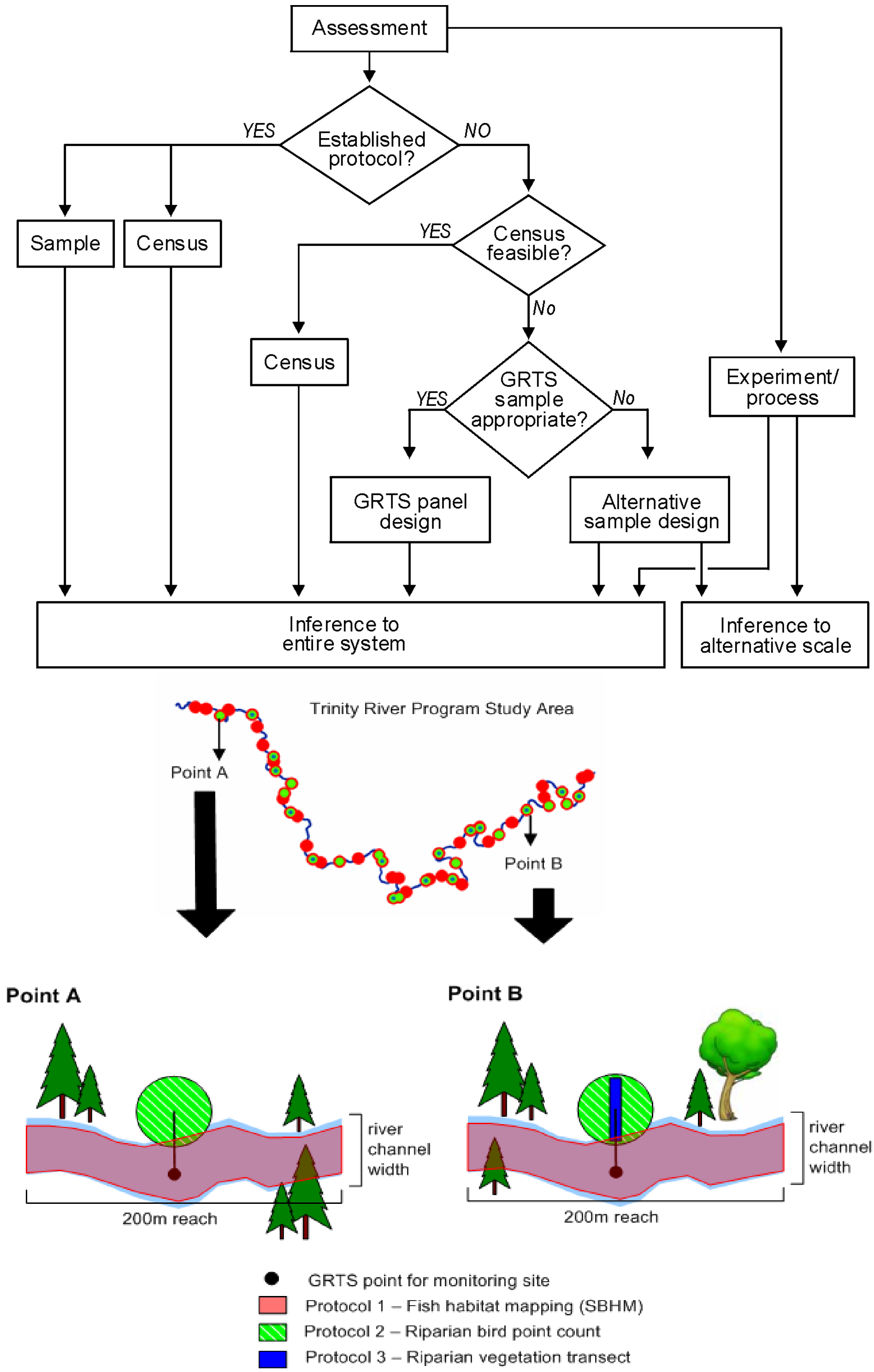


Figure 8-23: Alternative sampling designs for generating inferences at various scales of interest (upper figure) and benefits of a common sampling designs to maximize analyses of associations across ecosystem components (lower figure). Source: TRRP and ESSA 2009.

Another valuable step to restoration for co-managers and practitioners in the Klamath River Basin is to **gather information on the cost of monitoring both in the Klamath Basin and other river-basins**, building on work done in other basins. For example, scientists from federal, state and tribal agencies in the Columbia River Basin worked with ESSA to develop an Integrated Costs Database Tool[54] (ICDT) for estimating the costs of various types of fish monitoring programs.

As mentioned above, the monitoring design must generate sufficiently precise estimates to detect effects of interest for decisions, against the background level of natural variability. Key metrics, such as estimating the numbers of outmigrating smolts, may require sophisticated statistical approaches to obtain satisfactory levels of precision (e.g., Schwarz et al. 2009) The USEPA provides substantial guidance for determining the required level of precision for a study as part of their Data Quality Objectives (DQO) process (EPA 2006), which is summarized in Appendix N of this report.

Monitoring methods will evolve as co-managers move from one restoration phase to the next. However, revisions to established monitoring methods should only be done after a period of evaluation and calibration between the old and new methods, to allow data from the old and new methods to be compared to ensure they are providing the same information (Peters et al. 2014).

## *Document Monitoring Protocols*

**Where they are not already, protocols for carrying out priority sampling and field measurements should be documented**. This includes methodological assumptions and limitations, including technical issues that may still need to be resolved through pilot testing, etc. The list of questions in Appendix M provides a useful best practice guide when documenting monitoring and sampling protocols. Table 8-15 summarizes the potential main products that would be generated from this step of Plan development.

Table 8-15: Summary of potential task-process tools and techniques to generate main products for designing the integrated monitoring and evaluation Framework.

| Task-Process Tools | Suggested Main Product(s) |
|---|---|
| 1. Obtain statistical advice.<br><br>2. Technical presentations on options/ meetings on draft versions of framework.<br><br>3. Peer review of framework.<br><br>**This process will be highly iterative** | Document key statistical advice within the monitoring plan (e.g., results of power analysis).<br><br>Common monitoring and evaluation framework document to guide monitoring practices including how to roll-up and integrate information at different spatial scales.<br><br>Document monitoring approach/protocol for each key performance indicator.<br><br>If required, update preceding Plan elements (conceptual models, critical uncertainties, etc.). |

54 http://cfw.nwcouncil.org/CSMEP/web/content.cfm?ContextID=22

### 8.4.7 Develop a Data Management Plan

Large-scale restoration and monitoring efforts generate an enormous volume of data and information. This difficult task is made more difficult by the fact that data will be collected by a multitude of different federal and state agencies, Tribal staff, non-governmental organizations and others. The Plan should describe an integrated approach to the collection, storage and retrieval of restoration and monitoring data. **This will involve developing a plan for information management, and implementing that plan. Ideally, the data management system should unify existing systems, and coordinate storage of KEY monitoring and assessment data to support rapid feedback from monitored outcomes, data analyses, and modeling**. This system will need to be flexible to accommodate data of widely varying types (time-series, spatial, reports) and define and enforce a meta data standard that promotes coordinated analysis. Additionally, specific responsibilities for quality assurance will need to be identified, documented and practiced. The overall process will likely require **one or more dedicated individuals to act as data stewards** who ensure the necessary data are stored and quality assured. The resultant information management system would normally become the primary tool used to generate quantitative reports annually.

With respect to monitoring data, KBMP is particularly well positioned as a functioning platform with up-to-date and user-friendly web-based integration and interactive mapping (KBMP 2016; http://kbmp.net/). However, the KBMP platform emphasizes water quality information with limited data on other habitat and fish population attributes. The data management plan should leverage existing data compilations within KBMP and others. For example, Klamath Tribal Water Quality Consortium has compiled a database of Klamath Basin stream temperatures which includes more than 28 million individual measurements from more than 4,300 site-years, collected by entities including the U.S. Forest Service, Salmon River Restoration Council, Yurok Tribe Environmental Program, Yurok Tribe Fisheries Program, U.S. Fish and Wildlife Service, Karuk Tribe, Quartz Valley Indian Reservation, U.S. Bureau of Land Management, and the California Department of Fish and Wildlife.

**This element of the Plan will most likely require technology development or at the very minimum enhancement of one or more existing data management systems.** To ensure the approach is robust both over time and to varying types of data, the development of this plan would start with **defining user needs, functional requirements, meta data standards, technology standards, and consider existing data holdings and how they can be best integrated in service of Plan goals and objectives.** This initial requirements and design options stage would eventually be proceeded by implementation, deployment, training, testing and refinement of the preferred data management system (or systems). Once requirements, systems and meta data standards are clarified, it is also likely that several meta data and data formatting guideline documents should be produced and shared with restoration and monitoring practitioners to increase consistency with standards and improve quality. Figure 8-24 shows the overall structure of the Online Data Portal used for the Trinity River Restoration Program.

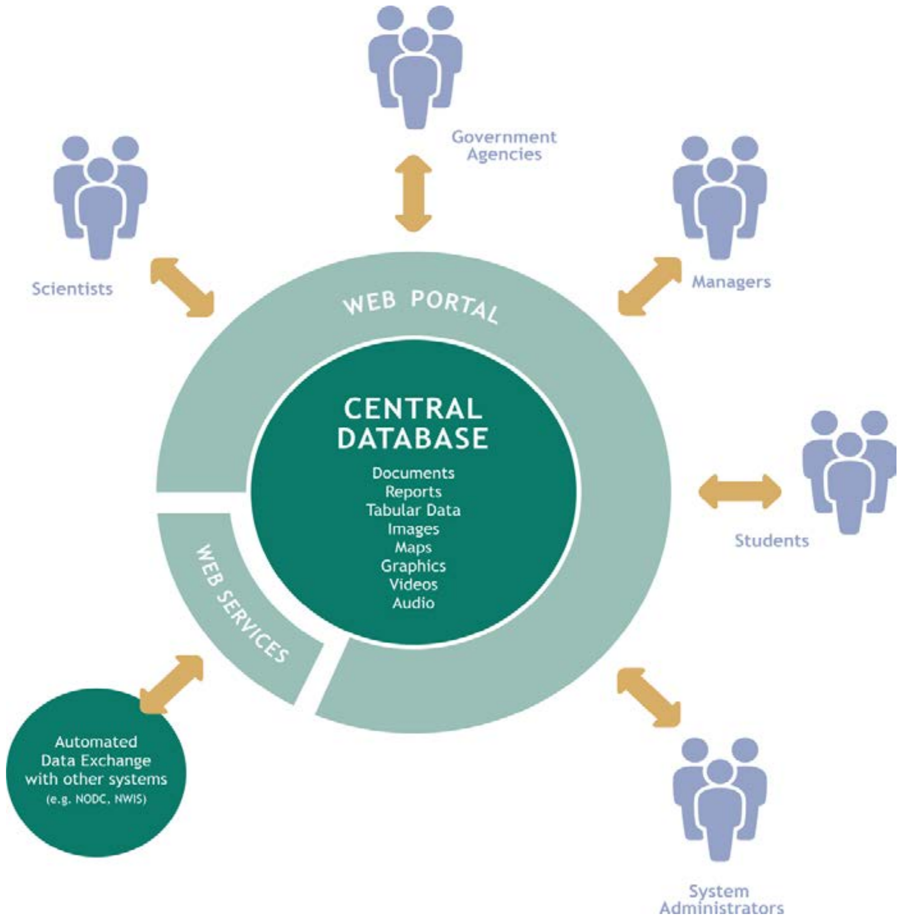


Figure 8-24: Structure of the Online Data Portal used for the Trinity River Restoration Program. Chosen (and often shifting) technology software/hardware licensing and procurement standards by some government agencies impact how much centralization is feasible.

Table 8-16 summarizes the potential main products that would be generated from this step of Plan development.

Table 8-16: Summary of potential task-process tools and techniques to generate main products for the integrated data management plan.

| Task-Process Tools | Suggested Main Product(s) |
|---|---|
| 1. User and functional requirements assessment. | User and functional requirements assessment. |
| 2. Review of existing data holdings and systems, incld. KBMP, others, starting with Synthesis. | Draft / Final Data Management Plan, with Guidelines. |
| 3. Technical meetings on design options / recommendations. | (Potential technology development, depending on findings, budget). |

### 8.4.8 Assemble Master Plan Document

The written outcomes and products from the steps above produce the final IFRMP. **This document and associated technical appendices, circulars, tools, brochures and infographics will collectively form a road map guiding integrated fisheries restoration and monitoring in the Klamath Basin**.

As described above, Plan components and chapters would be iteratively peer reviewed prior to Plan finalization.

Importantly, **it will be essential to update the full plan on a 5-yr timeframe** to avoid the Plan falling out of step with findings and priorities.

### 8.4.9 Implement Plan - Evaluate Results - Adjust

Adaptive management requires routinely evaluating results and adjusting hypotheses, conceptual models, triggers, monitoring and management decisions. This involves continuously updating and reporting action effectiveness and priorities.

As part of the IFRMP, the following activities should be considered following Plan adoption:

- **Annual adaptive management reports** to succinctly communicate learning to co-managers, decision makers and other interested participants.
- **Annual or bi-annual science symposia** to communicate learning at a more technical and scientific level.
- High level infographics, social media and other **public outreach** techniques to clearly **communicate what has been learned,** and to in turn learn from the public.

### 8.4.10 Task-Process Fundamentals

Completing the steps identified above will require an enormous *cooperative* effort, considerable input from local experts and independent peer review. Pillars to the process will be **committed executive leadership** and **impartial technical facilitation** at ***numerous*** topic meetings, workshops and symposia. Codes of conduct will likely be needed, amongst many other facilitation techniques and practices.

It will be necessary to convene a variety of **workshops and technical meetings on specific topics** (e.g., goals, objectives; conceptual models; gap identification; prioritization criteria; candidate assessments and monitoring methods; design monitoring and evaluation framework; data management plan; etc.).

There will also need to be substantial cooperation from co-managers, experts and other interested participants to review documents and **directly contribute to various writing groups**. This goes well beyond attending calls and meetings and reviewing materials written by contractors to actively contribute expertise on specific topics.

In addition to serving as lead facilitator, the contractor responsible for developing the Plan must assemble a team that is *expert* in the **practice of adaptive management** and capable of serving as the **lead scientific editor of the Plan**.

Also essential, the contractor should also have disciplinary expertise in **aquatic ecology**, **statistics** and malleable **science communication** skills. A variety of other kinds of disciplinary expertise will be required, and will be sourced from the broader community of co-managers, experts and interested participants.

As identified above, external **peer review** is another fundamental pillar in iterative Plan development. Maintaining a peer review process to ensure consistency with the direction emerging from the IFRMP is essential to both the integrity of the plan and future funding decisions.

## 8.5 Develop Governance Structure and Process in Parallel

As described in Section 8.2.2 (and Table 8-3), **it is important to distinguish technical and scientific roles and responsibilities from management roles and responsibilities**. **It is also important to have both.** “Technical” teams, work groups and independent peer review panels represent only two of the approximately five to six functional units in the example governance structures provided in Section 8.2.2. Without transparent governance and decision-making processes, it will not be possible to implement the scientific and technical advice developed for the Plan. The best scientific plans only come to fruition with good participatory, transparent systems of governance that make it clear how all interested participants, co-managers, implementing agencies, and restoration practitioners will be engaged.

### 8.5.1 Convene a Governance Forum

Prior to Plan implementation, **we recommend convening a governance forum** to hear lessons and advice from other large-scale river restoration leaders in other basins. Examples include the Missouri, Platte, Trinity, and Elwha River basins. This small expert panel would provide summary presentations and impartial advice on lessons learned in planning and conducting large-scale adaptive management efforts and assist PSMFC and cooperating partners to develop proven strategies for adaptive management governance in large-river basins. The invited panel of experts could deliver overview presentations and be guided through completing the challenge-strategy-lesson template similar to the one in Table 8-17.

Table 8-17: Challenges-and-strategies template for adaptive management in the Klamath Basin.

| Attributes of governance which can enable or inhibit AM | Challenges in establishing these attributes in the [Case Study Basin] | Strategies for overcoming these challenges | Other lessons |
|---|---|---|---|
| **Trust and commitment to AM** | | | |
| **Problem context** | | | |
| **Mindset (around uncertainty, risk, and AM)** | | | |
| **Problem definition** | | | |
| **Executive direction** | | | |
| **Leadership and vision** | | | |
| **Integration of AM into management structure** | | | |
| **Legislation** | | | |
| **Planning** | | | |
| **Communication and organizational structure** | | | |
| **Community involvement and informal networks** | | | |
| **Facilitation, bridging, and team building** | | | |
| **Knowledge generation and flow** | | | |
| **Knowledge interpretation** | | | |

Following planning and delivery of this type of governance forum, a summary report would be produced and turned over to the PSMFC who would from that point forward work with USFWS, NOAA and other cooperating partners to develop a governance structure for development and implementation. Once an agreed-upon governance structure is written down and established (various models are described in Section 8.2.2), there ought to be an opportunity for federal, state and tribal agencies, as well as NGOs and other interested participants to actively apply the processes defined in that governance structure. One of the first applications of the governance structure would be to integrate the IFRMP into the operations of member entities, and to move forward implementing the IFRMP in an annual adaptive management cycle.

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# Appendix A: List of Workshop Attendees

| Last Name | First Name | Agency |
|---|---|---|
| **Holmstrom** | Donald | BLM (Bureau of Land Management) |
| **Bean** | Caitlin | California Fish and Game |
| **Alexander** | Clint | ESSA |
| **Murray** | Carol | ESSA |
| **Porter** | Marc | ESSA |
| **Tamburello** | Natascia | ESSA |
| **Hilton** | Andrea | McBain Associates / ESSA Subcontractor |
| **Franklin** | Robert | Hoopa Valley Tribe |
| **Kautsky** | George | Hoopa Valley Tribe |
| **Orcutt** | Mike | Hoopa Valley Tribe |
| **Corum** | Susan | Karuk Tribe |
| **Soto** | Toz | Karuk Tribe |
| **Tucker** | Craig | Karuk Tribe |
| **Turner** | Randy | Klamath Basin Monitoring Program |
| **Skinner** | Megan | Klamath Tribes |
| **Swerdloff** | Stan | Klamath Tribes |
| **White** | Scott | Klamath Water Users Association |
| **Purkey** | Andrew | National Fish and Wildlife Foundation |
| **Simondet** | Jim | NMFS |
| **Williams** | Thomas (Tommy) | NOAA Fisheries Southwest Fisheries Science Centre |
| **Creager** | Clayton | North Coast Regional Water Quality Control Board |
| **Hiatt** | Mike | ODEQ (Oregon Department of Environmental Quality) |
| **Dale** | Alan R ("Chip") | Oregon Department of Fish and Wildlife |
| **Ebert** | Demian | PacifiCorp |
| **Hemstreet** | Tim | PacifiCorp |
| **Wheaton** | Chris | PSMFC |
| **Schaefer** | Sarah | Quartz Valley Indian Reservation |
| **Campbell** | Amy | Shasta Valley Resource Conservation District |
| **Garayalde** | Adriane | Shasta Valley Resource Conservation District |
| **Nielsen** | Elizabeth | Siskiyou County Resources Conservation District |
| **Wise** | Ted | State of Oregon |
| **Hendrixson** | Heather | The Nature Conservancy - Oregon Klamath Basin |
| **Lambert** | Chrysten | Trout Unlimited |
| **Watson** | Dani | UKBCA Party |
| **Bottcher** | Jared | USBR |
| **Baun** | Matt | USFWS |
| **Clarke** | Robert | USFWS |
| **Edwards** | Mike | USFWS |
| **Ericson** | Jenny | USFWS |
| **Hamilton** | John | USFWS |
| **Hetrick** | Nicholas J | USFWS |
| **Rasmussen** | Josh | USFWS |
| **Polos** | Joe | USFWS - Arcata Fish & Wildlife Office |
| **Janney** | Eric | USGS |
| **Woodson** | David | USGS |
| **Belchik** | Mike | Yurok Tribe |
| **Hillemeier** | Dave | Yurok Tribe |
| **Thaler** | Parker | State Waterboard |
| **Sinnen** | Wade | California Fish and Game |
| **Hereford** | Mark | Oregon Department of Fish and Wildlife |

| Last Name | First Name | Agency |
|---|---|---|
| **Mallory** | Karen | Shasta Valley RCD |
| **Roninger** | Robert | Klamath Falls BLM |
| **Hankin** | David | Humboldt State University |
| **Witmore** | Shari | NOAA Fisheries |
| **DiMonte Miller** | Bobbie | Klamath National Forest |
| **Gangl** | Kristen | SWRCB |
| **Moss** | Brady | California Natural Resources Agency |
| **Thome** | Darrin | USGS Pacific Region |
| **Robinson** | Crystal | Quartz Valley Indian Reservation |
| **Schenk** | Liam | USGS |
| **Conlon** | Terrence | USGS |
| **Tompkins** | Mark | Flow West |
| **Jordan** | Danny | Hoopa Valley Tribe |

# Appendix B: Synthesis of Workshop Feedback

ESSA organized and facilitated the workshop titled “Development of an Integrated Fisheries Restoration and Monitoring Plan for the Klamath Basin Project Initiation Workshop” in Yreka, CA on November 14-15, 2016. The two-day event involved 54 participants representing Tribes, County, State and Federal agencies, NGOs, and Academics. The main objectives of the workshop were to introduce ESSA as a service provider to parties with vested interests in fisheries restoration and monitoring in the Klamath Basin, and to elicit information about this subject from local experts. Participants were led through a series of exercises in which they supplied information about ideal goals and objectives for an Integrated Fisheries Restoration and Monitoring Plan (IFRMP), key stressors affecting fish populations and uncertainties related to their restoration, and information about existing projects currently underway in the basin. The following tables and figures summarize the workshop outputs. Table B-1 summarizes goals and objectives identified by participants. Strong fish populations and healthy habitat were most frequently mentioned.

Table B-1 Goals and Objectives

| Theme | Comment Frequency |
|---|---|
| Strong fish populations | 42 |
| Healthy habitat | 20 |
| High water quality | 9 |
| Effective monitoring | 7 |
| Prosperous agricultural sector | 3 |
| Cooperative relationships | 2 |
| Healthy communities and economy | 2 |

Table B-2. Identified Stressors

| | Upper Klamath | Lower Klamath |
|---|---|---|
| **Watershed Inputs (W)** | Irrigation tailwater<br>Impoundments<br>Over-grazing riparian corridor<br>Land-use<br>Invasive species (e.g., juniper)<br>Over-allocation of surface & groundwater<br>High temperatures<br>Low dissolved oxygen<br>Legacy Lake loss (Lower Klamath Lake)<br><br>Internal and external phosphorous loading<br>Marijuana cultivation<br>Drought<br>Loss of freshwater wetlands/marshes<br>Biostimulatory conditions (sediment > phosphorous > excess algae & cyanobacteria > dissolved oxygen & pH stress)<br>Climate change (warming) | High water temperatures<br>Droughts (compounded by legal and illegal water diversions)<br>Forest management (if forests were harvested in controlled manner there would be more water in streams)<br>Capture of cold spring inflow for irrigation<br>Changes in sediment input resulting from land management actions (e.g., timber harvest, road construction/density, development)<br>Drought<br>Loss of natural flow regime<br>Pesticide/chemical impacts from increasing marijuana cultivation in tributaries<br>Nutrient loading in upper basin due to loss of wetlands<br>Floods |
| **Fluvial / Geomorphic Processes (F)** | Hardened banks and no riparian vegetation<br>Low summer flows<br>Coarse sediment starvation<br>Levees/dikes<br>Disruption of sediment transport/bedload transport<br>Dams/human-made structures altering river processes<br>Straightened/widened channels<br>Human altered flow timing and intensity (e.g., controlled flow regime)<br>Conflicting interests for available flow resources<br>No connectivity with floodplains | Sedimentation (below and behind dams)<br>Channelization and diking<br>Channel simplification<br>Unregulated groundwater pumping (esp. Scott Valley)<br>Loss of off-channel & floodplain habitats/winter rearing habitat |

| | Upper Klamath | Lower Klamath |
|---|---|---|
| **Habitat Structure, Complexity, Connectivity (H)** | Unscreened diversions (Suckers & Redband Trout)<br>Migration blockages/lack of connectivity (dams)<br>Altered flow regime<br>Diminished cold/cool water habitats<br>Lack of channel complexity (large woody debris, gravel)<br>Lack of Beavers<br>Sediment terraces & reservoir beds (Copco Reservoir)<br>Thermal loading<br>Temperature<br>Low nitrous oxide<br>Lost River ("need I say more")<br>Loss of functioning riparian corridors<br>Disconnected from marine-derived nutrients<br>Diked and drained wetlands | Loss of flood plain connectivity<br>Availability of thermal and low velocity refugia for juvenile salmonids<br>Loss of riparian vegetation (solar radiation)<br>Barriers to movement from instream structures<br>Legacy impacts from mining and dredging<br>Ocean conditions/survival<br>Lack of large woody debris<br>Beaver eradication |
| **Biological Responses (B)** | Reintroduction of disease<br>High temperatures<br>pH extremes<br>Pathogenic bacteria and parasites<br>Reduced Sucker spawning populations<br>Parasite spillback<br>Invasive species (Flathead minnow; bullhead)<br>Lack of Sucker recruitment<br>Loss of anadromy<br>Cyanobacteria toxins<br>Disease (myxospore, *C. shasta*)<br>Algal blooms<br>Population isolation (bull trout)<br>Disease (Ich)<br>Elevated pathogens due to biostimulation lab conditions (irregular maturation) | Large hatcheries (poorly managed; effects on wild stocks; disease)<br>Fish screens<br>Invasive species (Brown Trout, mussels, sunfish, snails, etc.)<br>Increasing rates of Ich (*Ichthyophthirius multifiliis*) in adult spawners<br>Increased frequency of cyanotoxin blooms (due to increased nutrient loading and warm surface temperatures)<br>Low genetic diversity due to small population size<br>Excessive fishing pressure on recovering populations<br>Artificially high concentration of spawners below hatchery<br>Loss of run diversity (sub-types - Fall vs. Spring Chinook) |

Table B-2 lists the stressors workshop participants identified in the upper Klamath and lower Klamath Basins across four categories used to organize comments: Watershed Inputs; Fluvial/Geomorphic Processes; Habitat Structure/Complexity/Connectivity; and Biological Responses.

Table B-3 Identified Uncertainties

| | Upper Klamath | Lower Klamath |
|---|---|---|
| **General:** While there is good sense of what broad actions needs to be undertaken there are major uncertainties as to WHERE these restoration actions should best be undertaken (need information that can improve pathways to site selection and implementation of projects)<br>Uncertain where to direct funds/efforts to get most benefit to the system<br>Uncertain what kind and intensity of monitoring is needed to enable meaningful before-after comparisons (in anticipation of potential dam removal) that can inform concrete management actions | | |
| **Watershed Inputs (W)** | How much of a factor are watershed inputs at creating fish disease conditions?<br>What would be "ideal" conditions in this regard?<br>What actions for reducing inputs need to be emphasized/<br>What is feasible to do for reducing inputs given landowner permission/interest, time, and funding constraints?<br>What are current sediment and nutrient loads?<br>How will inputs be affected by warming and hydrological shifts that might occur with climate change? | Potential water quality data gap may occur after IMI5 money expires with surrender of dam licenses<br>Groundwater-surface water balance (data gap)<br>Key gauges have uncertain funding<br>More gauges needed (data gap)<br>Post forest-fire impacts to streams<br>Update LiDAR and add tributaries (data gap)<br>Need screening level data for chemicals from marijuana and other agriculture (data gap)<br>Impacts of grazing in key locations<br>Funding for Shasta water temperature monitoring<br>Need to monitor sediment contributions from road networks (data gap)<br>Impacts of changes of water use efficiency (Shasta)<br>Need real time groundwater monitoring (data gap)<br>Update existing thermal refugia data & mapping (data gap)<br>Evaluate changes in stream shade over time (Scott & Shasta) (data gap)<br>Need to report irrigation diversions<br>Impacts of upland fire suppression |
| **Fluvial/Geomorphic Processes (F)** | Effects of drought from possible future climate change<br>Effects from depression of geomorphically influential flows | Baseline suspended sediment supply & post-dams needed (data gap)<br>Magnitude of flows to flush infected |

| | | |
|---|---|---|
| | below Keno and elimination in reservoirs | polychaetes<br>Bed load and suspended sediment monitoring totally lacking (data gap) |
| **Habitat Structure, Complexity, Connectivity (H)** | Extent/effect of past habitat fragmentation<br>Impacts of low summer flows<br>Effects from long-term loss of marine derived nutrients<br>Effects from long-term loss of wetlands and lakeshore vegetation | Habitat availability & quality is unknown in some tributaries below dams, under reservoirs & upstream of dams<br>Recruitment (data gap)<br>Availability of large woody debris in streams (data gap) |
| **Biological Responses (B)** | What to measure to best reflect ecosystem health - e.g., populations, CPUE, individual species endpoints, whole food web (i.e., stable isotope signatures in fatty acids)?<br>How will species interact after reintroduction of anadromous fish (if dams are removed), not just in mainstem but also in tributaries?<br>How might future recruitment be affected by possible climate change impacts?<br>Effects of invasive species (yellow perch, fathead minnow, bullhead) | Steelhead abundance and trends not fully known<br>Fish monitoring needed for non-anadromous fish (e.g., sturgeon, lamprey) (data gap)<br>Ocean conditions and survival<br>Impacts of non-native predatory fish<br>Prevalence of C. Shasta<br>Fish history<br>Water quality from upstream affecting downstream fish disease (data gap)<br>Aquatic invertebrate monitoring (data gap)<br>Survival of juvenile fish from Shasta (needs funding)<br>Juvenile production estimates from Scott & Shasta (data gap)<br>Salmon River Spring Chinook juvenile life history, limiting factors |

Table B-3 lists uncertainties workshop participants identified in the upper Klamath and lower Klamath Basins across the same four categories used in Table B-2.

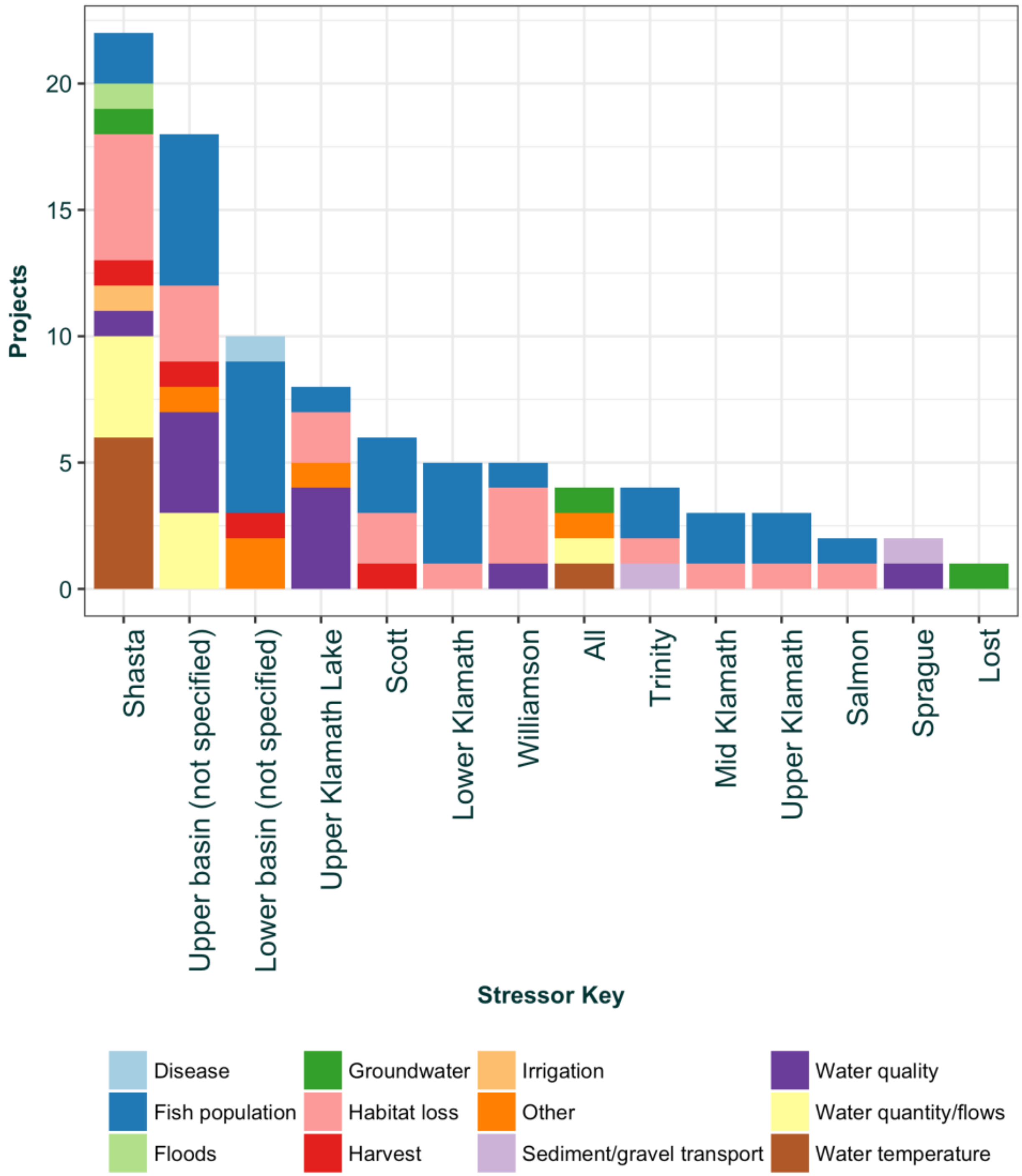


Figure B-1 Monitoring Projects by Stressor and Basin Location

Figure B-1 summarizes current monitoring projects identified by participants organized by the stressor type monitored and location in the Klamath Basin. Monitoring of fish populations, habitat and water quality were most commonly noted throughout the basin. Monitoring projects in the Shasta sub-basin were most frequently highlighted.

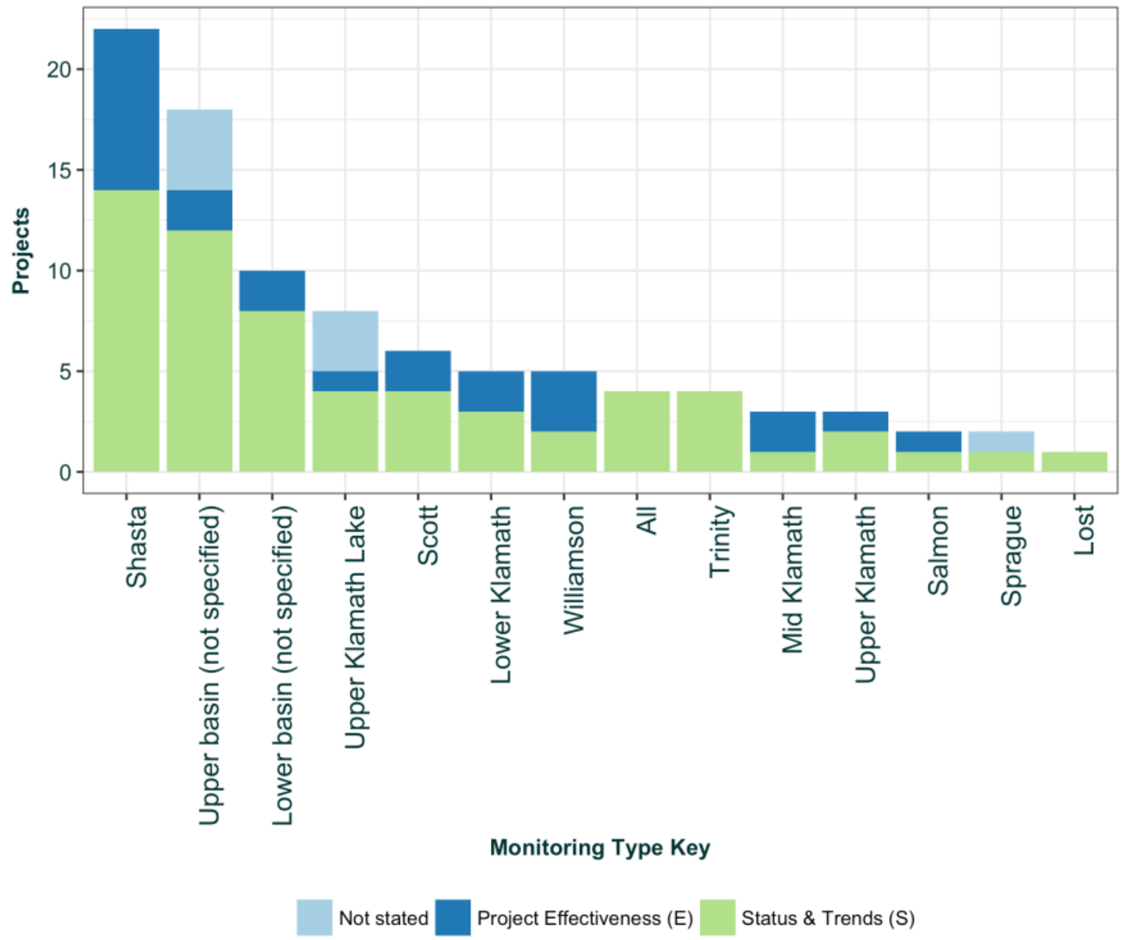


Figure B-2 Monitoring Projects by Basin Location and Monitoring Type

Figure B-2 summarizes current monitoring projects identified by participants organized by monitoring type (Project Effectiveness; Status & Trends) and location in the Klamath Basin. Status and Trend Monitoring was most frequently reported. The proportion of Project Effectiveness Monitoring to Status and Trend Monitoring was highest in the Williamson, Mid Klamath and Salmon sub-basins. The greatest numbers of monitoring projects involving both types of monitoring were reported in the Shasta sub-basin.

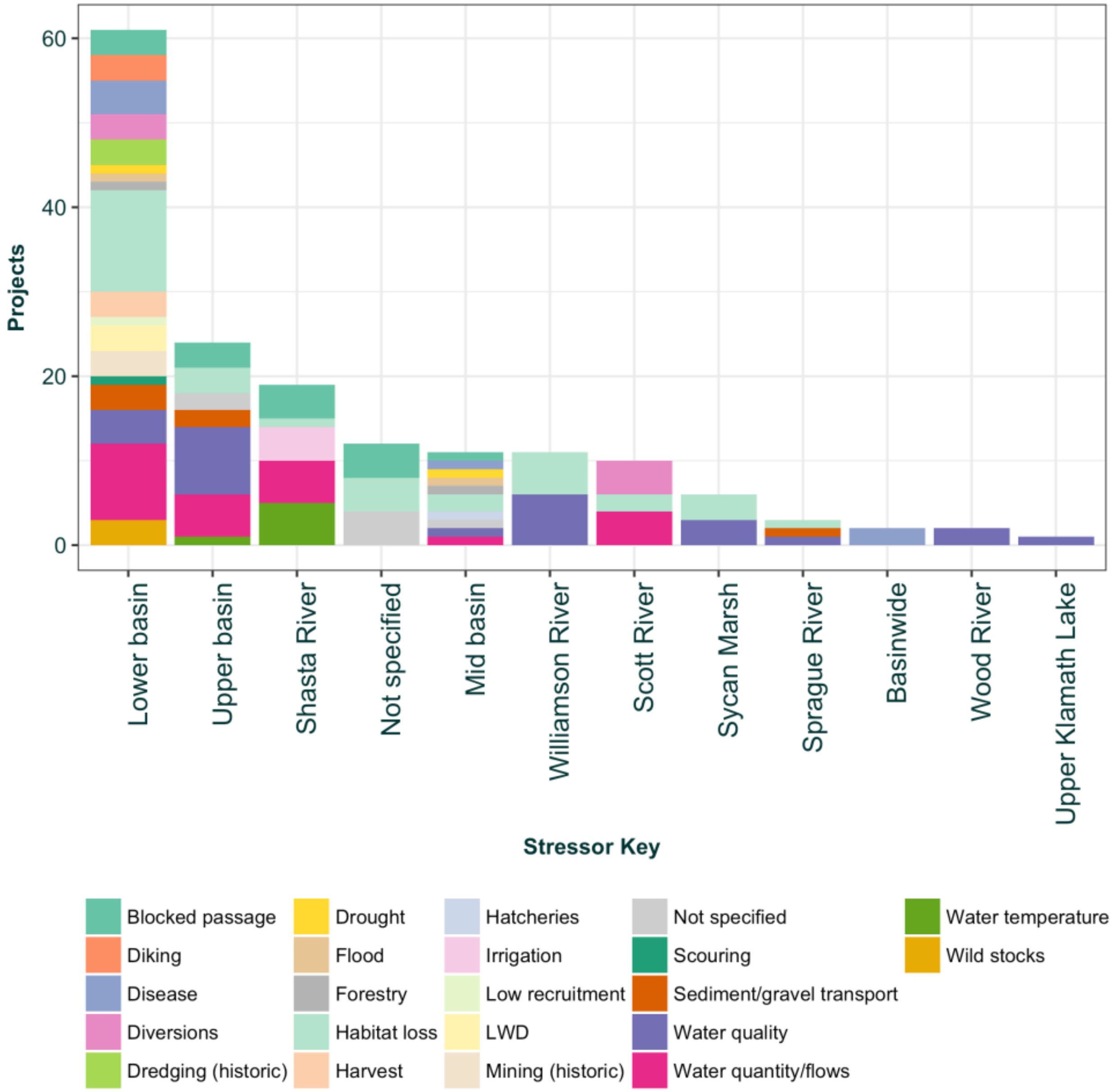


Figure B-3 Restoration Projects by Stressor and Basin Location

Figure B-3 summarizes current restoration projects identified by participants organized by the stressor type targeted and location in the Klamath Basin. Restoration of habitat, water quality and water quantity/flows are most commonly noted throughout the basin. Restoration projects in the Lower basin (general) were most frequently highlighted.

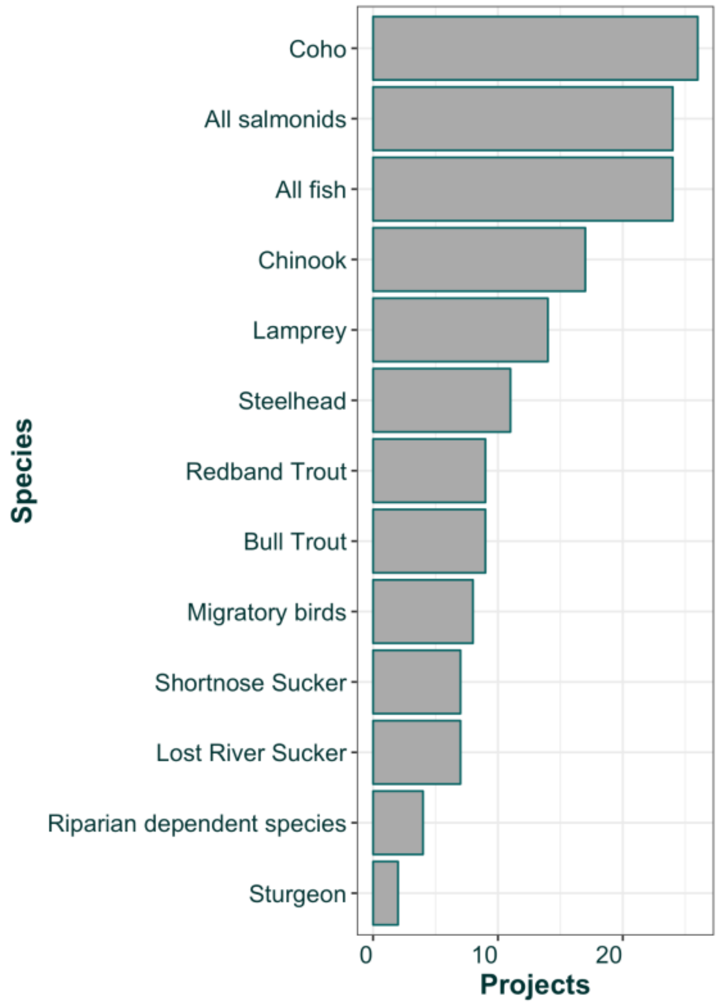


Figure B-4 Restoration Projects by Species

Figure B-4 summarizes current restoration projects identified by participants organized by species. Coho are most commonly noted while salmonids and/or fish species more generally are also frequently addressed by the projects participants identified. Note that restoration projects targeted at restoring migratory bird habitat and general riparian dependent species habitat also affect fish species and were highlighted by some participants.

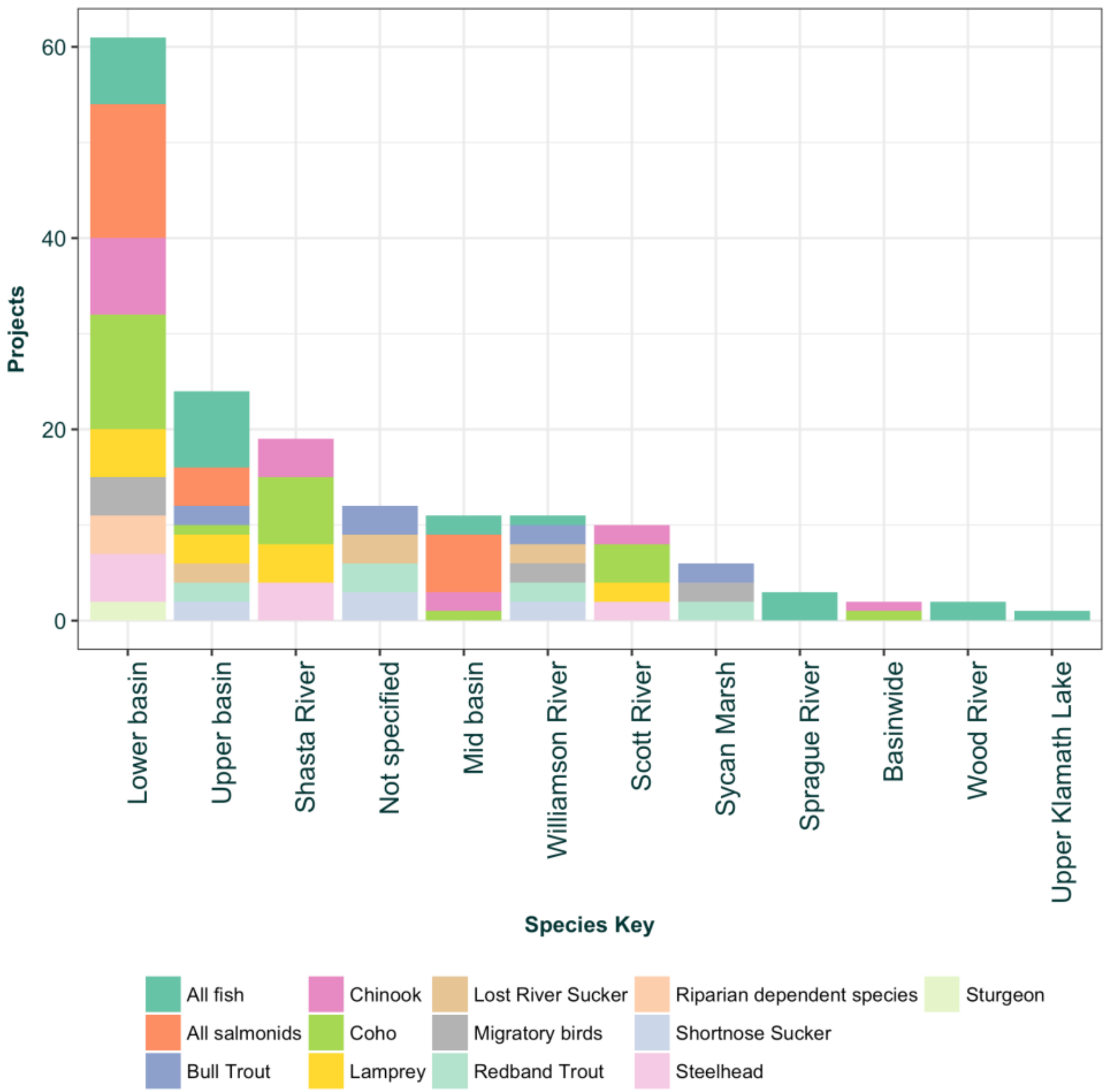


Figure B-5 Restoration Projects by Location by Species

Figure B-5 summarizes current restoration projects identified by participants organized by location and species. Participants most commonly cited projects in the Lower basin, which focus primarily on salmonids (esp. Chinook and Coho), fish generally, and lamprey. Upper basin projects were mentioned less frequently but similarly focus on Chinook, Coho and lamprey. Projects targeting restoration of Shortnose Sucker, Lost River Sucker and Redband Trout are also more frequently highlighted in the Upper basin and in the Williamson River.

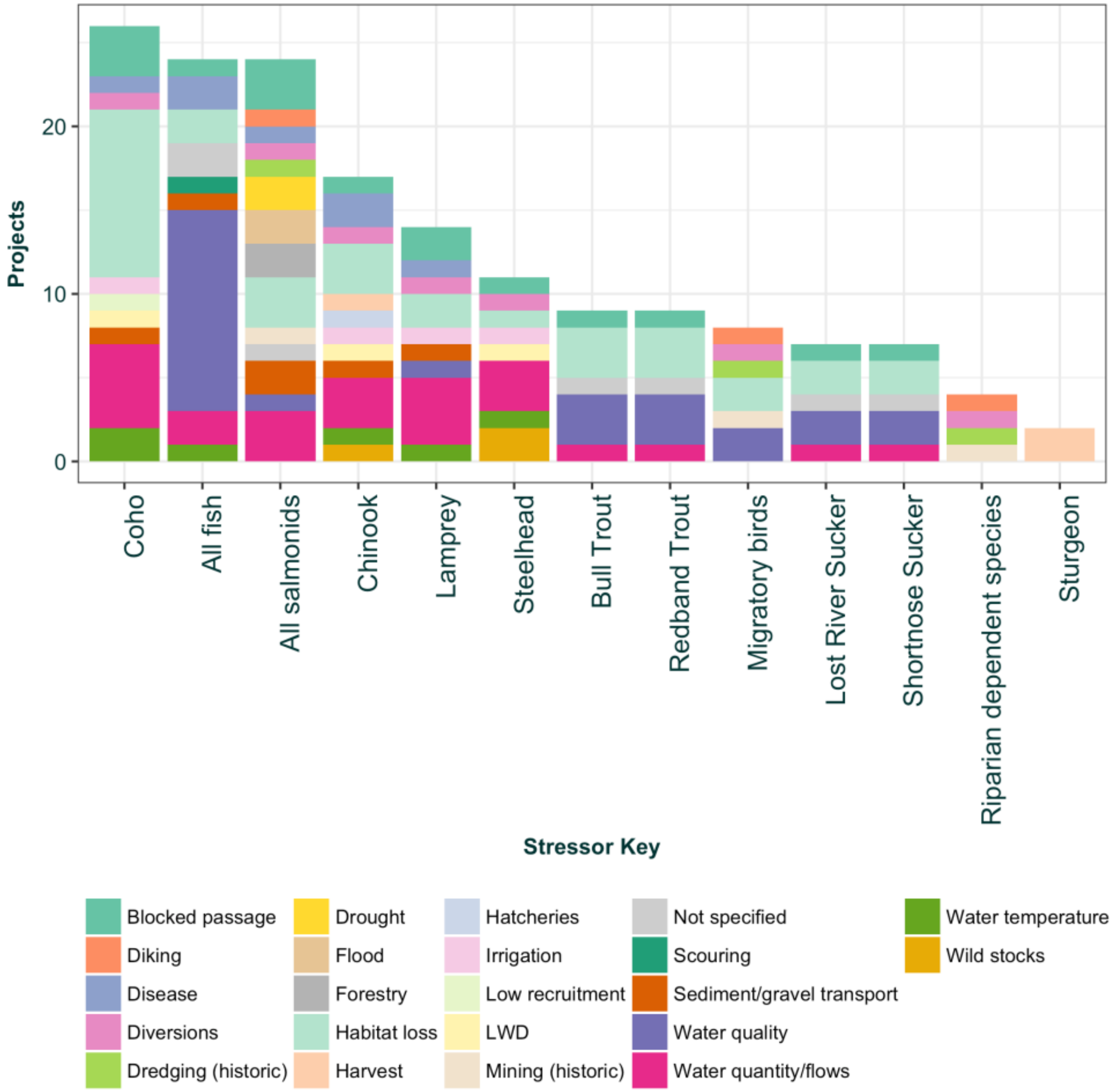


Figure B-6 Restoration Projects by Species by Stressor

Figure B-6 summarizes current restoration projects identified by participants organized by species and stressor. Projects targeting habitat loss, water quality and water quantity/flows are most commonly noted across several species. Habitat loss appears to be a particularly strong focus for Coho restoration.

# Appendix C: Interview Questions

## Integrated Fisheries Restoration and Monitoring Plan (IFRMP) for the Klamath Basin

### Project Purpose

Significant investments for improving habitat and fish populations have been made throughout the Klamath Basin for decades. Restoration work is being funded and carried out by state, federal, local and tribal partners as well as by watershed groups, private landowners, conservation organizations and other entities.

Pacific States Marine Fisheries Commission, using funding from the U.S. Fish and Wildlife Service, is helping to develop a science-based, basin-wide fisheries restoration and monitoring plan that follows the recommendations of the National Research Council (2008)[55] which found that science and restoration in the basin was being done by "bits and pieces" and concluded that there needs to be a "'big picture'" perspective encompassing the entire basin and its many components."

Toward this end, Pacific States Marine Fisheries Commission is working with ESSA Technologies to help develop the Plan for the Klamath Basin which will: 1) take a basin-scale approach to restoration and monitoring actions; 2) ensure that the best available science is used in decisions; and 3) guide the design and prioritization of monitoring and restoration work throughout the Basin within an overarching Adaptive Management framework.

As we begin the initial stage of the project, we look forward to working with a number of interested participants who can offer perspectives on conservation activities in the Basin. This includes a series of interviews with agencies and organizations involved in ongoing restoration and monitoring activities in the Klamath Basin and a technical workshop scheduled for Nov. 14 and 15 in Yreka, Calif.

The initial stage of the project is to develop a Synthesis Report that summarizes relevant past and current information, and lays the groundwork for the broader Plan. ESSA will work with PSMFC, partners and interested participants to outline and develop restoration and monitoring goals and use a collaborative process to identify logical steps to implement restoration and monitoring for the Klamath within an overall Adaptive Management approach. The initial stage of this initiative is the acquisition and synthesis of contemporary information and restoration plans developed for the Klamath Basin as well as to leverage innovative concepts taken from similar planning efforts in other basins.

[55] NRC (National Research Council). 2008. Hydrology, Ecology, and Fishes of the Klamath River Basin. Washington, DC: The National Academies Press.

## Purpose of interviews

Interviews will offer a valuable source of insight into the diverse perspectives of the broader community of agencies, tribes, stakeholders and interested parties (for general ease, hereafter "*interested participants*"). The interview results will also give us information from which to determine **alignment** on goals and objectives, and identify issues having the greatest potential to affect the success of the Plan, and insights on whether there are interested participants **not at the table**[56]. Interviews can also highlight issues that deserve special consideration due to their **strategic importance** to the Plan. In addition, participant input during interviews will complement our synthesis of literature and information, and help our team **uncover gaps** and/or areas of potential **misalignment**. More generally, first-hand information from interested participants is essential for our team to understand the **mosaic** of real **on-the-ground roles, responsibilities, needs, priorities, and issues** necessary for this project to proceed efficiently. We hope that by conducting the interviews on an 'individual' basis interested participants will feel able to speak freely when answering the questions.

## What we will do with the information

The results are primarily for the use of the ESSA team. Unless directed otherwise, we intend to use the interview responses to support our development of the **Synthesis Report**. However, we promise strict Confidentiality in respecting candid opinions or anything else you specify that you do not want shared or written in any project correspondence or deliverables.

## Interview format and time management

We are allotting 60 minutes per interview. Considerable effort will be made to interview a representative and inclusive group of agencies, tribes, cooperating partners and interested participants. Interviews will be conducted in "waves" before and after our kick-off workshop November 14/15 2016, and used to support development of the Synthesis Report. Some interviews will be by phone, others in person depending on what works best given geography and schedules. Recipients will have the option to provide answers in writing up front that we will then review during the "live" interview to further clarify and develop additional context. Having an initial written response will also allow our interview team to spend more time in meaningful dialogue rather than being overly focused on recording the discussion.

During the "live" interviews, we thank-you for governing the length of your answers to allow us to get through as many questions as possible. We realize passion to respond to certain questions may be high. To offset this challenge and ensure a level playing field, interviewees will have both the opportunity to provide input before the interview and will be encouraged to submit follow-up answers in writing if they wish to relay additional information. This approach will also help us engage other colleagues that you may invite to the in person, "live" interview. Another suggestion we may try during the "live" interview, is to consider answering initially with only the top 1-2 most important elements of your answer, in a first pass through, and then circle back to add more details. Internal note: [* = tier 1 priority question].

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[56] It is essential that our team consider input from a *representative* set of interested participants.

## The Questions

Interviewee name, affiliation:

Interviewee email, phone:

1. *What is your **role** within your organization? How many years have you worked in this role? *~And/Or~* More generally, how did you "land" in your current role?

2. * (a) What is the focus of your organization's main interests and responsibilities in relation to Klamath Fisheries Restoration and Monitoring?, and (b) What is the focus of the work that you do?

(a)

(b)

3. *With which agencies/organizations/groups/interested participants do you typically **collaborate** most closely? Why?

4. * Generally, how do you rate the **level of coordination** among the various agencies and interested participants with respect to restoration and monitoring activities in the Klamath?" Do you think an IFRMP is needed in the Klamath? Do you think it **overlaps** with other programs already underway?

5. How would you **define 'success'** for the Integrated Fisheries Restoration and Monitoring Plan? What would be the top 2-3 major "performance measures" you would consider important for determining success?

6. *From your perspective, what do you feel are the **key challenges** surrounding the PSMFC and ESSA's effort to support development of this Plan?

7. *Historically, in restoration planning to date, are there any interested participants that you feel **have not been 'at the table'** that should be engaged in a more complete way? Why have they not engaged fully?

8. *What are the **most critical decisions** that need to be made by your organization *or other organizations* that directly affect the success of Klamath Basin fisheries restoration, in (a) the short-term and (b) the long-term?

(a)

(b)

- **What do you see as the most **critical uncertainties** affecting these decisions?

- **What new science based **efforts** or analyses could help to **reduce these uncertainties**?

9. We are interested in updating the **fisheries restoration and monitoring plan outline** that some state, federal and tribal fish managers developed in 2011 as an exercise of the now-expired Klamath Basin Restoration Agreement (*see Appendix A below). While this agreement is no longer in play, **are there elements of this outline that are still relevant that should be considered? Can you share your "likes and dislikes" and if you wish, potential alternative structures?** ~OR~ Do you think there is **anything missing or out of place**?

10. *Please identify EXISTING documents/information/presentations/resources that you consider critical building blocks for ESSA's Synthesis Review and Synthesis Report. In particular, help us to uncover the latest, most accepted:
    a. conceptual models, hypotheses, critical uncertainties
    b. restoration plans
    c. monitoring plans

d. grey literature,

You may choose to highlight the most relevant EXISTING sources listed here: https://klamathrestoration.gov/ | http://www.klamathcouncil.org/

Note: We are equally interested in information sources that are NOT found on these web sites.

11. How familiar are you with the concept of Adaptive Management? Do you feel this approach will be helpful in the Klamath? Which of the critical uncertainties you identified do you feel would be most amenable to adaptive management approaches?

12. *What is your best advice to us regarding resources needed (financial, technological, political, human) — which your agency specifically can help to mobilize — to encourage success of the Plan?

## Appendix A: Proposed Outline and Approach in KBRA for Basin-wide fisheries restoration and monitoring plan

1 Fisheries Restoration Program goals
2 Conceptual model development
3 Timeframe
4 Context (Phase I and Phase II Restoration Plan, Monitoring Plan, Reintroduction Plan)
5 Spatial extent
6 Spatial scale (tributaries of tributaries, and similar-sized mainstem segments)
7 Temporal scale (short and longer-term goals)
8 Development of program metrics
   *i. Metrics will be developed across spatial scales, where appropriate, to track restoration project success and guide effectiveness monitoring*
   *ii. Metrics will be defined for monitoring to track species-specific population and habitat changes*
   *iii. Metrics will consider and integrate the four parameters for evaluating population viability status including abundance, population growth rate, genetic diversity, and spatial structure.*
9 Primary goals of the Restoration and Monitoring Plan
   *i. Define the restoration component of the plan as described in Section 10.1.2 to prioritize restoration projects (instream, riparian, and upland) that:*
      *a. Directly benefit existing fish resources*
      *b. Significantly contribute to protecting and preparing habitats for use by*

*anadromous fish after passage is restored (Phase I Restoration)*

c. *Significantly contribute to protecting and preparing habitats for utilization throughout the Basin as abundances of anadromous and nonanadromous fish increase (Phase II Restoration)*

10 Define the monitoring component of the plan as described in Section 12.2:

i. *Status and trends*
   a. *Methods for stock identification*
   b. *Collecting information to assess status and trends in sizes of fish populations and availability of their habitats and distribution, including riparian areas*
   c. *Providing information on restoration actions and for management of fisheries dependent on Klamath Basin populations*
   d. *Species will include Chinook and coho salmon, steelhead trout, resident rainbow trout, lamprey, suckers, bull trout, sturgeon, and eulachon.*

ii. *Data related to environmental water*
   a. *Collect data on water quality and quantity*
   b. *Evaluate water outcomes from implementation of Water Resources Program*
      - *Monitor Klamath River instream flows and Upper Klamath Lake water surface elevations*
   c. *Assist TAT in developing Annual Water Management Plan*
      - *Provide in-season management recommendations*

iii. *Restoration effectiveness*
   a. *Evaluated based on a priori selection of:*
      - *Representative indicators of ecosystem status*
      - *Multi-scale indicators of progress towards achieving long-term goals of the monitored restoration actions*
   b. *Used to inform adaptive management actions*

iv. *Limiting factors*
   a. *Assessments to evaluate factors limiting recovery and*
   b. *restoration of fish populations*
   c. *Used to identify measures to eliminate, reduce, or mitigate threats*
      i. *To inform restoration priorities and adaptive management actions*

11 Criteria for project selection

i. *Based on contribution to overall, Basin-scale goals and objectives*

ii. *Restoration action priorities set at Basin scale, then geographically prioritized by ecological benefit*

# Appendix D: Synthesis of Interview Responses

ESSA Interviewed 30 participants. Interview participants were identified in collaboration with the TSC and comprised a representative cross-section of key experts in specific areas of Klamath Basin management, as well as different Tribes and agencies at multiple levels of governance. Interviewees were contacted first by email or phone to arrange an interview date/time and were provided with the semi-structured interview questions in advance (see Appendix C). Interviewees were encouraged to respond to the interview questions electronically prior to the interview to ensure a timely interview process. Interviews lasted between 1 and 2.5 hours and took place either in-person or by phone and were recorded via note taking by the interviewer. Prior to submission for processing, all interview notes were reviewed for recorder accuracy by each interviewer and, where requested, by the interviewee. Interview processing involved importing electronic copies of all interview notes into NVivo software for qualitative coding and analysis. Coding followed a typical qualitative analytic approach over four stages: a) preliminary organization of text into major themes, b) categorization of text under each major theme into sub-themes, c) review and revision of major themes and sub-categories as required and, d) final tallying and analysis of results. The results are summarized below in major thematic groups with tallied sub-themes. Tallies are based on frequency of comments across all interviewees.

## Critical uncertainties and challenges to a successful IFRMP

Interview participants noted several challenges that could impact successful development and implementation of an Integrated Fisheries Restoration and Monitoring Plan in the Klamath Basin. Foremost among these was **competing priorities** across different uses of the river. These challenges were primarily expressed geographically as conflicting upper and lower basin objectives (e.g., irrigation needs in the upper basin conflicting with conservation priorities in the lower basin), politically as disagreement or potential disagreement among agencies and between Tribes, and biologically in terms of competing species' needs. Several **implementation obstacles** were also raised, including the cost and difficulties associated with implementing Adaptive Management, lack of capacity in terms of personnel, land and water use rights of irrigators and Tribes, currently unclear objectives, and poor coordination and monitoring for compliance and enforcement. **Lack of funding** was frequently mentioned and often linked to the expiration of the KBRA and associated money that was originally anticipated under that agreement. The KBRA experience, while instrumental in building the collaborative foundation that already exists in the Klamath, has clearly eroded trust in the ability to secure sufficient federal and state funds to keep all affected parties interested in negotiating (i.e., Better Alternatives to a Negotiated Agreement (BATNAs) are higher than under KBRA). Key obstacles to process success frequently cited were **lack of trust and buy-in**, negative **perceptions of other parties** and **distrust of science**. The degraded status of sections of the Klamath mainstem and/or tributaries in terms of **water quantity, quality and fish habitat** was identified as a hurdle for meeting fish restoration goals and/or prioritizing restoration and monitoring projects. Additional difficulties included **political obstacles** such as uncertainty under the new federal administration, and political differences across affected parties. Several issues with **institutional design and culture** were raised including institutional inertia/resistance to change, lack of clear leadership, lack of third party oversight and poor accountability across affected parties, lack of structured decision-making, and limited public outreach. Lastly, some interviewees viewed the sheer **complexity and diversity** of the basin in terms of scale and scope, as significant obstacles to a truly integrative and coordinated approach

Table E-1. Uncertainties and Challenges Summary

| Theme | Comment Frequency |
|---|---|
| Competing Priorities | 53 |
| Implementation Obstacles (Adaptive Management Challenges, Lack of Capacity, Land/Water Rights, Unclear Objectives, Poor Coordination & Compliance) | 46 |
| Lack of Funding | 43 |
| Lack of Trust/Buy-in; Perceptions of other Parties and/or Science | 30 |
| Degraded Water Quantity, Quality and Fish Habitat | 29 |
| Political Obstacles | 24 |
| Problematic Institutional Design/Culture | 18 |
| Complexity/Diversity of Basin (Scale & Scope) | 13 |

## Science Needed & Information Gaps

Interview participants identified areas of scientific research and information gaps that need to be addressed to facilitate a successful IFRMP. These comments fell primarily under four categories: a) **Fish population status and trends**; b) **Habitat population and trends**; c) **Hydrology status and trends**; and d) **Science synthesis and information gaps**. Under the first category, in addition to general comments about the need for better understanding of fish populations, interviewees identified disease (esp*. c. Shasta*), re-colonization, hatcheries and life histories as key components of fish population status and trends requiring more study. Comments focused on multiple species at various life stages including salmon, steelhead trout, redband trout, lamprey, sturgeon and suckers (e.g., juvenile sucker disappearance, steelhead returns, lack of steelhead data, general lack of baseline/current state data).

Under the second category, general science needs included understanding the effects of stream temperature changes on different species, responses in stream quality due to habitat restoration and the effects of dam removal (e.g., downstream sediment loading, native plants, riparian areas). Both freshwater and marine habitats were emphasized, with the former focusing on water quantity, quality, the role of wetlands and identification of instream flow needs across multiple species, and the latter focusing on general ocean conditions such as cyclical climate patterns like El Nino and sea temperatures. Interviewees identified a need to assess limiting factors for fish productivity such fish passage barriers in tributaries, and general causes and locations of mortality.

For **hydrology status and trends**, interviewees commented on the need for a better understanding of the complex hydrology in the upper basin, as well as further study into the expected impacts of climate change. Participants emphasized the importance of studying surface/groundwater interactions and the lack of information about impacts of these interactions on fish species.

Many interviewees viewed **information gaps** and a lack of **science synthesis** (e.g., census of existing efforts, current status of fish populations, etc.) as significant obstacles to a truly integrative and coordinated approach. As noted above, most comments about missing information focused on uncertain fish data/science, habitat changes (freshwater and marine), and hydrologic change. Some individuals indicated a need for new and/or updated monitoring methods including genetic-based tagging and eDNA, systematic redd sampling techniques for each species, basin-wide PIT tagging, integration of LiDAR remote sensing data into existing mapping information, and application of adaptive management experiments. Others discussed the need for a common platform for tracking and scoring restoration efforts in order to effectively prioritize and coordinate these efforts. Some participants expressed a desire for third party review and independent advisory roles in the synthesis of existing science. A need to communicate collated information to the public was also raised.

Table E-2. Science Needed & Information Gaps

| Theme | Comment Frequency |
|---|---|
| Fish population status & trends | 42 |
| Habitat status & trends | 43 |
| Hydrology status & trends | 11 |
| Science synthesis & Information gaps (general) | 18 |

## Critical decisions needed

Many interviewees expressed the need for pre-requisite decisions to be made before effective planning and implementation of an IFRMP can proceed in the Klamath Basin. Foremost among these was **funding priorities** for specific governance, restoration and monitoring needs. Other frequently cited decisions included **flow allocation**, **governance structure and leadership**, **dam removal** (including PacifiCorp FERC application), **harvest and escapement targets for fish**, application of **Tribal rights** (esp. Klamath Tribe implementation of water rights), **scientific models and approaches**, and the degree of emphasis placed on **wild versus hatchery** raised fish. Inclusion/non-inclusion of the Trinity sub-basin was also raised as a key decision point.

Table E-3. Critical Decisions Summary

| Theme | Comment Frequency |
|---|---|
| Funding priorities | 51 |
| Pre-requisite decisions (general) | 19 |
| Flow allocation | 15 |
| Governance structure & leadership | 14 |
| Dam removal | 12 |
| Fish Targets (incl. harvest, escapement) | 7 |
| Application of Tribal rights | 7 |

| | |
|---|---|
| Scientific models and approaches | 4 |
| Wild vs. hatchery | 2 |

## Opportunities for success

Interview participants identified several opportunities for change that could help ensure the success of the Klamath IFRMP. Most frequently expressed was a desire to avoid re-inventing the wheel by harnessing and coordinating **existing resources and initiatives**. One example is the potential to capitalize on synergies between fish restoration and wildfowl habitat restoration. Other comments involved **available solutions to competing priorities** such as alternative dispute resolution mechanisms, different funding models (e.g., reduced lending rates for landowners who agree to participate in restoration and monitoring), communicating the potential for a reduced “regulatory cloud” for farmers if fish populations recover, and consideration of a hatchery-free system. Some interviewees emphasized the potential to utilize the existing cooperative foundation and **built relationships** resulting from the KBRA process to further coordinate and focus future efforts. Others commented on opportunities **for new research and management** approaches post-dam removal and the possibility of third party **involvement from outside the basin** as a positive step toward success.

Table E-4. Opportunities Summary

| Theme | Comment Frequency |
|---|---|
| Existing Resources & Initiatives | 9 |
| Available Solutions to Competing Priorities | 5 |
| Coordination and Focused Efforts | 4 |
| Built Relationships | 3 |
| New Research and Management Opportunities (post dam removal) | 3 |
| Involvement from Outside Basin | 2 |

## Representation and participation

Interviews revealed that a general perception of inclusiveness exists throughout the basin and that where representation is lacking it has less to do with opportunities to be involved than with principled decisions to forego participation. Regardless, participants felt that broad representation during any IFRMP process would be critical to its success. Many felt irrigators and landowners are underrepresented and need incentives to get involved, as do counties and county-based river basin groups. Some indicated that scientists and NGOs were missing from the table and others highlighted a lack of Tribal representation and/or power imbalances related to these affected groups. For example, some Tribal groups have limited resources/capacity to participate.

Table E-5. Participation Summary

| Theme | Comment Frequency |
|---|---|
| Participation/representation is critical to success | 13 |
| Irrigators & landowners (increase participation) | 12 |
| Scientists and NGOs (missing) | 12 |
| Counties (missing) | 10 |
| Participation/representation is sufficient | 5 |
| Lack of capacity | 3 |
| Imbalanced | 2 |
| Tribes (missing, power imbalance) | 2 |

## Indicators of success

Interview participants identified a number of success indicators related to IFRMP process and outcomes. Process indicators included the application of **rigorous and adaptive science**, a need for **buy-in, impartiality** and **basin-wide coordination** across multiple interested parties, securing of **adequate funds** and identification of the most **efficient uses** for those funds, the use of a **time-bound** approach that is phased, feasible and long-term, and development of **clear goals and performance measures** with those responsible held **clearly accountable**. **Political feasibility** and **public engagement** were also identified. Opinions differed about whether to apply “hard” or “flexible” metrics as indicators. For example, some felt that fixed indicators such as “increase coho populations by *x* amount” are more effective, while others felt that the failure of these types of indicators in other basins precluded their use and that more flexible metrics such as percent change or direction of change could be used. In terms of implementation outcomes, the most obvious indicator for many participants was **increased harvest and healthy fish populations**. Other indicators included successful **restoration of habitat**, **improved information about fish health**, **improved water quality** and **removal of dams**.

Table E-6. Success Indicators Summary

| Theme | Comment Frequency |
|---|---|
| **Process** | |
| Rigorous & adaptive science | 32 |
| Buy-in | 21 |
| Basin-wide coordination | 19 |
| Adequate funds and efficient use | 8 |
| Time bound (phased, feasible, long-term) | 7 |
| Implementation | 7 |
| Clear goals & performance measures | 6 |
| Accountability & enforcement | 7 |
| Political feasibility | 4 |
| Public engagement | 3 |
| Impartial planning process | 3 |

| Theme | Comment Frequency |
|---|---|
| **Outcomes** | |
| Increased harvest & healthy fish populations | 32 |
| Restoration of habitat | 13 |
| Hard vs. flexible metrics (debate) | 13 |
| Improved information about fish health | 12 |
| Improved water quality | 4 |
| Removal of dams | 2 |

# Appendix E: Public Review Comments and Responses

The Public Review Draft of this Synthesis Report was distributed for public commentary. We have addressed comments received and include the record of our responses in the table below. We have reproduced here only substantive comments and responses, and do not include comments requesting trivial changes such as corrections to spelling or grammar. The page and line numbers cited for each comment and response refer to the position of the original comments in the Public Review Draft version of this document, which is still available for download from the link below in order to cross-reference these comments.

Public Review Draft Download Link: http://kbifrm.psmfc.org/wp-content/uploads/2017/05/Klamath_Synthesis_PublicRevDraft_FINAL_Locked.docx

### Overarching Master Response on Water Quality Issues Referred to in Comment-Response Table

| Code | Overarching comment | Master Response |
|---|---|---|
| **MR-1** | The Plan is focused on fish; is fish centric, but water quality and other aspects of the ecosystem are important. The document needs to be more explicit about what is in and what is out with respect to water quality. | The general organizing framework presented in the Synthesis Report (Figure 3-1) takes an ecosystem approach, whereby various watershed inputs (e.g., water, sediment, large woody debris, nutrients) are considered to drive fluvial geomorphic processes (e.g., sediment transport/deposition/scour, channel migration, bank erosion, floodplain development) that determine physical geomorphic attributes and the structure and complexity of habitats in the basin. In addition to habitat quantity and structure (presence of migration barriers, distribution and characteristics of in-channel habitat, riparian habitat, wetlands, etc.), water quality (water temperature, dissolved oxygen, un-ionized ammonia, pH, turbidity, microcystin and other fish toxins) is one of the many important attributes of habitat quality for fish populations. Combined, habitat quantity and quality will in turn drive biological responses and are important determinants of fish abundance, distribution, and community composition. Stressors on any of the key inputs or processes at different levels of the hierarchy (Figure 3-1) could consequently affect fish populations either directly or indirectly. For example, stressors could act directly on fish populations (e.g., a disease that kills fish, etc.) or impacts from particular stressors could be indirect, with effects on biological responses cascading down from higher levels in the hierarchy and different stressors acting cumulatively at multiple levels in the hierarchy.<br><br>The Klamath River is currently listed as a Clean Water Act (CWA) impaired waterway (on the “303(d)” list) in both California and Oregon due to water temperature, sedimentation, pH, organic enrichment/low dissolved oxygen, nutrients, ammonia, chlorophyll-a, and microcystin (an algal toxin). Readers are encouraged to review Section 3.2.3 which provides an excellent overview of the current understanding of pathways in which nutrients and contaminants alter water quality and contribute to stress and mortality of various fish populations. Indeed, the words “water quality” appear over 380 times in the Synthesis Report. The Synthesis also summarizes the role of TMDLs (Total Maximum Daily Loads (see section 2.4) in setting allowable limits on the amount of phosphorus and other nutrients entering waterways of the Klamath Basin to improve water quality for a variety of purposes, including (but not limited to) fish. While the river does not meet CWA criteria for a number of fisheries-related beneficial uses, there are also numerous other beneficial uses related to human health, aesthetics, cultural, agricultural, commercial, water supply, navigation, recharge, and recreation that are considered to be impaired for the Klamath River (USDI, USDC, NMFS 2013). It is recognized and we respect that these impairments represent a variety of other parallel concerns that are critically important for agencies, Tribes and stakeholders in the Klamath Basin. However, water quality issues and other elements that are not directly related to having important effects on fish abundance, distribution, health, and community composition are beyond the scope of the Integrated Fisheries Restoration and Monitoring Plan (the Plan).<br><br>The Plan aims to use best-science and an adaptive management mindset for objectively articulating basin-wide fisheries restoration needs, with monitoring and restoration efforts within the Plan directed at key biological and physical factors that heavily influence fish populations (e.g., flow conditions, bedload and sediment, transport, water quality, water temperature fish disease, toxic algal blooms, etc.). The Plan does not provide a comprehensive review of all policy positions, nor does it evaluate how to balance all relevant beneficial uses and socio-economic objectives. Instead, the Plan will focus on developing a robust and broad set of ecosystem restoration and monitoring needs for the Klamath Basin using a representative set of focal fish species in a manner that considers stressors acting over all life-history stages, through a multitude of physio-chemical trophic cause-effect impact pathways, and at many locations. In summary, the whole of ecosystem processes and components within the Klamath Basin, including water quality and other attributes, is in scope for evaluation within the Plan but only insofar as they have important influences on the priority Plan focal species. |

## Remainder of Comments and Responses

| Organization | Section | Page and Line | Comment | Draft Response |
|---|---|---|---|---|
| PSMFC | Executive Summary | General | This document might be helpful;<br><br>https://www.fws.gov/arcata/fisheries/reports/tamwg/2015/2015_12/5%20Legislative%20and%20Administrative%20History%20of%20TRRP%20fishery%20Restoration%20Goals%20Working%20Draft.pdf<br><br>I suggest responding to Robert Franklin's Trinity-Hoopa comment by adding a reference to one or more of the statutes (perhaps the 1996 revision?) in that paragraph in the final draft. | Document added to the library. Reviewed for content. |
| KBMP | Executive Summary | Pg xviii | 2para of restoration: several State agencies: NCRWQCB is a key player as well and should be mentioned by name. | Revised as requested. |
| North Coast Regional Water Quality Control Board | Executive Summary | Pg xviii | Bottom para: (within CDFW, but independent). - Please add California North Coast Regional Water Quality Control Board to this list. We have funded numerous riparian restoration projects, small impoundment removal, tailwater return flow improvements, wetland restoration, treatment wetland construction, etc. | Revised as requested. |
| North Coast Regional Water Quality Control Board | Executive Summary | Pg xviii | First restoration para, last sentence: I seriously question the veracity of this statement: habitat in most tributaries remains severely degraded, pollutant and temperature levels are extremely high throughout the basin, and flow conditions remain critical in many key tributaries. We have accomplished less than 10% of the necessary restoration work that needs to be completed to provide supporting conditions. | This has been revised to the following statement to temper language, as in the original section 6.1 from which it originates: "The many decades of restoration efforts in the Klamath Basin have made great strides gradual progress towards restoring watershed function and fish populations in many waterways (Kier Associates 1999), and have set the stage for the substantial work that still lies ahead. " |
| **North Coast Regional Water Quality Control Board** | Executive Summary | Pg xxiii | Para 1: sentence ending in: migrate past the dams: This key principle limits the necessary scope of the plan to fish passage and habitat improvements. It does not mention the larger principle, which has been stated many times by participants, of watershed health, water quality, and flows. | Two paragraphs added to Executive Summary to clarify the ecosystem approach that is being taken, and help clarify the scope of the Plan (vs. other parallel efforts). Also, please see MR-1. |
| **PacifiCorp** | Executive Summary | Pg xxiii | Para 1: This would be determined in a FERC-managed relicensing process if such an event were to occur. The extent of fish passage requirements would be determined in that process. | Agreed that FERC would manage this process and decision. Our interpretation of the sum total of literature on the matter is that if dam removal were not to proceed, the quantity and character of enhanced fish passage infrastructure improvements that would need to be updated and introduced to provide the same benefits would need to be -- extensive. |
| **PacifiCorp** | Executive Summary | Pg xxiii | Para 2: This implies that the Klamath no longer is the third largest producer of salmon on the west coast when it probably remains so. If it's fallen to #4 or some other value, then the text should reflect that. This should also take into account the other 'H's': Harvest, hatcheries and habitat. While hydropower and agricultural development have had effects, the decline of the fishery cannot be laid entirely at the feet of hydropower or agriculture. These specific numbers require a citation to the relevant technical documents from which these estimates were derived. | We have revised the paragraph in question to provide appropriate level of breadth re: the multitude of human factors that have contributed to population declines. We attempted to confirm the historic vs. present "rank order" of the Klamath Basin as a salmon producer, but did not have current information for all Northeast Pacific population hubs (Alaska, Skeena, Fraser River, Columbia River, Oregon-Northern California-Klamath, Sacramento River). We therefore focused on the severe magnitude of declines relative to historic conditions removing "third largest". |
| **USFWS** | Executive Summary | Pg xxiii | The Klamath River Basin of south central Oregon and northern California once boasted the third-most productive salmon runs on the U.S. Pacific Coast. | We have corrected the contradiction. |

| Organization | Section | Page and Line | Comment | Draft Response |
|---|---|---|---|---|
| | | | This statement contradicts the following on the next page. | |
| **KBMP** | Executive Summary | Pg xxiii | Para 1: This is a bit too focused since as we've seen in multiple years (2002 adult fish kill, juvenile die off in recent years, and annual near zero DO conditions in Keno), water quality is also a key underpinning issue related to fish recovery. The list above doesn't even cover the regular sub-lethal stressors water quality impairments can cause to fish in the mainstem and some tributaries as well that should be considered part of any fisheries recovery plan. | Please refer to MR-1. |
| **KBMP** | Executive Summary | Pg xxiii | Para 2: These declines - Suckers? % decline? | We have revised the paragraph in question to provide appropriate level of breadth re: the multitude of human factors that have contributed to population declines. |
| North Coast Regional Water Quality Control Board | Executive Summary | Pg xxiv | Bottom of page: diversions for "irrigated" agriculture, | Appreciate the comment and have modified the text here accordingly. |
| **USFWS** | Executive Summary | Pg xxiv | The Klamath is the third largest producer of salmon | We attempted to confirm the historic vs. present "rank order" of the Klamath Basin as a salmon producer, but did not have current information for all Northeast Pacific population hubs (Alaska, Skeena, Fraser River, Columbia River, Oregon-Northern California-Klamath, Sacramento River). We therefore focused on the severe magnitude of declines relative to historic conditions removing "third largest". |
| CDFW - Northern Region | Executive Summary | Pg xxvii | Second para: Delta Smelt: Long-fin smelt? Thought to be extinct in the Klamath River. | Several authors have identified this mistake. There are references to Delta smelt in the Basin in the literature but we assume they must be erroneous. We have removed any listing of Delta smelt in the report. |
| Quartz Valley Indian Reservation | Executive Summary | Pg xxviii | The North Coast Regional Water Quality Control Board and Oregon Department of Environmental Quality should be added to The list of state agencies and programs involved in restoration.<br>Page xxix: restoration categories should include nutrient reduction | Revised to indicate that this is encompassed under "water quality restoration". |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | Executive Summary | Pg xxx | The 15 major monitoring programs should include water quality if it does not already. | Changed text to: "…monitor habitat (including water quality),…". |
| Hoopa Tribal Fisheries | 1 | General | We applaud the inclusion of "integrated basin-scale fisheries restoration goals and objectives" at #1 under section 1.1. Throughout negotiation of KBRA, the Tribe held that the establishment of quantitative fisheries restoration goals was an indispensable element of any agreement. The balance of these sections are well written, and we appreciate your discussion of Trinity River Restoration Program AEAM and its relationship to the basin-wide effort.<br><br>The Document Library you have created (which I've not had time to visit) strikes us as having great potential; it has been difficult to locate information from across the various political and geographic boundaries. Reclamation's impacts on the Trinity side are not described as they should be - hard for a reader to appreciate the scale of influence that Trinity River Division of Central Valley Project has had on Basin fisheries. | Kudos. No action required. |
| PacifiCorp | 1 | Pg 16: L 35 | Where are these flows supposed to come from? | The question referenced ("• What hydrologic conditions will exist at the time of dam removal and during the following 1-5 years? This will have important effects on the concentrations of suspended sediment") referring to a candidate list of key uncertainties. Additional information on management actions, conceptual models and linkages and interactions will be elicited in future stages of Plan development. |

| Organization | Section | Page and Line | Comment | Draft Response |
|---|---|---|---|---|
| California State Wildlife Agency | 1 | Pg 17: L 13 | page 17: line 13: Commercial fisheries were curtailed in the KMZ due to new tribal sharing agreements, Most commercial fisheries still operate south of here and have impacts on Klamath fish, additionally Yurok tribal fisheries have had recent commercial fisheries. The Klamath basin experienced the largest contemporary run of over 320,000 fall Chinook in 2012. Need to temper this comment with cyclical nature of stock size.<br>page22: line 21: This should be specific to Trinity Hatchery. Iron Gate Hatchery is owned by PacifiCorp and is solely operated by the CDFW. | Revised to provide the suggested clarifications. |
| USFWS | 1 | Pg 11: Figure 1-2 | page 11 Figure 1-2 I'm just curious why the Link River Dam is referred to as a "diversion" when that isn't typically the convention. Also, the symbol for Harpold reservoir should be in the river, not where it is. | Revised as suggested |
| Karuk Tribe DNR | 1 | Pg 22: L 31 | I was not aware the Hoopa actively co-manages Iron Gate Hatchery-please address if for correct | Sentence revised to read: "HVT also actively co-manages the hatchery on the Trinity River." |
| Hoopa Tribal Fisheries | 1 | Pg 22: L 5 | Description of the role of the Hoopa Valley Tribe in fisheries management. We feel it is of fundamental importance to describe the Tribe's unique co-management jurisdiction regarding the Trinity River Restoration Program; the Tribe enjoys a federally-legislated concurrence authority alongside Department of Interior. The Tribe stands alone in this relationship to federal authorities. | |
| PacifiCorp | 1 | Pg 24: L 22 | This seems a bit disjointed given the California funding support for dam removal. | The statement in question is: "The Interior Secretary was required to make this decision after the completion of numerous scientific, economic, and engineering studies, and a public Environmental Impact Statement/Report (EIS/R) process under the National Environmental Policy Act (NEPA) (USDI et al. 2012). The KHSA was at risk of being terminated after the KBRA expired in December 31 2015 because KHSA was originally non-severable and linked to the KBRA."<br><br>Revised to read:<br><br>"The Interior Secretary was required to make this decision after the completion of numerous scientific, economic, and engineering studies, and a public Environmental Impact Statement/Report (EIS/R) process under the National Environmental Policy Act (NEPA) (USDI et al. 2012). When signed in 2010, the KBRA and KHSA were linked together as companion agreements, considered to be non-severable from each other. When KBRA expired in December 2015, however, the future of the KHSA was uncertain. " |
| Klamath Tribes | 1 | Pg 25: L 27 | "To address this..." This seems premature- just last week we had a meeting with ODFW to discuss this and there are several options on the table. For instance, depending on migration timing of volitionally recolonizing and/or actively reintroduced Chinook and Steelhead stocks, water quality may be sufficient for adult migration (but not for any other life history stage) and trap and haul wouldn't be necessary. As such, I'm not sure this statement is appropriate right now; it may lead people to believe there is no way salmonids can migrate through those waterbodies, which is not necessarily what the most current research (or expert opinion) is showing. I understand that this may have been called for in the KBRA and you want to include it for that reason, but at a minimum, make a note that it is what was thought about at the time and may not be in line with the latest thinking. Ted Wise is a good contact for more info. | We tempered the language with reference to life stages and inserted wording related to this being a hypothesis and one of several proposals (vs. a concrete statement). |
| US Geological Survey, Oregon Water Science | 1 | Pg 3: Table 1-1 | We will need a more detailed description of which water quality or ecosystem functions are considered relevant to this plan and which aren't. | Point noted, please refer to MR-1. Development of specific water quality, ecosystem and other key performance indicators are intended to be developed in future stages of Plan development, but are beyond the |

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| Center | | | | scope of the Synthesis Report (Task 1.1). Regarding ecosystem functions, focal species of restoration are described in section 4.3. |
| PacifiCorp | 1 | Pg 30: L 8 | page 30: line 8: I believe the proposed action also included implementation of the KBRA. Incorporation of the KBRA into the overall proposed action helped to offset some of the impacts of dam removal on its own.<br>page 30:line 18: I would recommend that this statement be altered to reflect the miles of stream that would be accessible. The actual suitability of many of those areas to support anadromous fish has not been rigorously evaluated.<br>page 31:line 3: It is not clear what the habitat quality of currently inundated portions of the river will be following dam removal, thus it cannot be said that this habitat of unknown quality is critically important.<br>page 31: line 6: These benefits would also have been realized with the fish passage alternatives presented in USDI 2012.<br>page 31: line 17: Those algal toxins produced in Keno and Upper Klamath Lake would continue to be released into the river though.<br>page 31: line 20: Newer research has cast some doubt onto this conclusion. It is unlikely that carcass distribution would alter the spore loading. Using research done by USFWS and others on disease loading in individual carcasses and spore loading in Bogus Creek indicated that about 7% of carcasses were responsible for 76-95% if the spore loading in a given year (Foote et al. 2016). Given this information, it takes relatively few fish to completely 'seed' a stream with spores, thereby infecting polychaetes and furthering the disease cycle. So spreading carcasses out would not necessarily dilute the spore loading in any given location.<br>J. S. Foott, R. Stone, R. Fogerty, K. True, A. Bolick, J. L. Bartholomew, S. L. Hallett, G. R. Buckles & J. D. Alexander. 2016. Production of Ceratonova shasta Myxospores from Salmon Carcasses: Carcass Removal Is Not a Viable Management Option, Journal of Aquatic Animal Health, 28:2, 75-84, DOI: 10.1080/08997659.2015.1103803<br>page 32: line 15: Modeling indicated an 80 percent increase under NO HARVEST conditions. As nobody intends to remove dams and then not harvest fish, it is misleading to the public to point to this as a potential outcome of dam removal. Further, similar modeling was not conducted of the fish passage alternatives.<br>page 32: line 17: These numbers are misleading and reflect DOI's assessment and not PacifiCorp's. One cannot simply compare costs to determine economic superiority. While dam removal under the KHSA presents less costs to PacifiCorp, it also provides no benefits in terms of generation, which relicensing would. | For points of clarification (e.g, 80% improvement if no harvesting) we made those revisions.<br><br>For items that point out alternative/competing hypotheses re: cause effect mechanisms, we included these in summary form consistent with the fact that we are not attempting in the Synthesis Report to arbitrate one hypothesis or conceptual model over another.<br><br>Suggested missing references are added to the literature cited in the report, and to our Document Library. |
| North Coast Regional Water Quality Control Board | 1 | Pg 4: L 38 | page 4: line 38: and water quality<br>page 10: line 30: on modifications word: loss of wetlands, increase in nutrient and sediment inputs, impacts to riparian and channel structure, and diversions leading to reduced flows……<br>TMDL references would make this more complete.<br><br>page 32: line 1: These water quality improvements are now the focus of the nine approved TMDLs throughout the basin. | Revised to provide the suggested clarifications. |
| PacifiCorp | 1 | Pg 4:L 30 | page 4: line 30: While PacifiCorp releases water from Iron Gate into the Klamath River, the minimum flows target and ramp rates are all essentially determined by the National Marine Fisheries Service, which sets those requirements in Reclamation's BiOp. The text should note that Klamath River flows are essentially dictated either by mother nature or by federal agencies.<br>page 11: line 12: Technically Keno Dam was the final facility built with completion in 1967.<br>page 11: line 22: Technically water elevations in Keno are set by an operating agreement between PacifiCorp and Reclamation. This agreement is incorporated into the license (Article 38).<br>page 13: line 19: PacifiCorp was not a signatory to the KHSA.<br>page 14: line 30: This should be a "will", as Upper Klamath Lake/Keno reach water quality impairment will not be | For points of clarification (e.g, actual date of Keno Dam completion 1967; dam removal plan prepared by Reclamation and contractors, etc.) revisions made.<br><br>For items that point out alternative/competing hypotheses re: cause effect mechanisms, we will include these in summary form consistent with the fact that we are not attempting in the Synthesis Report to arbitrate one hypothesis or conceptual model over another. |

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| | | | addressed by dam removal, and nutrient impairment in the Klamath River downstream of Iron Gate dam will be exacerbated by Klamath dam removal since the hydroelectric reservoirs are a net sink of nutrients.<br>page 15: line 10: PacifiCorp did not develop this removal plan. It was prepared by Reclamation and its contractors.<br>page 16: line 25: The other upside down portion of the system is the fact that the nutrient loading is highest and water quality the poorest in the upper basin. These two conditions gradually improve as water moves downstream which is the opposite of most river system.<br>page 17: line 8: Coho salmon are not believed to have been historically present upstream of Spencer Creek (downstream of Keno dam) (Hamilton et al. 2005). Thus, it is speculative that coho would utilize upstream habitat of poor quality since they are not thought to have colonized upstream when habitat and water quality conditions were more favorable. Hamilton, J.B, G.L. Curtis, S.M. SNedaker, and D.K. White. 2005. Distribution of anadromous fishes in the Upper Klamath Watershed prior to hydropower dams – A synthesis of the historical evidence. Fisheries, Vol 30, no 4. pp 10-20<br>page 17:line 26: Other uncertainties include potential water quality impacts in the river and estuary of increased Klamath River nutrient concentrations following dam removal.<br>page24: line 18: This was really a collective decision by all the signatories to the KHSA, not just PacifiCorp. In pursuing the KHSA, PacifiCorp is not pursuing dam removal as an end, but rather a fair outcome for its customers to resolve the pending relicensing proceeding. | |
| Klamath Tribes | 1 | Pg 5: Table 1-3 | page 5: table 1-3: Mike Hiatt is an employee of the Oregon Department of Environmental Quality<br>page 6: table 1-4: Siskiyou County Board of Supervisors - Why is this listed twice?<br>page 6: table 1-4: US Bureau of Internal Affairs - This department doesn't exist. Maybe you meant US Bureau of Indian Affairs?<br>page 7: US Forest Service: Why is this listed so many times?<br>page 7: The Nature Conservancy: I thought you interviewed someone from TNC's CA office?<br>page 7: California Trout: Listed twice, with different x's<br>page 7: Academia - first one - I think this is a typo, probably remove.<br>page 10: line 25, whole para: I would mention sucker here too. So far, someone unfamiliar with the Upper Klamath Basin would think suckers weren't a critical component of how the river is managed and that their recovery isn't a priority.<br>page 10: line 41: This is the first mention of suckers and may be confusing/out of context for some readers since there isn't any previous information in the this section about this issue.<br>page 11: line 3 - As of March... This is out of context and implies that runs have been declining steadily since the fish kill. I don't think this is necessarily true and I recommend providing some context (i.e., fall-run CHK are at record low numbers in many west coast rivers, likely due to a sustained El Nino event over the last several years resulting in the warm water "blob" in the Pacific and subsequent declines in salmon prey). Obviously, factors inherent to the Klamath affect the run size too, but this statement is an oversimplification.<br>Figure 1-3: Aren't B and C photos of Glines Canyon Dam? I didn't think Elwha Dam was in such a canyon… Plus, Lake Mills was the reservoir behind Glines Canyon, not Elwha.<br>Page 17: line 39: Define acronym before using<br>Page 18: line 23: Include scientific names since this is the first time these species are specifically mentioned.<br>Page 22: line 22: Should be "Tribes'" since it's plural.<br>Page 25: line 25: That's not really it. Much of the water is reaerated in the Link River; DO issues in Lake Ewauna and Keno Reservoir are really related to decomposition of the massive algal biomass load coming out of Upper Klamath Lake. Also, the Klamath Straits Drain, Lost River, and other conveyance systems from the Irrigation Project have a substantial effect on temp and DO in this section of the river. Jacob Kann is a good contact for more info. | For points of clarification these revisions were made / tempering or qualifying statements.<br><br>For items that point out alternative/competing hypotheses re: cause effect mechanisms, we included these in summary form consistent with the fact that we are not attempting in the Synthesis Report to arbitrate one hypothesis or conceptual model over another.<br><br>The location names for photos in Figure 1-3 were reviewed.<br><br>The suggested additional interviews with other knowledgeable staff and experts will be noted and held to future stages in Plan development. |

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| Salmon River Restoration Council | 1 | Pg 7 | Although the Salmon River Restoration Council is listed as having been invited to the November 2016 workshop, we were unaware of the workshop until the night before when a USFS colleague mentioned it. We were unable to attend at the late notice and hadn't received to our knowledge an invitation. We also do not re-call further outreach after the November workshop nor an interview. We would very much have liked to be included in this process as the lead restoration group within the Salmon River watershed and participants in the Klamath dam settlement process and signatories to the agreements from the very beginning. We have been working with managing agencies, local Tribes and partners on assessing, monitoring, and restoring the Salmon River watershed for 25 years and are leading the extensive efforts at subbasin wide floodplain and mine tailing assessments and restoration on the Salmon River.<br>We also did not receive notification of this document and the review deadline until the last minute, making it hard to give it a proper review and make adequate in depth comments. | Apologies for the late notification. We will ensure Karuna and the Salmon River Restoration Council are added to our master contact list so the Salmon River Restoration Council is aware of future Plan development steps over the next 2-3 years. (We have also removed the erroneous "X" from Table 1-4 regarding having interviewed the Salmon River Restoration Council). |
| The Nature Conservancy- CA | 1 | Pg 7: Table 1-4 | Very few ag focused groups on this list. Disappointing to not see a larger representation of the ag community at least invited to attend (for Scott/Shasta). | A guiding principle behind the development of the IFRMP is "4. Use a broadly inclusive, transparent process involving representatives of all interested participants, with peer review." Please forward contact information to ESSA so additional groups/individuals can be included in subsequent phases of this process |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 1 | Pg 9 | Comment actually pertains to the Document Library, but there was no space on the web comment form for the Document Library so we are placing the comment here where it is referenced in Section 1. The version of the Stanford et al. 2011 report that is in the Document Library, and the citation info (missing Asarian as author), is not the final version. Please replace the draft version with the final version. The final version is included as a chapter within Thorsteinson et al. 2011. | Added to library. |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 1 | Pg 9 | Much important literature is missing from the document library- this includes many Tribal reports on Klamath River dynamics on the Klamath Tribal Water Quality Consortium website: http://www.klamathwaterquality.com/documents.html. | Website added to library. |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 1 | Pg 9 | In addition, the pertinent document: Klamath River Pollutant Reduction Workshop- Information packet is not included (nor many references cited within that document which provide essential background information not currently covered in the IRRMP). We would like to see the information contained in this document fully integrated into the IRRMP.Full citation: Stillwater Sciences, Riverbend Sciences, Aquatic Ecosystem Sciences, Atkins, Tetra Tech, ,NSI/Biohabitats, Jones & Trimiew Design (2012). Klamath River Pollutant reduction Workshop- Information packet. Prepared for California State Coastal Conservancy, Oakland, California. http://www.stillwatersci.com/resources/KlamWQ_InfoPack.pdf | Added to library. |
| KBMP | 1 | | No comments | N/A |
| USFWS | 1 | Pg. 11: Figure 1-2 | I'm just curious why the Link River Dam is referred to as a "diversion" when that isn't typically the convention. Also, the symbol for Harpold reservoir should be in the river, not where it is. | Revised as suggested. |
| Bureau of Land Management - Klamath Falls Resource Area | 2 | Pg 112 | 2.4 Sub-Basin Profiles -Consider adding BLM managed Wood River and Wood River Wetland restoration projects as significant in this sub-basin. Re-check Threatened fish species in this sub-basin, we believe Warner sucker; Hutton Springs tui chub; Foskett speckled dace are only in Lake County. | Revised as suggested. |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 2 | Pg 34 | the Wood River draining the Wood River Valley is omitted and is a 4th major tributary draining the basin above UKL. See Walker et al. 2012. | Revised as suggested. |
| North Coast Regional Water | 2 | Pg 34: L 16 | Is it worth making the point that while the Klamath Basin is composed of many subbasins that the species have evolved using the entire basin as a single unified ecosystem? For example, the tributaries provide refugia during | Added text: "These boundaries are used in this report primarily to facilitate synthesis and should not be misinterpreted as indicating |

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| Quality Control Board | | | critical life stages for several species when the mainstem river itself is less than optima. | separated or self-contained ecosystems. The subbasins in the Klamath comprise a single unified ecosystem. Many species have evolved to utilize some or all of these subbasins. For example, a region and its tributaries may provide refugia for fish while another (e.g. the mainstem sections) has sub-optimal conditions. " |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 2 | Pg 35 | The map excludes the Wood River. The Wood is very important in terms of land use, nutrient load, and inflow quantity to UKL. | |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 2 | Pg 35: L 11 - 12 | Change “Creeks in the lower basin commonly dry up during summer low-flow conditions (Voight and Gale 1998) …” to “Some creeks in the lower basin have dry alluvial reaches during summer low-flow conditions (Voight and Gale 1998)” | Revised as suggested. |
| CDFW - Northern Region | 2 | Pg 35: L 15-16 | Shasta River is spring fed and while the Scott is alluvial there is zero base flow in the valley due to groundwater pumping among other things. | Revised as suggested. |
| CDFW - Northern Region | 2 | Pg 35: L 16-18 | In the recent past, the Scott and the Shasta Rivers have reached base-flows of only 5 cfs at the confluence with the Klamath. Not too much contribution to lower basin during the dry months. | Revised as suggested. |
| CDFW - Northern Region | 2 | Pg 35: L 18-19 | This isn't accurate if the comment is specific to the Shasta and the Scott. Both of these watersheds have a temperature TMDL. | Revised as suggested. |
| USFWS | 2 | Pg 36: L22-23 | When the city of Klamath Falls and the unincorporated area of Altamont adjacent to KFalls are combined the population is closer to 40,000. https://en.wikipedia.org/wiki/Altamont,_Oregon | Revised text: "The City of Klamath Falls and the adjacent unincorporated area of Altamont form the largest population center in the upper basin (pop. ~40,000) (Census Bureau 2012). " |
| CDFW - Northern Region | 2 | Pg 36: L 16 | I know what you mean but, as you mentioned previously, there is a Quartz Valley Reservation. | Revised as suggested. |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 2 | Pg 36: L 38 | This sentence “In contrast to the upper basin, dense redwood forests characterize the lower basin (NMFS 2015)” is misleading and not supported by the reference. Suggested replacement: “Vegetation in the lower basin includes some conifers also found in the upper basin (ponderosa pine, Douglas, grand, and white fir) as well as hardwoods such as madrone and oaks, with redwoods and other temperature rainforest conifers near the coast (Thorsteinson et al. 2011).” | Revised as suggested. |
| CDFW - Northern Region | 2 | Pg 36: L 40 | Don't forget Cascade-Siskiyou National Monument | Revised Upper Klamath River subbasin profile; Revised the map. |
| Klamath Tribes | 2 | Pg 37: L 17 | The Klamath Tribes do not currently have a reservation, but do have treaty rights within the former (1954) reservation boundary. | Revised as suggested |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 2 | Pg 37: L 17-20 | The two sentences beginning with “Seven Tribes…” need revision. The designations of tribal lands are complicated, and may be incorrectly described. It is not necessary to differentiate reservations vs. non-reservations. Also, the “(USGS, USDI 2011)” citation is not included in the references list. Suggested revision: “The Klamath Basin is home to six federally-recognized tribes: The Klamath Tribes, Hoopa Valley Tribe, Yurok Tribe, Karuk Tribe, Quartz Valley Indian Reservation, and Resighini Rancheria. In addition, the Shasta Nation is not federally recognized.” Note: similar sentences also exist in the executive summary and need revision. | Revised as suggested (including in exec summary). Missing reference removed. |
| North Coast Regional Water Quality Control Board | 2 | Pg 37: L 18 | In the Exec summary the Yurok and Quartz Valley were combined (no comma) and here it is stated that Quartz Valley has no reservation. Which is correct? | Revised as suggested. |
| USFWS | 2 | Pg 37: L 7 | The basin historically produced large runs of steelhead, Chinook salmon, coho salmon, green sturgeon, eulachon, coastal cutthroat trout and Pacific lamprey and remains the third largest producer of salmon in the lower United | No change required in Section 2. Revised exec summary to refer to the contiguous US. |

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| | | | States (NMFS 2015). Relates back to comments on page xxiii and xxiv and Page 10, line 10. [Comments p. xxiii The Klamath River Basin of south central Oregon and northern California once boasted the third-most productive salmon runs on the U.S. Pacific Coast .<br>This statement contradicts the following on the next page.; p. xxiv The Klamath is the third largest producer of salmon] | |
| Hoopa Tribal Fisheries | 2 | Pg 38: Figure 2-2 | The town of Hoopa should appear on this map, in the center of the gray-shaded square (Hoopa Valley Indian Reservation) just north of Willow Creek | Revised as suggested. |
| USFWS | 2 | Pg 40: Figure 2-3 | 1-The label for Link River is in no man's land. It isn't really identifying the actual feature. 2- The city in CA is spelled Tulelake (one word) instead of Tule Lake as listed. 3- The Tule Lake NWR has two labels, one of which is pointing to ag lands. It should point to the lake. 4- Lower Klamath Lake NWR label is pointing to Tule Lake NWR. The line should point to the west under the label for Lost River, which I believe is mis-colored as intensive agriculture. | |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 2 | Pg 41 | Sub-basin profiles. Consider adding the NMFS 2014 coho recovery plan to Environmental Plans in Upper/Middle/Lower Klamath, Trinity, South Fork Trinity, Salmon, Scott, and Shasta profiles. | Revised as suggested. |
| Klamath Tribes | 2 | Pg 42 | Williamson figure: ODEQ Upper Klamath and Lost River Subbasins Total Maximum - This isn't the correct title. The most recent TMDL is the Upper Klamath Lake Drainage TMDL. | Revised as suggested. |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 2 | Pg 42 | Williamson River profile:<br>- D.O. and pH of Upper Klamath TMDL (ODEQ 2002) does not include the Williamson River (just Sprague). Therefore, this phrase should be deleted: "low dissolved O2 and high pH in perennial streams" | Revised as suggested. |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 2 | Pg 42 | Williamson River profile:<br>- Unclear what this phrase in Other Stressors box means: "…possible nutrient loading and phytoplankton interactions…" Please re-word. Phosphorus from the Williamson River and other tribs exacerbates phytoplankton blooms within UKL, but primary production is Williamson River is primarily benthic (i.e., algae and plants attached to the riverbed) not free-floating phytoplankton. | Deleted. |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 2 | Pg 42 | Williamson River profile:<br>- As currently worded, readers are likely to misinterpret this sentence: "Largest tributary to Upper Klamath Lake (50% of inflow)" Most of flow in Williamson River comes from Sprague River, which enters the Williamson a short distance upstream from the Upper Klamath Lake. Walker et al. 2012 says Sprague is 29% of UKL inflow, and Williamson (excluding Sprague) is 20% of UKL inflow. Suggested revision is to replace the sentence with: "Williamson River is largest tributary to Upper Klamath Lake (50% of inflow, the majority from the Sprague River)." | Revised as suggested. |
| River Design Group | 2 | Pg 42 | Check the Williamson, Sprague, Lost and UKL summary boxes, Warner sucker, Foskett speckled dace, and Hutton Springs tui chub are included in both. These species are actually in the Warner Lakes Basin to the east. Under the Sprague summary, remove Winter Ridge as a settlement. Winter Ridge is adjacent to Summer Lake. | Revised as suggested. |
| Klamath Tribes | 2 | Pg 43 | same comment as above | Revised as suggested. |
| Klamath Tribes | 2 | Pg 44 | Klamath Tribes Wetland and Aquatic Resources Program Plan - Doesn't apply to Lost River- this plan only focuses on areas within the 1954 reservation, which does not include the Lost River. | Revised as suggested. |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 2 | Pg 45 | Upper Klamath Lake profile:<br>- "high nutrient loads; ~39% external phosphorous loading from agriculture/livestock; ~61% internal loading during summer from sediments" should be revised to read: "~39% of the external load on an annual basis is from anthropogenic sources such as agriculture, livestock, and related erosion; sediment recycling of previously loaded external phosphorus during summer months accounts for 61% of the load entering the lake on an annual basis." | Revised as suggested. |
| Quartz Valley | 2 | Pg 45 | Upper Klamath Lake profile: | Revised as suggested. |

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| Indian Reservation/Karuk Tribe DNR | | | - Another environmental plan is the Revised Recovery Plan for the Lost River Sucker and Shortnose Sucker. https://www.fws.gov/klamathfallsfwo/suckers/sucker_news/FinalRevLRS-SNSRecvPln/FINAL%20Revised%20LRS%20SNS%20Recovery%20Plan.pdf | |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 2 | Pg 46 | Upper Klamath River profile Unique Characteristics box:<br>- Unclear what "California and Oregon Total Maximum Daily Load impairment listings are in progress for Lake Ewanna/Keno (2016)" means. | Deleted. |
| CDFW - Northern Region | 2 | Pg 47 | SHASTA: Unique Characteristcis: • Uppermost tributary in the lower Klamath Basin - Wouldn't that be Bogus Creek? | Revised text: "Uppermost of the major tributaries in the lower Klamath Basin". |
| The Nature Conservancy- CA | 2 | Pg 47 | Shasta Table: "Other Stressors"= high nutrient levels? The Shasta is naturally high in N and P (at spring sources) which lead to aquatic macrophyte growth and support a large food web for fish. Curious what the nutrient stressor is mentioned? "Spring Inflow" isn't the stressor, it's diversion of these cold springs that it the stressor. Aluminum and Mercury? May want to double check that- maybe a relic from the Scott or perhaps this is specific to only certain section in the Shasta (Yreka Creek)? | Revised as suggested. |
| Salmon River Restoration Council | 2 | Pg 49 | Salmon River Threatened Fish should include: coho salmon; green sturgeon, Pacific lamprey, spring Chinook, (fresh water muscle - not exactly a fish) | Revised. |
| Salmon River Restoration Council | 2 | Pg 50 | The Salmon River has an active TMDL and is listed for temperature impairment. Under TMDL's established in this table it is listed as N/A, this is incorrect. | Revised as suggested. |
| USFWS | 2 | Pg 50 | Unique Characteristics •Second largest tributary after Trinity The Scott is listed as Second largest tributary on preceding page | Removed sentence in Shasta profile. |
| USFWS | 2 | Pg 51 | Unique Characteristics •Up to 40% of downstream migrant juvenile Chinook have died in this section before reaching the ocean This needs context. 40% historically? 40% annually due to disease? | Changed text to: "• High salmon mortality can occur in this section (see stressors)". |
| USFWS | 2 | Pg 52 | Unique Characteristics •Up to 40% of downstream migrant juvenile Chinook have died in this section before reaching the ocean This needs context. 40% historically? 40% annually due to disease? | Changed text to: "• High salmon mortality can occur in this section (see stressors)". |
| The Nature Conservancy- CA | 2 | | Wide alluvial valleys in the central portions that produce groundwater supplies similar to those of the upper basin (The alluvial valleys in the watershed do not support the springs/ie groundwater supplies. It's the fractured volcanics which drive the hydrology. | Revised as suggested. |
| Salmon River Restoration Council | 2 | | Under Characteristics: • Also supports spawning populations of fall Chinook, steelhead trout, green sturgeon and Pacific lamprey (spring Chinook and coho should be added to this list of spawning populations)<br>Other stressors should also include: excessive sediment load from historic hydraulic mining causing bed coarsening, and lack of LWD and in-stream structure leading to poor bed load sorting and a lack of suitable spawning gravels | Revised as suggested. |
| Salmon River Restoration Council | 2 | | Environmental Plans: Should include - Salmon River Subbasin Restoration Strategy and the Salmon River Spring Chinook Recovery Plan | Revised as suggested. |
| Salmon River Restoration Council | 2 | | The IFRMP should identify the federally recognized tribes in this section. | Revised as suggested. |
| Quartz Valley Indian Reservation | 3 | General | General comments on this section. We are not sure where in the doc this should go (perhaps page 68?), but the synthesis report currently does not cite... a number of recent, major summaries of middle/lower Klamath River and reservoir water quality dynamics (i.e., nutrients, ecosystem metabolism, periphyton, and phytoplankton). Key references to that should be added are available at the Consortium's website: http://www.klamathwaterquality.com/documents.html) | Appreciate the comment. We have endeavored to improve the comprehensiveness of this section by incorporating information from the recent Klamath water quality reports available from the Consortium. |

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| Salmon River Restoration Council | 3 | General | The Iron Gate hatchery facility tried to hold spring-run Chinook for several years following the hatcheries installation, but the water was not cold enough to sustain them. The Iron Gate Hatchery abandoned its' spring-run Chinook program by the mid -1970"s and since has not grown any spring-run Chinook salmon at this facility. | Appreciate the additional information. Have adjusted the text for this section to better reflect the historical and current status of IGH spring Chinook production. |
| PacifiCorp | 3 | P 67: L 38 | As noted above, mining as a key economic driver in the basin is no longer the case. | Appreciate the comment. In this section we feel mining is correctly represented as a historical stressor in the basin. Comment more applicable for intro section where an adjustment will be made. |
| North Coast Regional Water Quality Control Board | 3 | Pg 57: Figure 3-1 | Recommend revising first bullet under Habitat Structure, Complexity, Connectivity: Instream aquatic habitat / water quality | Appreciate the comment but the general framework we are presenting represents water quality elements (e.g., sediment, nutrients, chemical pollutants, temperature) more explicitly at the levels above in the hierarchy (watershed inputs and fluvial geomorphic attributes. Water quality then feeds into the mix of integrated elements that represent conditions for instream aquatic habitat for fish (as represented at the third level of the hierarchy. We feel it would be confusing to identify water quality specifically at this level. |
| USFWS | 3 | Pg 59: L 3 | The Link River Dam more accurately regulates the lake levels of the previously existing Upper Klamath Lake. | Appreciate the comment. Have adjusted the text for this section to more accurately reflect that Link River Dam regulated Upper Klamath Lake water levels |
| USFWS | 3 | Pg 59: L 9 | This statement may have some inaccuracies. The Link River and Keno Dams do make diversions possible that do affect the water supply in both the river and the lake. You probably meant the 4 Hydroelectric dams, but that wasn't explicit. | Appreciate the comment. Have adjusted the text for this section to more accurately reflect water management impacts across the dams/reservoirs |
| Quartz Valley Indian Reservation | 3 | Pg 59: L 9-10 | This statement "The dams do not affect annual volumetric water supply or availability to the Klamath River and Upper Klamath Lake (USBR 2011)" is not exactly correct. The reservoirs increase surface area of open water, which increases evapotranspiration. Peak summer ET of Iron Gate and Copco is up to 20 cfs (see Asarian et al. 2009: http://www.klamathwaterquality.com/documents/asarian_et_al_2009_Cop_IG_Budget_may05dec07_report.pdf). We suggest adding "Other than slightly increasing evapotranspiration, " to the beginning of the sentence. | Appreciate the comment. We have adjusted text for this section accordingly. |
| Quartz Valley Indian Reservation | 3 | Pg 60 | A major change in hydrology pre-1913 was in the operation of UKL and associated lake elevations. See figure C-32 in Stillwater 2012 | Appreciate the comment. Recognize that the data represented by the pre-1913 hydrograph is not pristine historical conditions, but it does represent conditions prior to the major dams and full development of irrigated agriculture. Given the lack of gauge data prior to 1904 the description here from the Secretarial Determination would seem to represent the best obtainable depiction of a pre-dam era hydrograph for the Basin. |
| Hoopa Tribal Fisheries | 3 | Pg 60 | Lengthy description of regulatory flows into and from the Klamath Project. You are aware that the Tribe successfully sued the federal government in early 2017, resulting in a court ordered re-consultation of the Biological Opinion and overwinter flow management below Iron Gate Dam. An update on these matters is needed. | Supporting information in regard to the recent BiOp adjustments have been obtained from Robert Franklin and have been used to update the text on flow management in this section. |
| CDFW - Northern Region | 3 | Pg 63: L 23 | Dwinnel Dam is a channel spanning irrigation dam at river mile ?? on the mainstem Shasta River. The dam blocks access to an estimated 22% of the watershed. Due to the 1932 adjudication, the only water that the MWCD is required to release at baseflow is for priority water rights downstream. | Thanks for this information. We have added it to the descriptions within this section. |
| California State Wildlife Agency | 3 | Pg 63: L 5 | There is now a Record of Decision in place for these flows and criteria See BOR website | We have updated this section to include information on the new ROD management prescriptions for Trinity flows for reducing downstream disease. |
| KBMP | 3 | Pg 64: L 41 | An additional cyanobacteria species, Microcystis aeruginosa is also prominent at times, typically later in the season following the Aphanizomenon bloom. Microcystis blooms are significant in other ways since they can produce toxins which can impact public and environmental health. See Stillwater Sciences, 2013 for more details. . | Impacts from Microcystis aeruginosa are discussed subsequently in this section. |
| Quartz Valley | 3 | Pg 66 | Add reference to Walker et al 2016 and Ciotti et al. 2010 showing relationship of land use to nutrient loading in the | Appreciate the comment. Have updated this section with the information |

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| Indian Reservation | | | Sprague and Wood River valleys:<br>- Walker, J. D., J. Kann, and W.W. Walker. 2015. Spatial and temporal nutrient loading dynamics in the Sprague River Basin, Oregon. Prepared by Aquatic Ecosystem Sciences, J. D. Walker, and W. W. Walker for the Klamath Tribes Natural Resources Depart. | from the recent references provided. |
| PacifiCorp | 3 | Pg 66: L 18 | These cooling effects also likely provide a benefit in reduced fish disease incidence that is not noted here. | Appreciate the comment. We don't feel that element fits into this section's description. This element of cooling benefits in relation to helping with disease is captured later in the report in the section on fish disease. |
| PacifiCorp | 3 | Pg 66: L 20 | Modeling indicates that by the time the water reaches the Shasta River (at River Mile 177) about 20 miles downstream of Iron Gate, temperatures are driven by atmospheric conditions, not releases from Iron Gate. This statement makes it sound like all the temperature issues in the Klamath are driven by project reservoirs. | Appreciate the comment. We have adjusted the text in this section to make it more clear that the dam effects are only part of the overall water temperature story, and downstream effects form the dam will diminish. |
| Quartz Valley Indian Reservation | 3 | Pg 66: L 24 | Add reference for degraded water quality linked to fish health: Kann, J. and Smith, V.H. (1999). Estimating the probability of exceeding elevated pH values critical to fish populations in a hypereutrophic lake. Canadian Journal of Fisheries and Aquatic Sciences 56(12): 2262-2270. | Appreciate the comment. Have updated this section with the information from the reference provided. |
| USFWS | 3 | Pg 66: L 33 | Klamath Project discharges are all below Upper Klamath Lake – it's other ag discharges above the lake that aren't part of the project. | Appreciate the comment. Have adjusted the text for this section to more accurately potential discharge sources above Upper Klamath Lake. |
| PacifiCorp | 3 | Pg 66: L 9 | The reservoirs are also net nutrient sinks. See Asarian, E. J. Kann, and W. Walker, 2009. Multi-year Nutrient Budget Dynamics for Iron Gate and Copco Reservoirs, California. Prepared by Riverbend Sciences, Kier Associates, Aquatic Ecosystem Sciences, and William Walker for the Karuk Tribe Department of Natural Resources, Orleans, CA. 55pp + appendices. | Appreciate the comment. We have provided additional text to better reflect this element. |
| Quartz Valley Indian Reservation | 3 | Pg 67: L 24-25 | The statement "For example, large blooms of M. aeruginosa cyanobacteria regularly occur during summer months in Copco 1 and Iron Gate reservoirs" should have a primary reference. We suggest: Asarian, E. and J. Kann. 2011. Phytoplankton and Nutrient Dynamics in Iron Gate and Copco Reservoirs 2005-2010. Prepared by Kier Associates and Aquatic Ecosystem Sciences for the Klamath Basin Tribal Water Quality Work Group. 60p + appendices. http://www.klamathwaterquality.com/documents/asarian_kann_2011_CopIG_res_2005_2010_rpt.pdf | Appreciate the comment. Have updated this section with the information from the recent reference provided. |
| Quartz Valley Indian Reservation | 3 | Pg 67: L 28 | The section on temperature modeling should cite Perry et al. 2011. Also, please verify that the numbers mentioned in the sentence match those listed in Perry, or adjust accordingly. | Appreciate the comment. Have updated this section with the information from the recent reference provided. Verified that temperature modeling outputs presented match those of Perry et al. (2011). |
| Quartz Valley Indian Reservation | 3 | Pg 70 | Also Otten et al. 2015 clearly demonstrates the link to downstream transport of cells and toxin: Otten TG, Crosswell JR, Mackey S, Dreher TW. 2015. Application of molecular tools for microbial source tracking and public health risk assessment of a Microcystis bloom traversing 300km of the Klamath River. Harmful algae | Appreciate the comment. Have updated this section with the information from the recent reference provided. |
| Klamath Tribes | 3 | Pg 71: L 24 | I was thinking that Walker et al 2012 and 2015 found that inflows to UKL and Sprague have increased…not positive on that one, but I recommend reviewing those reports to verify. | Appreciate the comment. It is correct that Walker et al. found increases to UKL and Sprague increased over their period of comparison but over the longer time frame of comparison there has been a decreasing trend. We note this in the report and comment on trend interpretation being dependent on time frames used. |
| Quartz Valley Indian Reservation | 3 | Pg 72: L 25 | After "…inflows to the Sprague and Williamson rivers have also been declining since 1981 (NMFS and USFWS 2013), we suggest the following new sentence be added: "These declines are only partially due to decreased precipitation (Asarian and Walker 2016)." Full citation: Asarian, J.E. and J.D. Walker, 2016. Long-Term Trends in Streamflow and Precipitation in Northwest California and Southwest Oregon, 1953-2012. JAWRA Journal of the American Water Resources Association 52:241–261. doi: 10.1111/1752-1688.12381. | Appreciate the comment. Have updated this section with the information from the recent reference provided. |
| KBMP | 3 | Pg 73: L 12 | Will predicted climate change impacts on key species be assessed here, or set up for assessment? Tuning in the predicted effects on each life stage will be an important way to assess what planned actions can best address the suite of impacts and what life stages are predicted to be most at risk. This will hopefully lead to key priorities to address in a restoration plan. It is thought that these changes could affect various salmonid species differentially in | Appreciate the comment and agree this would be a good thing to consider developing within next stages of the restoration Plan. For the current synthesis report we did not attempt to assess predicted climate change impacts on particular species/life stages. |

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| | | | response to the variable freshwater life history strategies that have evolved in Chinook, coho, and steelhead | |
| KBMP | 3 | Pg 74: L 12 | Important statement but buried in a paragraph about ocean conditions. Suggest moving to a summary paragraph. The 2013 biological opinion (NMFS and USFWS 2013) suggests that in the coming years, climate change will influence the ability to recover some salmon species in most or all of their watersheds. Specific factors of a population or its habitat that could influence its vulnerability to climate change include its reliance on snowpack, current temperature regime (i.e., how close it is to lethal temperatures already), the extent of barriers that block its access to critical habitat and refugia areas, the range of ecological processes that are still intact, and its current life history and genetic diversity (NMFS and USFWS 2013). | Appreciate the comment and agree with your suggested text re-arrangement. Good to put this statement more upfront in the section. We have therefore shifted this particular paragraph to the beginning of the Climate Change section. |
| Quartz Valley Indian Reservation | 3 | Pg 75 | For fluvial processes in the Upper Basin, O'Connor should be cited: O'Connor, J.E. McDowell, P.F., Lind, P., Rasmussen, C.G., and Keith, M.K. (2013). Geomorphology and flood-plain vegetation of the Sprague and lower Sycan Rivers, Klamath Basin, Oregon: U.S. Geological Survey Webpage. doi:10.5066/F7BG2M0R. http://or.water.usgs.gov/proj/Sprague/report/index.html | Appreciate the comment. Have updated this section with the information from the recent reference provided. |
| North Coast Regional Water Quality Control Board | 3 | Pg 76: L 34 | I believe that the current conceptual model for C. Shasta includes a host of environmental and water quality conditions that promote high concentrations of infectious spores. For example polychaetes feed on the abundant particulate organic carbon in the water column in addition to favorable flow characteristics. | Appreciate the comment and have added additional text to this section in regard to feeding requirements of polychaetes for particulate organic carbon. |
| KBMP | 3 | Pg 78: L 4 | Any need to mention court case won by tribes for modifications to the 2013 BiOp and changes to flow regime to avoid juvenile disease outbreaks? existing 2013 biological opinion | Yes, we have obtained information in regard to this recent court case and have adjusted text to reflect these new management elements for controlling disease. |
| KBMP | 3 | Pg 78: L 6 | This sounds very pie in the sky knowing that total water available is already in very short supply (overallocated by some estimates) in most years and reductions in diversions from Klamath Project are not expected. | Appreciate the comment. We have adjusted text to be more reflective of the persistent water issues that will remain in the Klamath even if dam removal should occur. |
| KBMP | 3 | Pg 79: L 18 | Consider adding a qualifier to reference the mainstem specifically. Tributaries are impacted by the reduction of marine derived nutrients. major limiting factor | Have adjusted the text to reflect the potential of benefit of returning salmon to tributary streams. |
| KBMP | 3 | Pg 80: Figure 3-6 | Should Figure use a juvenile salmon and not an adult? | Perhaps. This is a figure extracted from a report we cannot alter. The salmon in the figure is intended to represent either juveniles or adults (who can both be infected). We have adjusted the figure caption to reflect this duality. |
| KBMP | 3 | Pg 80: L 15 | Reference to 'late summer months' are likely related to how water quality and quantity impact disease organisms of adult salmonids (which may have a factor in loading of *C. shasta* into adult carcasses due to crowding in fall) but this paragraph is about juvenile disease organisms. Water quality and quantity in the spring months are perhaps more relevant to juvenile disease epidemics (recent BiOp lawsuit should have relevant citations to how scour in spring can dislodge polychaete host, etc. This paragraph should be updated to reflect latest findings and court rulings. | Appreciate the comment. We have undertaken considerable restructuring and editing of this Disease section as well as the Flow Management section to incorporate most recent reports/papers, court decisions in regards to disease management. |
| KBMP | 3 | Pg 81: L 3 | Did recent lawsuit introduce additional conditions which can increase infection rate besides those listed from 2013 study cited? . | Yes, we have incorporated recent lawsuit adjustments to the BiOP flow management into the revised report. |
| North Coast Regional Water Quality Control Board | 3 | Pg 82: Figure 3-7 | Conceptual model fails to account for water quality conditions cited in Alexander 2016. | Appreciate the comment. Cannot modify the conceptual model we have referenced in this regard but have added additional text indicating (as you have identified) that not all potential water quality contributions are accounted for in the model. |
| KBMP | 3 | Pg 82: L 13 | Is this the only method likely to be a management option? If so, that should be noted. | This is the primary method (to our knowledge) that is being explored currently. We have noted that in the text. |
| Hoopa Tribal Fisheries | 3 | Pg 82: L 8 | Section describing impacts of *C. shasta* on juvenile salmonids. This should be updated with recent information relevant to the lawsuit noted immediately above. There are two technical memos from USFWS Arcata, plus an intertribal memo that stemmed from the USFWS memos. | Recent tech memo information on C. Shasta management in the Basin has been added to supplement this section. Additional review has also been kindly provided by J. Bartholomew at Oregon State University to |

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| | | | | ensure we are providing accurate information. Results of ongoing flow pulse experiments in regard to C. Shasta management are not yet available to include. |
| Klamath Tribes | 3 | Pg 83: L 13 | May want to update with findings from flow management actions combined with natural flow events this winter/spring. So far, spore counts are low. I recommend referring to the reports that provided the basis for the court mandate related to flow management that was issues late 2016/early 2017. Additionally, perhaps the Batholomew lab could provide some insight you could cite in this report. | Great idea. We discussed with J. Bartholomew and updated our write-up for this section based on comments from her. Unfortunately spore count data collection/analysis in regard to court mandated flow management changes has not yet been finalized and therefore not available to incorporate in this report. |
| KBMP | 3 | Pg 83: L 17 | Releases from Trinity Dam can also have a slight decrease in water temperature as well, which can reduce stress and potentially bring water temperatures below migration barrier (>22 C). Releases from Iron Gate unlikely to decrease temperature in the fall. These pulsed increases in flows for the lower Klamath River are intended to disrupt the disease life cycle by diluting concentrations of Ich theronts searching for hosts while also reducing high concentrations of fish | Appreciate the comment. We have adjusted the text for this section to capture this element of potentially reducing temperature barriers to salmon migration as a method of disease mitigation. |
| Quartz Valley Indian Reservation | 3 | Pg 83: L 6 | At end of paragraph, we suggest adding this new sentence: "M. speciosa feeds on particulate organic matter and its abundance is generally highest in the 100km reach of the Klamath River between the Shasta River and Independence Creek, which also has high abundance and diversity of other filter-feeding macroinvertebrates (Malakauskas and Wilzbach 2012). Reducing organic matter in the Klamath River might reduce M. speciosa abundance." Full citation: Malakauskas, D.M. and M.A. Wilzbach, 2012. Invertebrate Assemblages in the Lower Klamath River, with Reference to Manayunkia Speciosa. California Fish and Game 98:214–235. | Appreciate the comment. Have updated this section with the information from the recent reference provided. |
| CDFW - Northern Region | 3 | Pg 84: L 26 | IGH not producing steelhead currently. | Thanks for the additional information in regards to production of steelhead at IGD hatchery. We have used it to update the descriptions within this section. |
| California State Wildlife Agency | 3 | Pg 84: L 33 | Quiñones et al. 2013 - This paper has many assumptions that many scientists feel are in error…. | We recognize that there is not full agreement on the analyses or interpretations of this paper. We do feel we should include this work as part of the current report, as it represents very recent peer reviewed analyses directed at the particular issue of hatchery stresses. We have however reduced the emphasis on this particular paper and brought in additional supporting work relating to the potential impacts of hatchery fish on Klamath wild salmon stocks. |
| California State Wildlife Agency | 3 | Pg 85: Figure 3-9 | I believe there are some serious flaws with this graph. | Given the expressed concerns over this particular figure we have removed it from this report. The report text does a sufficient job at presenting a general overview of potential issues with hatcheries in the basin and it is not considered necessary to present this figure. |
| California State Wildlife Agency | 3 | Pg 85: L 2 | I don't believe this to be true. Mitigation goals have not changed since the hatcheries were built and reductions of coho (500,000 to 300,000) and steelhead (800,000 to 450,000) have occurred at Trinity River hatchery. Additionally Iron gate Hatchery has not released any steelhead for a number of years and has not met coho goals many either. | Thanks for the updates. We have adjusted this section to be reflective of actual releases. |
| Klamath Tribes | 3 | Pg 85: L 41 - Pg 86: L 2 | I would recommend citing these statements. | Citations have been added for these statements (i.e., NMFS and USFWS 2013; Beamish et al. 1997; Stanford et al. 2011). |
| California State Wildlife Agency | 3 | Pg 86: L 28 | Irrelevant to the Klamath Basin. | Appreciate the comment. We have removed mention of Pink salmon. |
| CDFW - Northern Region | 3 | Pg 89: L 29 | Citation? This is the first I've ever heard of that. | Citation for this comment on historical small-scale sucker entry into the upper basin has been added: NRC 2004 |
| CDFW - Northern Region | 3 | Pg 89: L 29 | I noticed on page 159 a reference to Bond 1994. Did he say they made it to the upper basin or just above Iron Gate Dam? | Bond (1994) indicates above IronGate Dam, but NRC 2004 indicates potentially farther up. |

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| KBMP | 3 | | Land subsidence in these former wetlands is also an issue that makes restoration much more difficult. USGS paper cites up to 13' of subsidence in UKL wetlands. https://pubs.usgs.gov/sir/2009/5004/pdf/sir20095004.pdf | Have adjusted text for this section to reflect these additional impacts and include information from suggested reference. |
| Karuk Tribe DNR | 3 | | Same exact comments were provided for Section 3 as from Quartz Valley Indian Reservation | Revised |
| Salmon River Restoration Council | 4 | NA | For all of these reasons spring-run Chinook should be more of a focus of this document and the restoration of the Klamath Basin. | We recognize the historical significance of spring-Chinook as a primary food fishery, and its cultural and ceremonial importance to the Klamath Tribes. We have added new text in Section 4 to ensure that the historical and current importance of spring-Chinook to the local tribes is clear. Determining priorities for future restoration is outside the scope of the Synthesis Report, and will occur during subsequent stages of Plan development. |
| Salmon River Restoration Council | 4 | NA | Spring-run Chinook are the natural fish to inhabit and re-establish in the middle basin, above the dams, when the dams comes out. Recent, cutting edge genetics research has proven that spring-run Chinook are a unique species and will not re-evolve out of fall Chinook if and when habitat opens up for them. It is critically important that we protect and restore wild spring-run Chinook of the Klamath Basin if we have any intention if restoring a viable fishery above the dams when they come out. Genetics of salmon bones recently found in the upper basin indicate that spring-run Chinook may have migrated far higher in the basin than previously thought. | We recognize the concerns expressed here in regards to fully identifying the historical significance of spring-Chinook as a primary food fishery, as its cultural and ceremonial importance to the Klamath Tribes. In response we have added new text in Section 4 to ensure that the historical and current importance of spring-Chinook to the local tribes is well highlighted. |
| Salmon River Restoration Council | 4 | NA | We agree with the fish species selected as focal species, but believe more emphasis should be put on spring-run Chinook than the document currently does. | We recognize the concerns expressed here in regards to fully identifying the historical significance of spring-Chinook as a primary food fishery, as its cultural and ceremonial importance to the Klamath Tribes. In response we have added new text in Section 4 to ensure that the historical and current importance of spring-Chinook to the local tribes is well highlighted. |
| Salmon River Restoration Council | 4 | NA | Under the reintroduction of salmon into the Upper Basin above the four Klamath River Dams the document needs to examine the spring-run Chinook, as they migrate upward in the spring when water quality in Upper Klamath Lake is better and there is more of flow through Upper Klamath Lake into the Williamson River or the Wood River. | Appreciate the comment. We feel we have discussed the potential use of upper basin areas by spring Chinook if dams are removed. |
| Salmon River Restoration Council | 4 | NA | Tribal trust fisheries species should be mentioned. | Appreciate the comment. Tribal trust species are identified in the report and our focal species write-ups do include Tribal Trust species. |
| Salmon River Restoration Council | 4 | NA | There should be more mention of the cultural and spiritual significance of the spring-run Chinook to local tribes, particularly the Karuk Tribe. | We recognize the concerns expressed here in regards to fully identifying the historical significance of spring-Chinook as a primary food fishery, as its cultural and ceremonial importance to the Klamath Tribes. In response we have added new text in Section 4 to ensure that the historical and current importance of spring-Chinook to the local tribes is well highlighted. |
| Salmon River Restoration Council | 4 | NA | The IFRMP for the Klamath should clarify and point out that when talking about Chinook it is predominantly discussing fall-run Chinook, and not spring-run Chinook. | Appreciate the comment. Have adjusted the text as we can in the report to try to more clearly reflect that Chinook management in the Basin currently is primarily focused on fall Chinook. |
| Salmon River Restoration Council | 4 | NA | The document should discuss the plight of all fisheries above the current location of the Iron Gate dam and below Keno dam. | Appreciate the comment. We feel we have provided a comprehensive summary of the current population status of fish species in the upper basin dam and the stresses they face, both generally within Section 3 and then for key upper basin focal species in Section 4. |
| Salmon River Restoration Council | 4 | NA | Spring-run Chinook were once dominant run of salmon on the Klamath River and have suffered the most, with a decline of 98%. Spring-run Chinook are the highest valued fish on the Klamath as a food source and were heavily impacted by hatcheries due to their desirability. They are a culturally and spiritually significant species for the tribes of the Klamath River, and are the center of tribal ceremony. Since their unique genes and resulting life history require them to enter the river system immature sexually, and laden with fat, they come into the system early and in good | We recognize the concerns expressed here in regards to fully identifying the historical significance of spring-Chinook as a primary food fishery, as its cultural and ceremonial importance to the Klamath Tribes. In response we have added new text in Section 4 to ensure that the historical and current importance of spring-Chinook to the local tribes is well highlighted. |

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| | | | condition and remain in the upper tributaries into the fall. This made them the ideal and preferred salmon species for eating by all river dependent tribes. | |
| Salmon River Restoration Council | 4 | NA | Spring Chinook do not get the recognition in the IFRMP that the spring Chinook of the Klamath are due. One place that this is articulated in the IFRMP is in the "" List of Abbreviations" where the Klamath River Fall Chinook are given an abbreviation of "KRFC" but the spring run are not | We recognize the concerns expressed here in regards to fully identifying the historical significance of spring-Chinook as a primary food fishery, as its cultural and ceremonial importance to the Klamath Tribes. In response we have added new text in Section 4 to ensure that the historical and current importance of spring-Chinook to the local tribes is well highlighted. However it is not possible for us to also give an abbreviation for spring-Chinook matching the official KRFC abbreviation used for the fall Chinook stock by the PFMC. |
| Klamath Tribes | 4 | NA | Note that Klamath Redband are also a Federal species of Special Concern. | Added federal status rating for Klamath redband trout. |
| Salmon River Restoration Council | 4 | NA | I also wonder where other important aquatic species get accounted for, such as fresh water mussels. | Appreciate the comment. As our synthesis report in focused on fisheries in the basin we have not assembled any "focal species" information targeted on other non-fish aquatic species like mussels. The ecosystem stressors we describe in Section 3 are also of general relevance to other aquatic species in the Basin but we have not targeted them in our descriptions. |
| Klamath Tribes | 4 | P 150: L 30 | Sun and Annie Creeks are not in the Williamson; they are tribs to the Wood River, which you included in the UKL watershed previously in this report. | Thanks for the correction. Have adjusted the text and associated tables to reflect accurate tributary locations. |
| Klamath Tribes | 4 | P136: L 22-23 | This is such a concern that the NPS and USFS have installed passage barriers to keep Brook Trout out of areas with known Bull Trout populations. Dave Herring (Fish Bio, CLNP) and several papers by Buktenica (I believe in Transactions of AFS) are good sources of additional info. | Appreciate the comment. Have incorporated information from suggested reports/papers to bolster the section in regards to concerns around invasives, and methods of control. |
| California State Wildlife Agency | 4 | Pg 103: L 17 | This should say CA Fish and Game Commission, PFMC has authority for determining harvest allocations and meeting conservation thresholds. | Have adjusted text for this section in this regard (CFGC instead of PFMC where stated inappropriately). |
| California State Wildlife Agency | 4 | Pg 104: L 1 | Again in-river and ocean fisheries are managed by the state after allocations have been determined by the PFMC. | Have adjusted text for this section in this regard (CFGC instead of PFMC where stated inappropriately). |
| California State Wildlife Agency | 4 | Pg 104: L 3 | PFMC 2016 - This should be removed. | Have adjusted text for this section in this regard (CFGC instead of PFMC where stated inappropriately). |
| California State Wildlife Agency | 4 | Pg 104: L 40 | Starting at "This quota" These actions all by the CA State Fish and Game Commission, please change. | Have adjusted text for this section in this regard (CFGC instead of PFMC where stated inappropriately). |
| KBMP | 4 | Pg 108: Figure 4-5 | Note base year the % increase is referencing. Median annual percent increase in the harvest of Klamath River Chinook salmon in the ocean (commercial and sport), tribal, and in-river sport fisheries as predicted by the EDRRA (Evaluation of Dam Removal and Restoration of Anadromy) life cycle production model for dam removal and restoration action implementation. Figure from Hendrix 2011, as reproduced in USDI, USDC, NMFS 2013. | We have noted the base year for comparison in the figure caption so this will be more clear. |
| KBMP | 4 | Pg 108: L 12 | Stronger language is more realistic but look for more recent citations and studies for details, including documents from UGSS's The Powell Center and KHSA. | Have strengthened the language here to be more reflective of the potential degree of short term impact to salmon from any dam removal. |
| KBMP | 4 | Pg 108: L 14 | State expected duration of suspended sediment impacts e.g. through summer after dam removal…. | Have clarified the potential timeframe and extent of impacts under different scenarios, although there would be uncertainty in that regard. |
| KBMP | 4 | Pg 108: L 17 | If a description of impacts to downstream habitat is not included elsewhere, a sentence on impacts, and uncertainty, would be helpful to summarize what risks are. | Have clarified the potential timeframe and extent of impacts under different scenarios, although there would be uncertainty in that regard. |
| Karuk Tribe DNR | 4 | Pg 108: L 34 | "supporting restoration activities"-unfortunately the restoration activities to be funded under the KBRA have no current funding. It will take dam removal+restoration to improve conditions for these focal species. Dam removal alone is not sufficient. This section implies that those restoration activities will happen. | Appreciate the comment. We have adjusted the text for this passage to reflect that the original modeling of response included, in addition to dam removal, included other anticipated KBRA restoration actions |
| KBMP | 4 | Pg 109: L 6 | But in recent years has been much higher. Be sure to use latest science and not rely on literature which is older. | We are not able to obtain more recent information on mortality rates for |

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| | | | | Chinook at this time for valid comparison to past impacts. Have restructured the passage to more clearly indicate that such high mortality rates have only occurred in some years prior to 2013. |
| KBMP | 4 | Pg 114: L 14 | Activities which have impacted traditional floodplain and riparian areas,…emphasis on constraints placed by humans on a river's width and ability to meander and be functional habitat. | We have adjusted the text in this passage to better emphasize past effects on floodplain dynamics |
| KBMP | 4 | Pg 115: L 13 | More up to date science needs to be used as well here, even if it hasn't made its way into peer reviewed literature. Including both is important. People in the room should know this is outdated. (Nichols et al. 2008, as cited in NOAAF 2014). | We have been unable to obtain any more recent information on *P. minibicornis* infection rates for Klamath coho. The cited NOAFF 2014 report providing information from the single 2007 study year (Nichols et al. 2008) is the best we can present on this currently. |
| California State Wildlife Agency | 4 | Pg 126: L 2 | NMFS has classified fall steelhead as a stream maturing ecotype, similar to summer run. See Klamath steelhead status review. | Have adjusted text and brought in additional recent references for steelhead write-up to provide a clearer summary of ecotype differences among Klamath steelhead. |
| California State Wildlife Agency | 4 | Pg 127: L 9 | CDFW data indicates that fall steelhead may hold for up to five months prior to spawning, thus more like summer run. | Have adjusted text and brought in additional recent references for write-up in this section to provide a clearer summary of ecotype differences among Klamath steelhead. |
| Klamath Tribes | 4 | Pg 140: L 4 | Based on the maps of historical extent of anadromy, probably not… Most current "Bull Trout streams" that are considered oligotrophic (and would therefore benefit from marine nutrient additions) are higher in the system than we'd expect salmon/steelhead to migrate to. | Appreciate the comment. Have adjusted text to reflect this caveat around potential benefits of salmon re-introduction for bull trout. |
| Klamath Tribes | 4 | Pg 141: L 26 | And Tribal subsistence fishery. | Have added text and supporting citation as to importance of redband trout for current Tribal subsistence fishery. |
| Klamath Tribes | 4 | Pg 142: L 16-19 | I think the more recent theory is that Rainbow Trout in general are highly plastic and capable of adapting to habitat conditions found in interior waterways. I'm struggling to remember the appropriate paper, but "Comparison of growth and stress in resident Redband Trout held in laboratory simulations of montane and desert summer temperature cycles" by Cassinelli and Moffitt (2009), published in Transactions of AFS, will maybe address this. | Have adjusted text in regard to description of redband adaptability and incorporated information from recommended papers. |
| Klamath Tribes | 4 | Pg 142: L 5 | I think this is also true for the Sprague and upper portions of the Wood and tribs and the "Westside Tribs" . | Have added these additional streams to the description. |
| Klamath Tribes | 4 | Pg 144: L 16 | TKT: Not sure you've used this acronym yet… If not, spell The Klamath Tribes out fully. | Spelled out The Klamath Tribes here as was indeed first mention of this acronym. |
| Klamath Tribes | 4 | Pg 145: L 20 | ODFW 1997 This is a pretty old document in terms of disease research. I would recommend verifying this with ODFW personnel and OSU disease researchers. | Have supplemented this section with more recent literature on disease impacts. |
| Klamath Tribes | 4 | Pg 145: L 31 | (e.g., smallmouth bass - Yes, but this is probably not a good example since I don't think smallmouth bass are common in the Upper Basin. I recommend double checking- presence of smallmouth bass has serious implications for juvenile salmonids and this report shouldn't imply a threat that may not exist (if smallmouth are limited or non-existent in the Upper Basin). | Thanks for catching this. This was a mistype as was instead meant intended to reference largemouth bass as an example. The presence of largemouth bass, brown bullhead, and yellow perch in the upper basin have all been identified by ODFW as contributing factors in redband trout declines. |
| Klamath Tribes | 4 | Pg 150: L 36 | Jenny Creek is a tribe to the Klamath River and is not within the UKL sub-basin. | Thanks for the correction. Have adjusted the text and associated tables to reflect accurate tributary locations. |
| Karuk Tribe DNR | 4 | Pg 152: L 2 | Under "Population Trends" It should mention that lamprey have persisted for 400 million years (twice as long as the "living fossil" green sturgeon). They are probably the first colonizer of these freshwater habitats and as such are probably the most keystone of the keystone species. | Have added additional text for this section to emphasize the long lineage of Pacific lamprey and their historical importance to the Klamath Tribes. |
| Karuk Tribe DNR | 4 | Pg 159: L 25 | None of this paragraph makes sense in the context of juvenile lamprey using fine sediments as habitat. I also find it odd they refer to thermal refugia being important for lamprey since we rarely see them using these areas. We really need to help make the connection that the fines they want flushed away as soon as possible are potential habitat for ammocoetes, and the available habitat appears to limit their distribution. Therefore we should try to get this habitat helpfully distributed in the channel rather than just flushed away. | We have broken this response down into the two topics covered in the comment.<br>(1) Use of thermal refugia by lampreys has been cited as an important habitat need for lamprey in the basin, particularly under any dam removal scenarios where over-summering lamprey may need to make use of |

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| | | | | thermal refugia in tributaries upstream of the current location of Iron Gate Dam (e.g., Big Springs and Spencer, Fall, and Jenny creeks), to mitigate for the effect of higher spring and summer water temperatures in some areas. If this does not align with local observations, this should be further explored during development of the Integrated Fisheries Restoration and Monitoring Plan.<br>(2) We recognize the concern regarding potential future restorations being focused on improving habitat for salmonids (i.e. through reductions in fines) at the expense of degrading habitat used by lamprey ammocoetes. However modeling of dam removal scenarios has suggested that the total area of habitats available for rearing lamprey would be expected to ultimately be greater than the current situation, through redistribution of fines into other areas. This would be one of the considerations when developing the overall restoration Plan. |
| Klamath Tribes | 4 | Pg 161: L 22 - Pg 162: L 2 | Why is this included in a section specific to Lost River and Shortnose? Perhaps you need another section that mentions other suckers? I don't think the others were focal species though, so you can probably just remove this. | Appreciate the comment. Our original intent was to provide some coverage of other sucker species in the Basin. But agree not directly relevant to the focal species exercise. We have deleted the small section describing other sucker species in the Basin. |
| USFWS | 4 | Pg 163: L 19 | I haven't checked the citation recently, but I think this statement is incorrect. Generally the SNS run to spawn when temps are >12 C, no matter when that is. I don't think there is consistent evidence for two spawning groups or runs outside of temperature fluctuations. | Appreciate the comment. Have adjusted the text for this section to reflect this generic temperature trigger, rather than discussing unique spawning groups. |
| USFWS | 4 | Pg 163: L 23 | I don't believe anyone travels less than approximately 7 miles and the vast majority (probably 98% or more for both species) don't go beyond 12 miles upstream. | Appreciate the comment. Have adjusted the text for this section to reflect this more specific migration range. |
| Klamath Tribes | 4 | Pg 164: L 1 | 1,262.3 – 1,262.5 m - It makes most sense to convert this to feet since the BiOp and lake managers use feet; different lake elevations in feet have very specific meaning to folks involved in this work, and lake elevation in meters is therefore sort of meaningless. | Appreciate the comment. The report has a table providing the Imperial/Metric conversions for all metrics used in the report. But given the common use of feet for managing lake elevations we have added the Imperial units here as you suggest (but leave original metric values in brackets, as those are the lake elevation units reported in Burdick et al. 2015. |
| USFWS | 4 | Pg 164: L 28 | Juveniles migrate... or are entrained … | Appreciate the comment. Have adjusted the text for this section to better reflect potential entrainment of suckers. |
| Klamath Tribes | 4 | Pg 165: L 28 | SL is standard length (not snout length) in the fisheries world. | Corrected this mistype, now SVL. |
| KBMP | 4 | Pg 167: L 42 | Are these agreements in negotiation? It seems odd to mention this if there isn't something tangible in place. Where would this water come from? Ranchers above UKL as part of Klamath Tribes water calls? If so, state this explicitly. Elsewhere in the document, it states that water deliveries to the Klamath Project are expected to continue so this seems inconsistent and will likely get strong opposition from ag community. | We have revised the text in this passage to be more general (i.e. benefits of high lake elevations to sucker), without inferring that any additional lake level agreements are in negotiation. |
| Quartz Valley Indian Reservation | 4 | Pg 168 | There is much additional evidence for the effect of poor water quality on sucker health and survival in UKL. These docs should be cited more comprehensively in this section, especially since the Revised Recovery Plan (USFWS 2013) cites poor water quality as a primary factor limiting species recovery and negative impacts from water quality on all sucker life stages. A major recovery strategy is ameliorating adverse effects of degraded water quality. | Appreciate the comment. Have updated this section with the information from the recent references provided to better reflect current understanding of water quality impacts on suckers. |
| Klamath Tribes | 4 | Pg 168: L 10 | Well, nutrient loads that then fuel AFA bloom and crash cycles. | Appreciate the comment. Have adjusted the text for this passage to better reflect the pathway. |
| USFWS | 4 | Pg 168: L 14 | They were impacted by harvest before listing, but no more. | Appreciate the comment. Have adjusted the text for this section to indicate that harvest was a historical stressor for sucker populations, but |

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| | | | | is no longer considered a factor. |
| Quartz Valley Indian Reservation | 4 | Pg 168: L 39 | Statement about other toxins is unclear; the major difference between UKL and Clear lake is the lack of cyanobacteria blooms in Clear lake and substantially better water quality in Clear Lake. To the extent that toxins and disease impact sucker recovery, degraded water quality increases fish susceptibility morbidity and mortality when exposed to such agents. | Appreciate the comment. We agree our section on UKL and Clear Lake was confusing and was not really helpful comparison with the synthesis. Have simply removed this section from the report text. |
| Klamath Tribes | 4 | Pg 168: L 39-42 | I think this needs more context. For instance, does Clear Lake have microcystin-producing cyanobacteria and potentially harmful levels of microcystin? I don't know Clear Lake well. | Appreciate the comment. Agree this paragraph was confusing and did not add much to the assessment. Have deleted this paragraph. |
| Klamath Tribes | 4 | Pg 168: L 8 | What is meant by historically? Recall that AFA has only been present in the lake in large numbers since the turn of the 20th century. Some may interpret "historically" to mean geologic history. Maybe clarify. | Appreciate the comment. Have remove the term "historically" from this passage to eliminate potential confusion in this regard. |
| Salmon River Restoration Council | 4 | Pg 170 | Green Sturgeon - Green sturgeon have been documented spawning on the Salmon River. In one recent year, large numbers of juvenile green sturgeon were found in the rotary screw trap run by the Karuk Tribe. | Appreciate the additional information. Have adjusted the text for this section to better reflect green sturgeon distribution. |
| Hoopa Tribal Fisheries | 4 | Pg 171: L 1 | Describes green sturgeon distribution in Klamath, leaving out a description of known range within Trinity River. These fish are caught regularly by Hupa fishers, and travel upstream on the mainstem to at least the vicinity of the New River confluence at which point a series of falls might prohibit upstream passage. We are not clear on their distribution into the South Fork Trinity. | Thanks for this updated information on distribution of green sturgeon in the Trinity River. We have added this description to the green sturgeon write-up. |
| Klamath Tribes | 4 | Pg 90: L 15 | Not necessarily true- many reports/studies have identified the groundwater-dominated systems in the Upper Basin as key cold water refugia in the face of climate change. If fact, I think this report acknowledged this earlier, so this statement is contradictory to information already presented in this report. | Appreciate the comment. Have added text and supporting citations to the section in that regard (i.e. although the upper basin is dominated by warmer streams and lakes it also has groundwater-dominated areas that can serve as cold-water refugia). |
| Karuk Tribe DNR | 4 | Pg 90: L 5 | Suckers also historically produced large runs that contributed to substantial tribal fisheries- and even commercial fisheries. | Have updated the text for this passage to reflect the important historical contribution of the suckers to tribal and commercial fisheries |
| Quartz Valley Indian Reservation | 4 | Pg 90: L 5 | suckers also historically produced large runs that contributed to substantial tribal fisheries- and even commercial fisheries. | Appreciate the comment. Have updated this section to reflect the historical importance of suckers to tribal and commercial fisheries |
| Klamath Tribes | 4 | Pg 91: Table 4-1 | Klamath redband trout Vulnerable - OR. | Adjusted Oregon state status rating for Klamath redband trout. |
| Klamath Tribes | 4 | Pg 91: Table 4-1 | My understanding is that Shortnose Sucker are a Tribal Trust Species. Lost River sucker - same comment. | Appreciate the comment. While we recognize that Shortnose and Lost River suckers are key upper basin fish species of concern for the Klamath Tribes we can find no information to date that would permit us to apply the Tribal Trust Species designation to these 2 species as has been applied for key anadromous species in the Basin (i.e., steelhead, coho salmon, Chinook salmon, Pacific lamprey, green sturgeon, eulachon, chum salmon, coastal cutthroat). |
| Karuk Tribe DNR | 4 | Pg 92: Table 4-2 | The common bullhead species in the lower Klamath is the Yellow Bullhead Ameiurus natalis, Not the brown bullhead as listed. | Thanks for the notification. Corrected fish species list in the table. |
| Karuk Tribe DNR | 4 | Pg 93: L 2 | Disagree with using Focal Species. Managing for specific species instead of ecosystem health as a whole is why we the watershed is not recovering and conditions are worsening, despite many regulatory processes in place. Managing for only endangered species has not and will not recover the system. | Understand your concerns and agree with your comments about limitations of managing only for endangered species. Our report is intended to be focused primarily on broad system issues, but focal species summaries seemed an additionally helpful approach for identifying some additional, more specific fish-related issues to consider and so will retain in the report. Intent was that focal species selected could be representative of larger suite of fish species in the Basin. |
| Klamath Tribes | 4 | Pg 95: L 26 | And an important subsistence and cultural resource! Fishing for Redband is one of the few treaty rights The Klamath Tribes can still exercise. | Appreciate the comment. Adjusted text for this section to reflect the important subsistence and cultural importance of redband trout to the |

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| | | | | Klamath Tribes. |
| Karuk Tribe DNR | 4 | Pg 96 | Seems to be focused on habitat recovery and not water quality improvements. For restoration there need to be improvements in water quality, water quantity, and habitat | Agree with this statement about 3 elements required for habitat recovery. Could not determine any particular edit to make to report in this regard. |
| California State Wildlife Agency | 4 | Pg 96: L 6 | Neither IGH or TRH hatcheries had built then although there were egg take stations. Also, the loss of habitat above dams was a major factor for the loss of spring Chinook. | Have added this information to summary of earliest causes of spring salmon declines. |
| Klamath Tribes | 4 | Pg 96: L 8 | This contradicts your previous statements in this section that ecosystem restoration to benefit focal species can also be expected to benefit the general requirements of other native species. Perhaps rewrite for clarity. | Appreciate the comment. Have rewritten section on focal species for greater clarity on the intended purpose of evaluating focal fish species. |
| Klamath Tribes | 4 | Pg 99: L 8 | And Wood River and "Westside tributaries" (i.e., Sevenmile Creek and the like). | Appreciate the comment. Have adjusted text to incorporate additional streams. |
| CDFW - Northern Region | 5 | Pg 184: Figure 5-1 | There were canneries at the mouth of the Klamath River that effectively decimated returning adults until the canneries were outlawed. See: http://klamathbucketbrigade.org/NPS_SalmonCanneriesontheKlamath040406.htm | The onset of canneries has been added as a point on the timeline based on the provided reference. |
| Hoopa Tribal Fisheries | 5 | Pg 186: Figure 5-1 | A timeline of restoration milestones for Klamath Basin should include Trinity-side events: 2000 Record of Decision for Trinity River Mainstem Fisheries Restoration; and preceding monitoring/restoration efforts of which there are many examples stretching back through the decades. | We have revised the timeline to include the 2000 ROD and make mention of the preceding decades of monitoring and restoration efforts, however, there is not sufficient space in the figure to record the timing of individual actions. |
| Klamath Tribes | 5 | Pg 186: Figure 5-1 | I think you're mixing up part of the events in 2013 with what happened in 2001; specifically, the shut off of water to the project occurred in 2001, not 2013. This was "the big shut off" and the impact to the ag community was severe (there is still a lawsuit over this action in the courts).<br>Additionally, 2013 was the year that The Klamath Tribes' water rights were quantified through the adjudication process and given the "time immemorial" status. This is a key event, because without this, the UKBCA agreement would not have come about. | Thank you for the clarification, we have updated the timeline to reflect the events as described. |
| US Geological Survey, Oregon Water Science Center | 5 | Pg 187: L 30 | As expected these are all 100% fish centric. Where does water quality fit? | The content for this section reflects the range of fisheries restoration actions in the basin, which includes restoration to improve water quality (Water Treatment and Management paragraph on p. 189). The Synthesis Report intentionally focuses on fisheries restoration, as its purpose is to support the development of an Integrated Fisheries Restoration and Monitoring Plan. See also response MR-1 at the beginning of this Appendix. |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 5 | Pg 188: L 10 | This is misleading. Short term flow buying (like Scott River Water Trust) should not be considered a restoration success as it is very limited in scope and timing and did not actually restore the system. Permanent dedication of instream flows and conservation measures that reduce flow demand (like retiring of croplands) should be noted as restoration success. | We have revised this section using the provided reference to distinguish between the level of benefit accrued from short vs. long-term or permanent transfers. |
| Hoopa Tribal Fisheries | 5 | Pg 188: L 10 | Line 10 and on discuss instream flow restoration events. The 2000 ROD for Trinity stands as the most substantial example, raising minimum release volumes on a scale seen nowhere else, based on the recommendations of the Trinity River Flow Evaluation Study (USFWS and Hoopa Valley Tribe, 1999). | We have added this statement as the first example in this category supported by the provided citation. |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 5 | Pg 188: L 20-29 | It is unclear whether floodplain restoration projects such as side channels, alcoves, and beaver dam analogues would be considered "Instream Habitat Restoration" or "Riparian Habitat Restoration" | They would be considered instream habitat restoration - text has been revised to clarify this point. |
| Hoopa Tribal Fisheries | 5 | Pg 188: L 29 | Describes riparian restoration efforts. The Trinity River Restoration Program has restored riparian function and plant communities along many reaches of the Trinity mainstem, largely on federal lands. | We have added this statement as an example in this category. |
| Quartz Valley Indian Reservation/Karuk | 5 | Pg 188: L 32 | Goal is not to provide nutrients but to reduce nutrient and sediment loading by increasing riparian and floodplain function. | Have added a statement describing the role of riparian restoration in nutrient and sediment load reduction. |

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| Tribe DNR | | | | |
| Klamath Tribes | 5 | Pg 188: L 32 | Not sure all are attempting to "provide nutrients"; rather, many are attempting to reduce nutrient and sediment loading by increasing riparian and floodplain roughness such that deposition of particulate matter in surface runoff and high flow events is more likely to occur. Riparian/floodplain restoration certainly increased prey abundance/food production for fish, but I think the way this sentence it currently worded is an oversimplification and may be misinterpreted. | Have revised the wording to "food" rather than "nutrients", as this was the original meaning intended as the commenter suggests, and have added a statement describing the role of riparian restoration in nutrient and sediment load reduction. |
| Klamath Tribes | 5 | Pg 188: L 34 | Riparian exclusion fencing OR riparian fences and grazing management. In many places, grazing still occurs, but is managed to facilitate recovery and restoration of riparian vegetation, etc. | Revised to clarify as suggested. |
| Karuk Tribe DNR | 5 | Pg 188: L 35 | Instream flow and water level is also an important determinant of riparian habitat restoration. | Revised to clarify as suggested. |
| Karuk Tribe DNR | 5 | Pg 189: L 2 | Suggested change "vegetation management to reduce the risk of wildfires" to "vegetation management to reduce the risk of high-severity wildfires". Fire is inevitable. The question is what kind of fire do we want to have? | Revised to clarify as suggested. |
| KBMP | 5 | Pg 190: Figure 5-2 | Figure should not say Status and Trends Monitoring at the top. This is all Project Effectiveness Monitoring. Figure 5 2: Relationships among types of monitoring for a fisheries restoration project. | Figure revised so Status and Trend monitoring encompasses entire diagram. The figure is not intended to be only about Project Effectiveness monitoring. |
| North Coast Regional Water Quality Control Board | 5 | Pg 190: Table 5-1 | There is clearly a direct connection from upland sediment erosion and delivery and stream temperature. Changes in channel structure and integrity from sediment loading contribute to warmer water column conditions. Likewise riparian habitat contributes to filtration of sediment and streambank integrity which directly effects channel structure and complexity. Flow objectives are critical to water quality. Hoping this table can be revisited. | We have updated the shading in this table to highlight the relationships stated by the commenter. |
| US Geological Survey, Oregon Water Science Center | 5 | Pg 190: Table 5-1 | "Water Quality" and "sediment" are too ambiguous here. Please define them more clearly. This is my biggest overarching issue with this document, i.e. it refers to and uses "water quality" in too vague a way so nobody knows what's included and what's not. I assume DO and temperature are relevant to fish. I assume this plan and the Fisheries agencies don't really care about nutrients, algal toxins, sediment contaminants, bacteria, pH, or other water quality parameters unless shown to directly affect fish. But, these are important to other people, for other reasons, so many will still care. The document needs to explicitly state what's included and what's not, so that we can get on with other processes to account for and restore or monitor water quality in the basin. | We agree that water quality is important. The characterization of water quality in the Synthesis Report reflects past and current fisheries restoration projects that emerged from our search of restoration projects in the Basin. The Synthesis Report provides background information to *inform* the development of the Integrated Fisheries Restoration and Monitoring Plan. Developing the Plan, and determining what will be included, has not yet occurred. Table 5-1 in the Synthesis Report is a high-level summary of what types of past/current restoration activities in the Basin are targeting which types of stressors on fish populations. Water quality parameters will be among the stressors examined during Plan development. |
| USFWS | 5 | Pg 194: L 12-16 | Northern California Resource Center should be listed with these groups as well. | Added. |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 5 | Pg 194: L 41 | Change "Klamath Tribal Water Quality Consortium and Work Group" to "Klamath Tribal Water Quality Consortium". Old name was "Klamath Basin Tribal Water Quality Work Group". New name is "Klamath Tribal Water Quality Consortium". Just use the new name. | Revised as suggested. |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 5 | Pg 195 | Comment actually pertains to Appendix G Sources and Methods of Project Information Synthesis, but there was no space on web comment form for appendices so we are placing the comment here where it is referenced in Section 5. Appendix G does not say anything about how overlap between datasets was addressed during data compilation and summarization. This could be a substantial issue. For example, almost everything in CHRPD will also be in PCSRF, because most CHRPD projects are funded through PCSRF. PCSRF will include additional projects funded directly to tribes (rather than to states) that will not be listed in CHRPD. Please add explanation of how duplication was addressed. Since the duplication is not explained, we assume that many projects were double-counted? | Data were extensively checked for duplicates as they were integrated into our main database - we have added a more detailed explanation of this process. |
| The Nature Conservancy- CA | 6 | Figures 6-2, 6-3, 6-4 | Great figures! (6-2/6-3/6-4) curious to know where the data comes from? Maybe it's in the document and I didn't see it. | This information is described in detail in both Section 5 and in Appendix G, we have now added a short reference to the source of the data to each |

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| | | | | figure caption. |
| Salmon River Restoration Council | 6 | NA | In this section the non-government groups such as the Salmon River Restoration Council- SRRC, the Mid- Klamath Watershed Council - MKWC, and the Scott River Watershed Council - SRWC should be identified as entities that convene, plan, design, implement a significant portion of the fisheries restoration activities within the basin and should be discussed as major restoration organizations. | We have now added a new subsection on Watershed Councils briefly describing the work of these groups. |
| Salmon River Restoration Council | 6 | NA | There should also be an identification and discussion of the Klamath Basin Fisheries Restoration Task Force (KBFRTF), perhaps the KBFRTF can also be identified in the "List of Abbreviations". | This is already included in the list of abbreviations, and we have now added more direct mention of the KRBFTF and its purpose in Section 5.1, where we discuss the broader history of restoration in the basin. |
| Salmon River Restoration Council | 6 | NA | In this section the non-government groups such as the Salmon River Restoration Council- SRRC, the Mid- Klamath Watershed Council - MKWC, and the Scott River Watershed Council-SRWC should be identified as restorationists and discussed. b. There should also be an identification and discussion of the Klamath Basin Fisheries Restoration Task Force (KBFRTF), perhaps the KBFRTF can also be identified in the "List of Abbreviations". | We have now added a new subsection to Section 6.2 on Watershed Councils briefly describing the work of these groups. The KBFRTF is now discussed in more detail at the beginning of Section 5.1 describing the history of restoration in the basin. |
| KBMP | 6 | Pg 197: L 14 | This is a feel good sentence but is cited from something from nearly two decades ago. Can it be said in 2017 that we've made great progress towards restoring fish populations in many waterways? If so, show examples (e.g. species X in the Y River). Have we merely held off extinction or actually restored populations? The many decades of restoration efforts in the Klamath Basin have made great strides towards restoring watershed function and fish populations in many waterways (Kier Associates 1999) | We have updated this statement to temper language - "progress" rather than "great strides", and "substantial work ahead" rather than simply "work ahead". |
| Bureau of Land Management - Klamath Falls Resource Area | 6 | Pg 197: Section 6 | We should add a narrative section discussing BLM restoration work and provide a $ est. WRW work along with forest work like road decommissioning and large wood placement fits nicely for this section. Please contact Robert Roninger 541-885-4173 or rroninge@blm.gov for narrative. | We have contacted Robert Roninger to obtain this narrative and we did not hear back, therefore it has not been included. |
| USFWS | 6 | Pg 198: L 17 | It may be worth noting that not all the activities occur under FAC. In particular, PFW funding comes through the Refuges Program area and WSFR is separate from FAC. Some funding for "restoration" efforts also comes through the Endangered Species Program as part of recovery (which I assume is unmentioned because it doesn't always line up with habitat restoration). The simplest fix would be to remove the reference to FAC. | We have removed reference to FAC as suggested. |
| Hoopa Tribal Fisheries | 6 | Pg 198: L 17 | Section 6.2.1 describes federal agencies and programs involved in restoration activities, and should include a section on US Bureau of Reclamation's Trinity River Restoration Program which spends upwards of $15M annually in pursuit of fish restoration. | We have now added a separate section on Multi-Agency Programs that describes the TRRP and refers the reader to more information in other sections of the report that address the TRRP. |
| Karuk Tribe DNR<br>___________<br>Quartz Valley Indian Reservation | 6 | Pg 199 | 6.2.2 There have been projects funded by the SWRCB as well, particularly I think from 319. | We have revised this section to include a subsection on the role of the California State and Regional Water Resources Control Boards, including the grant programs they manage (e.g., 319(h)) which have funded work in the Klamath Basin. |
| North Coast Regional Water Quality Control Board | 6 | Pg 201 | I can provide information on the large number of restoration projects that the Regional Water Board has sponsored and is sponsoring throughout the Basin including diffuse source treatment wetlands in Oregon. Seems like a key oversight since there is such a key linkage between restoration, water quality, and fish. | Many of the projects in the FAAST grant tracking database which we were referred to by Regional Water Board staff are already included in our collection (including 319(h) projects) by virtue of their inclusion in other databases, although these are labelled by the implementing agency (with RWB / 319(h) identified as a funding source or partner).Given already significant representation of Regional Water Board projects and the technical working group's decision not to focus further on this data for the next steps of the process, we will not be investing further effort into expanding the database at this time. |
| CDFW - Northern Region | 6 | Pg 202: L 26 | Contributing partners: Meaning grant applicants? Private landowners are not eligible for FRGP funding. | Contributing partners refers to those contributing to the funding of the projects whether though cash allocations or provision of in-kind donations |

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| | | | | (in the case of many private landowners). We have revised this statement to clarify. |
| CDFW - Northern Region | 6 | Pg 202: L 30 | You might want to mention other grant programs available through the Watershed Restoration Grants Branch. | Revised to include. |
| USFWS | 6 | Pg 202: L 8 | The CDFW has field offices in Eureka and Redding California, and contributes<br>CDFW has an office in Yreka as well. | Revised as requested. |
| Karuk Tribe DNR<br>__________<br>Quartz Valley Indian Reservation | 6 | Pg 204 | 6.2.3 The Tribes restoration work should be broken out into separate paragraphs or sections instead of lumped into one. Each Tribe is its own government, therefore it should be formatted similar to how you treated each federal and state agency, especially for the Tribes who have active restoration or strategic plans. | We agree that the Tribes have been leaders in implementing restoration work, and this is reflected by the number of Tribal restoration projects highlighted as case studies in Section 6. Because detailed information on restoration activities is not publicly available for all Tribes, we will defer to each of the Tribes to provide a summary of their work and would be pleased to add provided information to the document in the future. |
| Karuk Tribe DNR<br>__________<br>Quartz Valley Indian Reservation | 6 | Pg 204: L 26 | Instead of just saying that Karuk has a plan similar to Yurok, it would be better to list out highlights in separate sections for each Tribe just like you did for agencies and NGO's. Again, you give each agency and NGO its own section yet lump the Tribes which to the reader diminishes the value of the Tribe's work. The Tribes have been leaders in implementing restoration work, yet this document fails to make this point. Each Tribe can work with you on specific examples. Here are a few for Karuk. Karuk DNR decommissioned roads in sensitive watersheds, built networks of off-channel ponds to provide summer and winter habitat, is working towards co-management with the USFS to actively manage the forest using thinning and prescribed fire, etc. | We agree that the Tribes have been leaders in implementing restoration work, and this is reflected by the number of Tribal restoration projects highlighted as case studies in Section 6. Because detailed information on restoration activities is not publicly available for all Tribes, we will defer to each of the Tribes to provide a summary of their work and would be pleased to add provided information to the document in the future. |
| Karuk Tribe DNR<br>__________<br>Quartz Valley Indian Reservation | 6 | Pg 205: 5 - 99 | Two sentence about the Klamath Tribal Water Quality Consortium mis-states the membership (The Klamath Tribes are not members) and lack context. We recommend revising those sentences to read: "The Yurok Tribe, Hoopa Valley Tribe, Karuk Tribe, Quartz Valley Indian Reservation, and Resighini Rancheria formed the Klamath Tribal Water Quality Consortium to collaborate on water quality issues including monitoring, assessment, and restoration planning. Each tribe has its own water quality plan, but the Consortium member tribes also jointly produced and are working to implement an Upper Klamath Basin Nonpoint Source Pollution Assessment and Management Program Plan (KTWQC 2016)." | Revised as requested - thank you for providing suggested language. |
| The Nature Conservancy- CA | 6 | Pg 206: L 1-4 | Add TNC's role in enhancing flows in the Shasta River through leading the Shasta River Water Transaction Program. | Revised to include. |
| Karuk Tribe DNR<br>__________<br>Quartz Valley Indian Reservation | 6 | Pg 206: L 9 | TU is also implementing diffuse source treatment wetland pilot projects to reduce nutrients in irrigation return flow. | Revised to include a brief mention of the DSTWs here, but note also that the work of TU on these wetlands is already described in greater detail as a case study in the water quality section (6.5.7). |
| CDFW - Northern Region | 6 | Pg 207: L 26 | Might want to add Resource Conservation Districts. | Revised as requested. |
| Klamath Tribes | 6 | Pg 207: Table 6-1 | Several people (I'll include myself here) have complained that this table is nearly impossible to read, even when printed on an 11x17 paper. In particular, the names of plans are illegible. I recommend reformatting in some way so this table can be used. Because I was having difficulty reading this table (zooming way in and then scrolling back and forth to read row headings the "x"s corresponded too wasn't effective- too annoying and time consuming), I did not assess the content. It would be wise to reformat and send out for comments prior to finalizing this synthesis report. | We have now split this table over two pages to improve its legibility. |
| CDFW - Northern Region | 6 | Pg 210: Figure 6-1 | How do you define "industry"? | Defined here as for-profit businesses other than farms, ranches, or utilities - we have revised the text referring to the figure to clarify this point. |

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| Klamath Tribes | 6 | Pg 212: Figure 6-3 | Also, it's clear that the Williamson River wetland restoration in 2006/7 had a huge impact on spending for this type of restoration. As such, may be worth adding a note about that restoration project. Similarly, I would be interested to know why spending on upland habitat and sediment is so high in 2003. | We have added a note within the caption to describe the source(s) of the spending in 2006/7 (Williamson River wetland restoration) and in 2003 (Regional Ecosystem Office Projects). |
| CDFW - Northern Region | 6 | Pg 213 | Figure 6-4: I wonder why DFW is shown as contributing few projects? | This is likely due to the fact that CDFW was a supporting member or contributed funds to other projects (e.g., through FRGP), but these projects are listed under the lead agency. This figure is intended to reflect those agencies implementing projects, rather than those funding projects. We have added a statement to the caption to clarify this point: "These are classified according to the lead implementing agency as identified in project database records, not the agency or organization funding or supporting the work." |
| North Coast Regional Water Quality Control Board | 6 | Pg 213: Figure 6-4 | I would appreciate the opportunity to have Regional Water Board restoration projects included in this inventory since a large part of our TMDL implementation activities are tied to restoration projects. | Many of the projects in the FAAST grant tracking database which we were referred to by Regional Water Board staff are already included in our collection (including 319(h) projects) by virtue of their inclusion in other databases, although these are labelled by the implementing agency (with RWB / 319(h) identified as a funding source or partner).Given already significant representation of Regional Water Board projects and the technical working group's decision not to focus further on this data for the next steps of the process, we will not be investing further effort into expanding the database at this time. |
| Karuk Tribe DNR<br>___________<br>Quartz Valley Indian Reservation | 6 | Pg 213: Figure 6-4 | Oddly, the Smith River Alliance is included on this chart as a pretty big spender(Just below the Yurok Tribe). Is that correct? | Thank you for pointing out this error - the two projects carried out by the SRA on Mill Creek were erroneously assigned a location within the boundaries of the Klamath Basin in the original data set, we have now removed these projects which are not relevant to the basin and have regenerated this figure without the SRA. |
| The Nature Conservancy- CA | 6 | Pg 215: Figure 6-6 | At first glance there are a few watersheds that seem off. Sub-map C: Butte watershed (are there that many projects and is there that much money being spent there)? Sub-map B: Curious to know where the data is coming from. I believe it but am surprised it ranks this high. | We have updated the caption based on this and other comments to add context explaining the disproportionately high average project cost in Butte sub-basin, which is skewed by a few especially large expenditures on land acquisitions there. |
| KBMP | 6 | Pg 215: L 4 | Not actually what the graphs describe. Butte has very few, but on average most expensive projects. Most of the spending has occurred in the Shasta and Butte basins. | This was indeed an error and has been corrected. We have also added a statement to provide additional context around the driver of high mean project costs in the Butte sub-basin, which is explained by several large land acquisition expenditures. |
| CDFW - Northern Region | 6 | Pg 215: L 4 | That doesn't make sense since Butte is a closed basin. I think you meant Scott and Shasta basins. | This was indeed an error and has been corrected. We have also added a statement to provide additional context around the driver of high mean project costs in the Butte sub-basin, which is explained by several large land acquisition expenditures. |
| Klamath Tribes | 6 | Pg 219: Figure 6-9 | How did you categorize different projects relative to these conceptual model stages? I see that the Upper Klamath Basin had a lot of habitat projects, many of which I assume are riparian/floodplain restoration projects. I (and many others) would argue that riparian/floodplain restoration affects watershed inputs, fluvial processes, and habitat. This is relatively well known, so I can't really point you to a single report or study. I can send you a draft conceptual model for the Upper Klamath Basin Watershed Action Plan that highlights the effect of riparian restoration on process/function, habitat, nutrient/sediment loading, etc. if you you're interested. | The caption refers readers to the classification scheme in Appendix I. With regards to the remainder of the comment, recall that this colour-coding refers to the conceptual model introduced in Section 3, which describes how the higher categories all feed into the lower ones, i.e., that they are not independent as this comment suggests. We will update the figure legend and caption to clarify and add a link to the original conceptual model. |

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| Klamath Tribes | 6 | Pg 223: L 1-4 | Not sure this is very compelling/relevant for the Klamath Basin, given that only the upper headwater portions of streams are really oligotrophic. Everything else is relatively productive. Now, return of salmon may provide other opportunities like new food sources (salmon eggs and fry for piscivorous fish; adults and adult carcasses for terrestrial and avian predators), but in terms of marine-derived nutrients, it's really not something we're focused or keyed in on given the current productivity of our streams. | Revised to re-frame this statement as restoring the flow of new food resources (rather than nutrients) as suggested. |
| Klamath Tribes | 6 | Pg 223: L 14-16 | Sediment flush increased the quality of habitat in and improved function of the Elwha estuary. | We have revised this section to clarify the distinction between short-term fine sediment waves and later coarser sediment waves that improve habitat, and have clarified the context for timelines to reflect the fact that sediment changes occur within years, but that reaching a new equilibrium may take years or decades. |
| US Geological Survey, Oregon Water Science Center | 6 | Pg 223: L 8 | I think this timeline is not correct. Hart et al 2002 was before most of the bigger removals have happened. Experience is showing that the river's adjust quickly, within a few years. Also, "complete flushing" is a misconception, since it's unlikely that the reservoir sediment will be completely flushed. It may still take many years for the sediment evolution or the channel adjustment to equilibrate but the changes in a few years will likely be incremental, rather than catastrophic. | We have revised this section to clarify the distinction between short-term fine sediment waves and later coarser sediment waves that improve habitat, and have clarified the context for timelines to reflect the fact that sediment changes occur within years, but that reaching a new equilibrium may take years or decades. |
| Klamath Tribes | 6 | Pg 225: Table 6-3 | Seems like you should include Farmers Conservation Alliance's Farmer's Screen since it is widely used in Oregon, including in the Upper Klamath Basin. | Revised table to include this type of screen with a footnote linking to the Farmers Conservation Alliance Farmer's Screen website. |
| USFWS | 6 | Pg 226: L 7 | Many of these more recent fish passage projects have been led by Tribal Agencies on tribal lands as well as the USFWS Partners for Fish and Wildlife Program on private lands<br>The National Fish Passage Program (USFWS program) has been very active in barrier removal on public and private lands as well.<br><br>Document spanning comment:<br>I'm not sure I see the use of calling out individual projects in the restoration section. It adds considerable length to the document and these projects may be better placed in an appendix. | Revised to include content pertinent to the first and last comment.<br><br>With regards to the comment on case studies, these have been included to provide some context around how these types of projects are implemented and have been requested by several agencies, and so will remain. |
| Salmon River Restoration Council | 6 | Pg 227 | Whites Dam Removal Project - this description doesn't mention the more important barrier that was removed as a part of this project, dam across the channel, upstream from the culverted crossing that was used to provide water to a private hydro-electric system. This dam was removed and an alternative method was installed to supply water to the hydro-electric system. | We have added the following statement to address this comment: "This project complemented two upstream dam removal projects that were completed in 2008 by the Salmon River Restoration Council, CDFW and the NOAA Open Rivers grant program (Five Counties 2010)." |
| CDFW - Northern Region | 6 | Pg 229: L 3 | It restored free flowing waters and year round access, it was a temporary barrier during the summer (generally when there was no impact to fisheries since the water temperatures are so high in that reach.) The way it is written here it sounds like it was new access to 30 miles of habitat. | Revised to reflect this context. |
| Karuk Tribe DNR<br>__________<br>Quartz Valley Indian Reservation | 6 | Pg 231: L 10 | This paragraph contains discussion of fine sediment and their potential negative impact on salmonids. It again ignores the potential for this sediment to provide habitat once distributed in the sediment starved downstream reaches. | In response to this and other comment on this issue, we have modified the language in this paragraph to refer to the potential negative effects of "excess sediments" and have also added a counterpoint indicating that, over the longer-term, coarser sediment transport could benefit salmonids through expansion of suitable spawning habitat, citing Hart et al. 2002 as a supporting document. |
| PacifiCorp | 6 | Pg 231: L 9 | See previous comment about who developed this plan. | Revised to reflect that the plan was developed solely by the U.S. Bureau of Reclamation and its contractors as specified in a previous comment. |
| Salmon River Restoration Council | 6 | Pg 232 | If we want to keep salmon from going extinct in the Klamath Basin we need to focus efforts on keeping our rivers and streams as cold as possible for as long as possible. Restoration of high elevation meadows and wetlands should be discussed. With climate change increasing temperatures and reducing snow pack it is critically important that we focus efforts on storing as much cold water for as long as possible. Many high elevation wetlands, meadows, and | This comment partly refers to impacts and stressors, which are covered in Section 3. With regards to the relevance for restoration, we have now added some new content and supporting references describing the importance of restoration of high-elevation wetlands for stream |

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| | | | sparse forested areas have been degraded through grazing and/or encroached by conifers and brush from lack of fire. This reduces their ability to act as a sponge and retain cold water late into the season. Additionally, dense forest at high elevations keep a solid snow pack from forming, by allowing most of the snow to evaporate directly from the canopy without creating a dense icy snow pack on the ground. The resilience, and health of these areas are becoming increasingly important if we want our rivers to remain cool enough to continue to foster salmon of any species. | temperatures in Section 6.5.7 (under Restoration of Natural Wetlands). |
| Salmon River Restoration Council | 6 | Pg 232 | The Mid Klamath Watershed Council and the Salmon River Restoration Council have worked with their multitude of governmental, tribal and NGO partners to create details Candidate Action Table for in-stream fisheries restoration in the Mid Klamath and Salmon River subbasins. These efforts have brought together the knowledge of a multitude of partners and experts and gained agreement on restoration actions and priorities within these areas. These efforts should be considered in this process because they lay out a road map for collaborative fisheries restoration within the basin. | In response to this and other comments, we have added a subsection in section 6.2.4 to describe the roles of watershed councils in restoration, and have also now included the provided information on the roles of these agencies in creating a Candidate Action Table for specific sub-basins. The individual actions in this Candidate Actions Table will be considered as part of the next phase when building the plan. |
| Salmon River Restoration Council | 6 | Pg 232 | There should be more discussion of the impacts of over 100 years of effective fire suppression within the Klamath Basin, and the massive impacts this has and continues to have on the fishery. The results of this management practice have been disastrous, ranging from the lack of LWD input into streams and waterways, the proliferation of large mega-fires with increased size and scale of high intensity burn patches, heavy erosion from high intensity fires destroying critical spawning and rearing habitat, overly dense forests reducing the amount of cold water reaching cold water refugia, ..... The Western Klamath Restoration Partnership is doing amazing collaborative work to restore fire process and resilient forest at a landscape scale. They are just beginning to implement large scale restoration projects that could positively change how land is managed within the forested parts of the basin. | This comment describes impacts and stressors, which are covered in Section 3. With regards to the relevance for restoration, we cover fire management in the write-up on the US Forest Service's activities and under the heading of Upland Land Use Management in section 6.5.6. We have now added additional content in section 6.5.6 to describe the role of natural fire regimes in ecosystem health, the impacts of historical fire suppression practices, and the work of the and discuss the work of the Western Klamath Restoration Partnership. |
| Salmon River Restoration Council | 6 | Pg 232 | Spring-run Chinook Salmon should be called out as a species that would have a significant positive impact with dam removal. Spring Chinook should not be lumped in with fall Chinook. | Table row on Chinook has been revised to make this distinction. |
| Salmon River Restoration Council | 6 | Pg 232 | While hatcheries have played a significant role in the fisheries of the Klamath Basin, they have been very detrimental to wild stocks. The hatcheries within the Klamath Basin need to undergo a full review with recommendations to improve their operating procedures to reduce impacts on native stocks. The gene diversity present in native fish stock, especially spring Chinook are critical important to preserve. Spring Chinook are the most well suited salmon species to repopulate the middle and upper Klamath after dam removal. It is really important that this document doesn't lump spring and fall Chinook together and that they are treated separately. Their distinct life history gives them distinct advantages under different conditions. Spring Chinook's propensity to enter the river systems early when flows are higher and migrate high into the upper reaches of the watershed and tributaries makes them especially suited to re-populate the Klamath basin after dam removal.<br>The Salmon River retains the last viable run of wild spring Chinook Salmon. It is critically important that this wild run and the genetics that they carry be protected and their habitat restored to make sure that these fish can re-populate the upper basin when the ideal habitat is made available. | This section is meant to explore the use of hatcheries as a restoration tool, whereas this comment refers to potential impacts which are already addressed more thoroughly in Section 3.5.2. Moreover, Section 3.5.2 has been updated in response to further comments on that section. |
| Karuk Tribe DNR<br>__________<br>Quartz Valley Indian Reservation | 6 | Pg 232: L 8 | The idea that a more virulent *C. shasta* will gain access to the upper basin with dam removal is not in line with current scientific research. Please contact Jerri Bartholomew at Oregon State University to discuss this topic. | We have reached out to Dr. Bartholomew and have now updated this section with more accurate information referencing a 2016 report on fish health by Dr. Bartholomew and colleagues. |
| Klamath Tribes | 6 | Pg 232: L 9-10 | This is not accurate and this was the argument PacifiCorp attempted to use to prevent fish passage prescriptions as part of FERC re-licensing; they lost that legal fight. I commented on this extensively during the steering committee review period; those comments were informed by a conversation about this specific statement with a member of Jerri Bartholomew's lab. Please refer to my previous comments and/or speak to someone in Bartholomew's lab. This is | We have now spoken with Dr. Bartholomew regarding this comment and have revised this section to reflect the correct current thinking about the potential influence of dam removal on C.shasta, and have added several supporting citations from USFWS and Fish Health reports. |

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| | | | something that must not remain in this report as it does not reflect the most recent science and it resurrects an old argument that was proven wrong in court. | |
| Klamath Tribes | 6 | Pg 232: Table 6-4 | Suckers section: How will dam removal improve habitat in UKL? | This statement lacked context from the original source - no direct benefits of dam removal to sucker habitat are expected, however, the dam removal option assessed in the expert panel report on resident fish included habitat restoration in the upper basin which would benefit suckers. We have clarified the statement to reflect this. |
| Karuk Tribe DNR<br>__________<br><br>Quartz Valley Indian Reservation | 6 | Pg 232: Table 6-4 | To the extent that fish in the river below the dams are impacted by Microcystis blooms and toxin from the reservoirs, exposure will be eliminated. | We have added this statement to the block of text above the table where it complements an existing statement on reduced disease. |
| California State Wildlife Agency | 6 | Pg 234: L 29 | The IGH has not been meeting coho production goals in recent years | Revised to indicate this. |
| CDFW - Northern Region | 6 | Pg 234: L 8 | You might want to mention Klamathon (1918): https://books.google.com/books?id=rKojAQAAMAAJ&pg=RA1-PA93&lpg=RA1-PA93&dq=hatchery+at+klamathon&source=bl&ots=BxsJHpXELM&sig=wFPnfHjy-DtqYP6h1s5Nd5o7Rew&hl=en&sa=X&ved=0ahUKEwj426r5l_PUAhUpiVQKHaDMCyAQ6AEIKjAC#v=onepage&q=hatchery%20at%20klamathon&f=false (page 93). I think they were trying to compensate for the decimation caused by the canneries. | Revised to add this as a historical egg-collecting station along with the already listed Camp Creek and Bogus Creek. |
| Karuk Tribe DNR<br>__________<br><br>Quartz Valley Indian Reservation | 6 | Pg 237 | 6.5.3 Instream voluntary flows-these are not the best way to restore flow and are quite controversial even though they are gaining in popularity. See attached paper on cost effectiveness metric for environmental water transactions. Paper shows that the most cost effective way to spend restoration money for flows is on permanent dedications, not temporary band-aid fixes of buying little pockets of water. This topic should be added to the document instead of currently high praise in the document is put on short term transactions for restoration. | We have revised this section using the provided reference to distinguish between the level of benefit accrued from short vs. long-term or permanent transfers. |
| PacifiCorp | 6 | Pg 237: L 13 | This is actually within 6 months of the DRE's acceptance of the FERC surrender order. (See IM 19). | Revised as suggested. |
| PacifiCorp | 6 | Pg 237: L 26 | As has been stated previously, the KBRA no longer exists as a viable agreement. This statement and the following one should be revised to reflect this. | Revised as suggested. |
| Klamath Tribes | 6 | Pg 238: L 24-26 | Yes, except for Spring Chinook above Link Dam- that will certainly be an active reintroduction effort. Ted Wise at ODFW can provide more info. | Revised as suggested. |
| Klamath Tribes | 6 | Pg 240: L 12-13 | I think some context needs to be provided- this statement was likely true at the time of the report (2004), but is certainly not true now; substantial tailwater returns flow into the Lost and Klamath Rivers now. | Revised to indicate that flow return conditions are different today. |
| Karuk Tribe DNR<br>__________<br><br>Quartz Valley Indian Reservation | 6 | Pg 240: Table 6-7 | Installing wells instead of surface diversions is listed as "Irrigation practice Improvement". We know this does not lead to increased instream flows so this is very misleading. | We have removed this statement from the definition, as we do not discuss restoration of this type further. |
| Karuk Tribe DNR<br>__________<br><br>Quartz Valley Indian Reservation | 6 | Pg 242: L 14 | It states "The Karuk Tribe which is without a ratified treaty reserves no such rights" (Water rights in this case). We were told that since the treaty was never ratified, the tribe never signed away ANY rights, therefore all rights are reserved (including water rights). | This statement was based on at least two sources reproduced below - however, Indian Affairs does clarify that rights that were not relinquished are technically protected as you say (see below). This statement has been updated to reflect this fact.<br><br>Milner 2015 (Cited in text): "The Karuk Tribe of the Lower Basin does not have a ratified treaty, and therefore does not have federally recognized hunting, fishing, or reserved water rights,115 leaving them with minimal |

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| | | | | land and uncertain rights."<br><br>Klamath Facilities Removal EIS/EIR, 2011, Chapter 3: "Congress never formally ratified the treaty negotiated between the United States and the Karuk Tribe in 1851, and no statute or executive order otherwise set aside reservation lands for the Tribe. ... Any fishing and concomitant water rights to which the Karuk Tribe may be entitled have not yet been determined."<br><br>US DOI Indian Affairs FAQ (https://www.bia.gov/FAQs/): "Any "special" rights held by federally recognized tribes and their members are generally based on treaties or other agreements between the tribes and the United States. The heavy price American Indians and Alaska Natives paid to retain certain rights of self-government was to relinquish much of their land and resources to the United States. U.S. law protects the inherent rights they did not relinquish. Among those may be hunting and fishing rights and access to sacred sites." |
| Karuk Tribe DNR<br>__________<br>Quartz Valley Indian Reservation | 6 | Pg 243: Figure 6-19 | Look at the amounts spent on "irrigation practice improvement". Best guess is that most of this money was spent on wells (see comment about table 6-7) which don't actually help improve instream flows. | Only three of the >100 projects included in this category involved installation or upgrades to wells. We have updated the description in this section to specify this. |
| The Nature Conservancy- CA | 6 | Pg 243: L 11-12 | I could be wrong but EQIP funding does not require that the "net water" saved in these projects is returned instream (at least in CA). They could use their $'s to provide net water instream but it usually doesn't occur unless another funding entity requires it of the landowner. Figure 6-20 puts too much emphasis that these EQIP projects result in some instream flow component. It's just not that accurate of a way to account for "instream flow" projects - at least when it comes to irrigation systems or water control and management projects. | Noted, however, this is currently our only and best source of data on projects of this type. To account for this potential misalignment, we have added the following caveat in text and to the caption for this figure: "However, it is important to note that not all of these projects necessarily result in gains in instream flow." |
| The Nature Conservancy- CA | 6 | Pg 244: L 6-8 | TNC' runs the Shasta River Water Transaction Program in the Shasta River Watershed which functions exactly like the Scott Water Trust and has been operational since 2012. It would be good to reference that this program exists in the Shasta Basin too. | We already reference this program at the end of the section on the Scott Water Trust, but we have updated this section to reflect the operational status of the program and include the year of launch. |
| Karuk Tribe DNR<br>__________<br>Quartz Valley Indian Reservation | 6 | Pg 245: L 1 | Doubtful that short term water leases are what really altered coho numbers significantly in the Scott. | We have tempered the language to downplay the role in increasing coho returns, saying simply that the transaction program has "benefited" returns without attempting to capture the magnitude of the increase. |
| Karuk Tribe DNR<br>__________<br>Quartz Valley Indian Reservation | 6 | Pg 245: L 21 | Efforts of moving fish were shown to be ineffective so this should be stated or this section should be removed. Tagged fish were not seen again. Moving fish during a drought in the Scott is not effective restoration or mitigation and should not be touted as such. There was a report from CDFW on this. | This section has been updated with the information provided by Caitlin Bean from the USFWS to reflect the mortality observed in subsequent surveys, and is supported by the suggested CDFW report provided to us. |
| CDFW - Northern Region | 6 | Pg 245: L 32-35 | I'll send you the CDFW report. Of the hundreds of PIT tagged juveniles only several were detected outmigrating indicating that we had very high mortality of the "rescued" fish. | Revised to reflect this outcome with supporting citation of a CDFW study report provided by Caitlin Bean. |
| CDFW - Northern Region | 6 | Pg 245: L 4-6 | I think TNC started it and asked SVRCD to collaborate. I don't think it's appropriate to say that it is "currently developing", they have been paying for water for at least several years. | Revised to clarify as suggested. |

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| Karuk Tribe DNR<br>__________<br><br>Quartz Valley Indian Reservation | 6 | Pg 245: L 8 | Put KBRT water transaction before Scott River as it is a better example of instream flow restoration since they prioritize permanent transfers. | Revised to reorder as requested. |
| Karuk Tribe DNR<br>__________<br><br>Quartz Valley Indian Reservation | 6 | Pg 249: Figure 6-22 | Karuk fisheries staff think there has to be a more modern idea of instream structures than Olsen and West 1989. When recently in Bluff Creek it appears these structures are barely better than nothing and far inferior to wood placement without adding boulders. Tt is as an example of past restoration work in the Klamath Basin, but an inferior one and should not be included or considered as best practices. | These figures were used because they were produced by a government agency and are in the public domain - no other more modern figures of this type were found that could be easily reproduced without infringing on copyright. However, we never suggest that the figures depict best practices, and describe more modern techniques. |
| CDFW - Northern Region | 6 | Pg 252: L 38 | Careful. In CA it is not legal to relocate beavers. | Revised statement to clarify this fact. |
| CDFW - Northern Region | 6 | Pg 252: L 42 | However, in the Scott River watershed the BDA's are channel spanning with questionable upstream fish passage for juveniles. | Revised statement to clarify this fact. |
| Karuk Tribe DNR<br>__________<br><br>Quartz Valley Indian Reservation | 6 | Pg 253: L 11 | Please add the following sentences: "A watershed-scale experiment in eastern Oregon found that beaver dam analogues significant increased density, survival, and production of juvenile steelhead without affecting migration (Bouwes et al. 2016). Beaver dams and analogues enhance groundwater-surface water connectivity and create thermal diversity (Weber et al. 2017)." Full citations:<br>- Bouwes, N., N. Weber, C.E. Jordan, W.C. Saunders, I.A. Tattam, C. Volk, J.M. Wheaton, and M.M. Pollock. 2016. Ecosystem Experiment Reveals Benefits of Natural and Simulated Beaver Dams to a Threatened Population of Steelhead (Oncorhynchus Mykiss). Scientific Reports 6:28581. doi: 10.1038/srep28581.<br>- Weber, N., N. Bouwes, M.M. Pollock, C. Volk, J.M. Wheaton, G. Wathen, J. Wirtz, and C.E. Jordan. 2017. Alteration of Stream Temperature by Natural and Artificial Beaver Dams U. G. Munderloh (Editor). PLOS ONE 12:e0176313. doi: 10.1371/journal.pone.0176313. | Revised as requested - thank you for providing suggested text and supporting references. |
| USFWS | 6 | Pg 253: L 15 | The USFWS has produced an extensive Beaver Restoration Guidebook<br>Version 2.0 released June 30, 2017<br>https://www.fws.gov/oregonfwo/Documents/BRGv.2.0_6.30.17_forpublicationcomp.pdf | Updated to cite new source. |
| CDFW - Northern Region | 6 | Pg 253: L 16 | There is now a 2017 version. (http://bit.ly/2usdV5N). | Updated to cite new source. |
| USFWS | 6 | Pg 253: L 3-7 | When placed at appropriate locations, these structures promote increased frequency of flooding and produced deeper, cooler pools, restored connections with floodplain swales and relict channels, and promoted the development of riparian vegetation (DeVries et al. 2012). Slowing flows also has the effect of contributing to elevation of the water table and increased groundwater recharge (Pollock et al. 2015).<br><br>Publication showing that BDAs buffer against diel temperature ranges<br>http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0176313 | We have now revised this section to add the results of this recent study in response to this and another similar comment. |
| Karuk Tribe DNR<br>__________<br><br>Quartz Valley Indian Reservation | 6 | Pg 258: L 25 | Does not mention important projects occurring after 1995. We recommend adding the following: "In 2014, the Scott River Watershed Council (SRWC) began constructing a series of beaver dam analogues (BDAs) in Scott River watershed. Monitoring showed positive results: groundwater levels rose, a stream reach that previously went dry in summer remained wet through an entire drought year, thousands of juvenile salmonids utilized the habitats formed by the structures, and adult salmon and steelhead migrated upstream past the structures (Yokel et al. 2016)." Full citation: Yokel, E., P. Thamer, C. Adams, L. Magranet, W. DeDobbeleer, R. Fiori and M.M. Pollock, 2016. Scott River Beaver Dam Analogue Program 2015 Interim Monitoring Report. Scott River Watershed Council, Etna, California. 87 pp. https://docs.wixstatic.com/ugd/afbfb7_08c2ac50b82349a4918f138d3d090836.pdf. | Revised as requested - thank you for providing suggested text and supporting references. |

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| Karuk Tribe DNR<br>__________<br>Quartz Valley Indian Reservation | 6 | Pg 258: L 26 | The Wood River wetland managed by BLM should be included here. The ~2000 acre wetland at the mouth of the Wood as well as the river channel restoration represent an important project in the basin. Same comment for page 274 line 3. | We have now added the Wood River wetlands restoration project as a second example in this section. |
| KBMP | 6 | Pg 259: L 14 | Whether here or elsewhere, it may be important to note that some challenges exist with wetland restoration around UKL due to subsidence of some former wetlands after decades of diking. These areas would no longer be shallow wetlands but deeper water habitat that may require extensive construction or importation of fill/dredge to restore elevation for a functioning wetland which could benefit suckers and WQ improvements. | We have now revised this section to add content explaining the implications of subsidence, citing Erdman and Hendrixson 2012. |
| Klamath Tribes | 6 | Pg 260: L 8 | loss of nutrient input: Or increase in nutrient input, especially increases in particulate P associated with soil/sediment. *I have a short lit review I can provide on this topic, if necessary.* | We have revised this section from "loss of" to "changes in nutrient input (e.g., loss of organic nutrients, gain in inorganic nutrients from eroding soils)". |
| Klamath Tribes | 6 | Pg 261: L 28-31 | This supports my comment above that riparian corridor restoration can have more than just an effect on shading and food production. | Noted - we have revised the previous section accordingly in response to the earlier comment to detail the broader benefits of riparian restoration. |
| KBMP | 6 | Pg 262: L 21 | Citation or conjecture? traffic to and from dams and other industrial facilities | Revised to clarify the evidence supporting this statement and to include two supporting references:<br>"The frequency of weed control projects in this region may be related to the propensity for utility corridors, vehicle traffic, and ongoing vegetation-management activities associated with dam operation to contribute to the spread of invasive weeds (see Section 8.8.1 of PacifiCorp 2004), as reflected by known infestations of invasive weeds in the areas surrounding reservoir shorelines in the basin (USBR 2012c)." |
| Karuk Tribe DNR<br>__________<br>Quartz Valley Indian Reservation | 6 | Pg 263: L 21 | A general comment about sediment from Karuk fisheries. We need to revisit the idea that sediment is bad and must be stopped and replace that idea with one that includes a sediment input balance. Lamprey need fine sediments and the problem with fines is not necessarily their presence, but the configuration and structure of the channel controlling how they are dispersed by high water. Road decom projects are important as is including fine sediment inputs in area that have issues like the Scott and Beaver Creek, however, we need to keep in mind that not all sediment is bad when the proper balance is maintained. | In response to this and other comment on this issue, we have modified the language in this paragraph to refer to the objective of reducing inputs of "excess sediments" in order to achieve a more natural sediment input balance, and we have also added a description of how desirable sediment input conditions vary by stream and species (salmonids vs. lamprey). |
| Karuk Tribe DNR<br>__________<br>Quartz Valley Indian Reservation | 6 | Pg 265: L 25 | Karuk Tribe has decommed in Bluff Creek as well. | Revised to include Bluff Creek in this list. |
| KBMP | 6 | Pg 273: L 7 | This is a good place to note that the PCSRF definitions of water quality project work types are not generally consistent with the types of water quality improvement restoration projects in the basin (reducing water temperature through shading and tailwater projects, reducing nutrient inputs through riparian protections and improved on farm management of soils and runoff, etc.<br>I don't say this to oppose the PCSRF definition or use of the PCSRF database categories, just to note that these Work Type categories were developed at a national level and don't reflect the bulk of work done in the basin to improve WQ, which are less driven by sewage and toxin cleanup efforts, stormwater projects, and industrial return flow projects.. Perhaps noting this is the PCSRF definition here, then in the following paragraph, expand on the list where it mentions projects are covered in previous sections. | In response to this comment, we have added a caveat further discussing the distinction between the PCSRF definition of water quality projects and the broader range of project types that could benefit water quality in both Section 5.2, where the category of Water Quality Projects is first described, and at the beginning of Section 6.5.7, where it is defined again: "It is important to stress that the PCSRF classification of water quality projects is defined primarily by the type of physical work, rather than the stressor being addressed, and that many other types of restoration work described in this section (e.g., riparian habitat restoration, upland habitat management) also contribute to water quality improvements as shown in Table 5 1." |

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| | | | | We also call greater attention to Table 5-1, where we demonstrate how each category of restoration action yields potential benefits for a broad range of stressors. |
| KBMP | 6 | Pg 274: L 1 | …beyond the pilot scale… PacifiCorp has performed pilot projects using chemical treatment and aeration to control algae in project reservoirs. | Revised paragraph to include this statement. |
| Klamath Tribes | 6 | Pg 274: L 15 | $30 million and $150 million (Stillwater Sciences et al. 2013).- I would recommend talking to TNC and updating this number to reflect what they actual spent for restoration and plan to spend for O&M for the Williamson Delta. | We contacted Amy Campbell to obtain this information and revised the paragraph. |
| Karuk Tribe DNR<br>___________<br>Quartz Valley Indian Reservation | 6 | Pg 275 | The paragraph on Algal Filtering includes some inaccuracies (i.e., focus on toxic algae, erroneously stating the technology has high cost, and mistaken locations) and does not include recent information. We suggest replacing it with the following paragraph:<br>"Filtering systems have been proposed as a restoration solution to address the prolific phytoplankton blooms from Upper Klamath Lake currently affecting the Keno Dam impoundment (Stillwater Sciences et al. 2013). A barge-based algae filtering system is already in intermittent use on Upper Klamath Lake to collect and refine some species of algae for commercial use as a dietary supplement. As part of KHSA implementation, the inter-agency Interim Measures Implementation Committee (IMIC) and a local algae harvest company evaluated the potential of an algal biomass removal system at the outlet of Upper Klamath Lake to remove nutrients and improve dissolved oxygen in the Keno Dam impoundment (CH2M 2016, 2017). The collected biomass could in turn be reused, depending on its toxicity, for human or animal dietary supplements, biofuels, soil amendment, compost, or landfill (Stillwater Sciences et al. 2013, CH2M 2016). Although the mechanics of this approach are understood, it remains unknown how much algae would need to be removed to significantly improve water quality. Regulatory agencies expressed concerns about the potential impact of algal biomass harvesting on endangered suckers (CH2M 2016, 2017). Due to these substantial regulatory hurdles, and the lack of a secure funding source for ongoing operating and maintenance costs, the IMIC decided not to continue evaluation of this technology (CH2M 2017). If these issues could be resolved, algal biomass removal could be the most cost-effective means to directly improve dissolved oxygen in Keno Reservoir in the interim period (i.e., years to a few decades) while waiting for watershed restoration in Upper Klamath Lake's tributaries to reduce phosphorus loading and diminish algal blooms. All IMIC project materials have been documented and are available for future use if the regulatory or funding environment changes (CH2M 2016, 2017)."<br>Full citations:<br>- CH2M. 2016. Technical Memorandum: Interim Measure 11, Activity 7 – Assessment of Potential Algae Harvesting and Removal Techniques at Link River Dam. Prepared for PacifiCorp by Ken Carlson and Brittany Hughes, CH2M. https://www.pacificorp.com/content/dam/pacificorp/doc/Energy_Sources/Hydro/Hydro_Licensing/Klamath_River/2016-IM11-Act7TRptF(7-12-16).pdf<br>- CH2M. 2017. Klamath River Hydroelectric Project Interim Measures Implementation Committee: Interim Measure 11, Link River Algae Removal Demonstration Project: Phase 1 Final Report. Prepared for PacifiCorp by CH2M, Portland, Oregon. https://www.pacificorp.com/content/dam/pacificorp/doc/Energy_Sources/Hydro/Hydro_Licensing/Klamath_River/2017-7-5_IM11LinkAlgaeRmvlPh1FinalRpt.pdf | Revised as requested - thank you for providing suggested text and supporting references. |
| Klamath Tribes | 6 | Pg 275: L 16 | Algal Filtering: This has more or less been shelved because the permitting process would be too onerous. *I can provide a report illustrating this, or Demian Ebert from PacifiCorp could provide further details.* | This paragraph has been updated with suggested text from the Karuk Tribe DNR and Quartz Valley Indian Reservation which addresses the regulatory hurdles and decision not to continue the work. |
| KBMP | 6 | Pg 275: L 19 | These blooms cause stressful or lethal dissolved oxygen and pH levels for aquatic species both within and downstream of Upper Klamath Lake. Additionally, some species also produce cyanobacterial toxins which can impact | Revised paragraph to include this statement. |

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| | | | public health and be an additional stressor on aquatic species… [From Stillwater Sciences 2013] | |
| KBMP | 6 | Pg 276: L 12 | On farm water conservation projects would be classified under the PCSRF as Instream Flow, not WQ so this statement and the example below are not a relevant comparison. water conservation | Noted, we have retained a brief mention that there may be additional projects under EQIP that benefit water quality, but have removed the rest of the statement and example on this topic which is more related to water quantity. |
| KBMP | 6 | Pg 276: L 2 | …benefit (as defined by the PCSRF Data Dictionary),…<br>My point here is that the PCSRF definition for Water Quality as a category is painfully narrow. One of the best projects we could do for water quality improvement is riparian restoration with fencing, yet this is categorized differently… I digress but feel the qualifier above is important. benefit | In response to this comment, we have added a caveat further discussing the distinction between the PCSRF definition of water quality projects and the broader range of project types that could benefit water quality in both Section 5.2, where the category of Water Quality Projects is first described, and at the beginning of Section 6.5.7, where it is defined again: "It is important to stress that the PCSRF classification of water quality projects is defined primarily by the type of physical work, rather than the stressor being addressed, and that many other types of restoration work described in this section (e.g., riparian habitat restoration, upland habitat management) also contribute to water quality improvements as shown in Table 5 1."<br><br>We also call greater attention to Table 5-1, where we demonstrate how each category of restoration action yields potential benefits for a broad range of stressors. |
| KBMP | 6 | Pg 277: L 16 | Any follow up studies on this to show it was a short term phenomenon? Heather Hendrixson from TNC should know. This phosphorous pulse is expected to be a short-term phenomenon, and the expectation is that the wetland would eventually reach equilibrium and begin retaining nutrients again (Wong et al. 2011). | We have already provided some information on follow-up studies below this statement, but have now clarified to indicate that phosphorous levels have leveled off to surrounding concentrations by 2013: "Ongoing project monitoring found total phosphorous concentrations in 2012 were 2.5 times lower in shallow water habitats and 2 to 4 times lower in open water, deep water, and lake habitats that at the onset of monitoring at project completion in 2008 and is now considered to have leveled off to surrounding concentrations. Overall, the project is considered to have successfully reduced nutrient loading to Upper Klamath Lake while also restoring natural hydrologic regimes to the site and providing wildlife habitat (TNC 2013)." |
| KBMP | 7 | Pg 278: L 19 | This is an overly optimistic and broad characterization. The phrase 'rely on healthy ecosystems to sustain crops and livestock' doesn't seem to fit with reliance on chemical fertilizers, pesticides, herbicides, and how farmers often oppose riparian protections, etc. farmers who rely on healthy ecosystems to sustain crops and livestock but worry about how fish restoration efforts will affect their need for a predictable water supply | Changed "rely on" to "benefit from". |
| Salmon River Restoration Council | 7 | Pg 283: Figure 7-2 | Frequency and spending for PCSRF habitat monitoring projects by start year (n=92). With no mention of the reason for the decline, this would leave someone from the general public to assume that monitoring is less important each year. In other words…is this budget decline, shifting priorities, lack of beneficial data from monitoring, etc? | Added text: "Note that Figure 7-2 is based on the data available in the PCSRF database, which does not indicate reasons for the decline in frequency and spending. Possible reasons include changing budgets, shifting priorities, inability to achieve data objectives via existing projects, and higher program startup costs relative to ongoing program maintenance costs." |
| KBMP | 7 | Pg 284: Figure 7-3 | Use of points in series B is unnecessary since they are shown in A and B only deals with time. Suggest removing in B. Figure 7 3 | Keeping the dots makes it easier for readers to view in relation to the underlying choropleth data. |
| Quartz Valley | 7 | Pg 286: L 10 | The temperature monitoring is actually a coordinated effort between USFS and Karuk Tribes and I think SRRC as | Revised. |

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| Indian Reservation/Karuk Tribe DNR | | | well. | |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 7 | Pg 286: L 10-14 | Karuk disagrees that there are any actual reference streams in the Klamath due to legacy mining effects, over a century of forestry mismanagement, and catastrophic fires. | Changed sentence to: "The U.S. Forest Service conducts ongoing monitoring of water quality (sediment and temperature) in USFS designated reference streams and managed streams across the Klamath National Forest (KNF), as well as base flow conditions in Mid Klamath tributaries. USFS designated reference streams show very little, if any, sign of human management and serve as a baseline for comparison with managed stream conditions. " |
| KBMP | 7 | Pg 286: L 29 | WQ monitoring info missing. Similar to Karuk note below (part of KHSA) and other monitoring is done as well. Suzanne Fluharty is a good contact. 707-482-1822 x 1013 or sfluharty@yuroktribe.nsn.us. | Revised. |
| KBMP | 7 | Pg 286: L 33 | …water quality,…Need to mention the Tribe's involvement in WQ monitoring as part of KHSA. Contact Susan Fricke for details if she hasn't commented on this. | Revised. |
| Hoopa Tribal Fisheries | 7 | Pg 286: L 39 | begs the question...who would you like to work with here at Hoopa Tribal Fisheries to develop information on the Tribe's efforts? Efforts of the Fisheries Department and of the Tribal EPA overlap with those of our Department of Forestry in monitoring streamflow, water quality, fish habitat, fish populations and more. | Revised |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 7 | Pg 287 | Tribal Agencies and Programs section:<br>- Add section for Quartz Valley Indian Reservation: "Quartz Valley Indian Reservation's Environmental Department monitors stream flow, water temperature, nutrients, and bacteria at approximately 10-20 sites in the Scott River sub-basin (QVIR 2013). QVIR also monitors groundwater levels within Quartz Valley and operates a continuous water quality probe which measures water temperature, D.O., pH, and conductivity at the USGS gage on the Scott River." Full citation: Quartz Valley Indian Reservation (QVIR). 2013. Water Quality Monitoring and Assessment Report 2013. Prepared by the QVIR Environmental Department Staff. Fort Jones, CA. 41 p. | Revised; citation added. |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 7 | Pg 287 | Add section here for Yurok Tribe Environmental Program: "The Yurok Tribe Environmental Program (YTEP) monitors nutrients, phytoplankton (including toxic cyanobacteria for public health purposes), and continuous water quality (water temperature, D.O., pH, and conductivity) at several sites on the mainstem Klamath River as well as the mouth of the Trinity River (YTEP 2013a, 2013b). YTEP also operates streamflow gages in several lower Klamath tributaries." Full citations:<br>o Yurok Tribe Environmental Program (YTEP). 2013. Final 2012 Klamath River Nutrient Summary Report. Prepared by Matthew Hanington and Kathleen Torso. YTEP Water Division, Klamath, CA. 56 p. http://www.yuroktribe.org/departments/ytep/documents/FINAL2012NutrientReport073013.pdf<br>o Yurok Tribe Environmental Program (YTEP). 2013. Final 2013 Klamath River Continuous Water Quality Monitoring Summary Report. Prepared by Matthew Hanington. YTEP Water Division, Klamath, CA. 59 p. http://www.yuroktribe.org/departments/ytep/documents/2012_sonde.pdf | Revised; citations added. |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 7 | Pg 287: L 16 | citations for the Klamath Tribes long-term monitoring are:<br>- Kann, J. (2017). Upper Klamath Lake 2016 Data Summary Report. Technical Memorandum Prepared by Aquatic Ecosystem Sciences LLC for the Klamath Tribes Natural Resources Department, Chiloquin Oregon. 79 p. May 2015<br>- Kann, J. (2017). Upper Klamath Lake tributary loading: 2016 data summary report. Technical Memorandum Prepared by Aquatic Ecosystem Sciences LLC for the Klamath Tribes Natural Resources Department, Chiloquin Oregon. 55 p. May 2015 | References added. |
| Hoopa Tribal Fisheries | 7 | Pg 288: Figure 7-4 | Figure 7-4 is missing a great deal on information from Trinity Basin. Much should be easy to get through staff at Trinity River Restoration Program. | The figure is shows KBMP data only. This is clearly stated in the figure caption and preceding text. The fact that Trinity data are missing from the KBMP dataset is something that should be flagged with Randy Turner. A |

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| | | | | limitation of the KBMP dataset is that it is reliant on survey responses. |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 7 | Pg 288: L 34 | Please expand this section. There are 2 programs at DNR that conduct monitoring related to fish and water: Fisheries and Water Quality. Each have separate monitoring priorities, locations, and parameters. Fisheries focuses on monitoring base flows and temperatures in tributaries to the mid-Klamath and also assist with fish health monitoring, carcass surveys, outmigrant trapping, and adult spawner surveys (among others, check with Toz). The WQ program monitors over 130 miles of the mainstem Klamath along with the mouths of the Salmon, Scott, and Shasta Rivers. They run real-time sondes at 3 mainstem sites and the 3 tributary sites that collect temperature, DO, pH, conductivity, turbidity, and phycocyanin. The real-time and historic data is available at: waterquality.karuk.us. They also sample nutrients, phytoplankton, algal toxins, and other parameters for baseline and public health monitoring needs and assist OSU with fish disease water sampling.<br>Note: that other than USGS measuring flow on the mid-Klamath, we are the only agency/entity monitoring water quality on over 130 miles of river, so it is very troubling when the authors diminish the monitoring programs of the Karuk Tribe and other Tribes in the basin.<br>Note: There could also be mention of the Klamath Tribal WQ Consortium as the 5 tribes coordinate WQ monitoring, QAPP's, SOP's to ensure that data is comparable as far as procedures and labs and that the data can be used effectively to analyze trends for regulatory processes such as TMDL development and implementation, 401's, and other Tribal, state, and federal processes. | Revised. |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 7 | Pg 288: L 38 | Add sentence to end of paragraph: "The Karuk Tribe monitors nutrients, phytoplankton (including toxic cyanobacteria for public health purposes), and continuous water quality (water temperature, D.O., pH, and conductivity) at several sites on the mainstem Klamath River as well as the mouths of the Shasta, Scott and Salmon Rivers (Karuk Tribe 2013). Real-time and archived continuous water quality data are available online at: http://waterquality.karuk.us:8080/". Full citation: Karuk Tribe of California. 2013. Water Quality Assessment Report 2013. Karuk Tribe Department of Natural Resources, Orleans, CA. 33 p. http://www.karuk.us/images/docs/wqdocuments/2013WQAR.pdf | Revised as suggested. |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 7 | Pg 288: L 40 | Here is some partial information to add regarding the Hoopa Valley Tribe's water quality monitoring: "The Hoopa Valley Tribe monitors nutrients, phytoplankton, and periphyton in the Klamath River at Saints Rest Bar and the Trinity River at Hoopa (HVTEPA 2013)." There is some additional information at: http://www.hoopatepa.org/water.html. Full citation: Hoopa Valley Tribal Environmental Protection Agency (HVTEPA). 2013. Water Quality Monitoring by the Hoopa Tribal Environmental Protection Agency 2008-2012. Prepared by the Hoopa Tribal Environmental Protection Agency in cooperation with Kier Associates. 21p. http://www.hoopatepa.org/hoopa_2013_WQreport20082012_final.pdf. | Revised. |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 7 | Pg 289 | 7.2.3 klamathwaterquality.com has WQ, public health, fish disease, etc documents published by Tribes. please make sure these resources are included. | Site added to document library. |
| Salmon River Restoration Council | 7 | Pg 289: L 26-27 | and population monitoring projects surveyed in 2015 - the highest quality annual dataset to date (Randy Turner, person… Not sure I agree with that statement. Nick Hetrick? KBMP is more of a directory TO websites that contain data, not a warehouse of data itself. | KBMP is also a database, but will clarify "highest quality annual dataset gathered by KBMP to date…" |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 7 | Pg 290: Box 7-1 | Box 7-1 Should include the algae tracker tool too | Added text: "Also on the website, KBMP maintains the Blue-Green Algae Tracker tool as part of an early warning system for toxic algal blooms along the mainstem Kalmath River and upper Klamath Lake." |
| Quartz Valley Indian | 7 | Pg 290: Box 7-2 | Box 7-2 Not sure the point of this box since the KBRA is defunct. "extensive monitoring" does not prevent excessive drawdown of ground water. Agencies have to regulate water users for that to happen. How about instead highlight the | Added sentence: "While the Agreement is no longer active, it is important to acknowledge its content and intent as a guide to future efforts." |

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| Reservation/Karuk Tribe DNR | | | Tribal WQ Consortium's work and their website klamathwaterquality.com? | |
| Hoopa Tribal Fisheries | 7 | Pg 291 | Section 7.2.5 is thin in regards to Trinity River fish monitoring efforts, which are substantial. | Revised. |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 7 | Pg 291: L 5 | This monitoring effort will end when the license for the dams is transferred or if KHSA ends. This makes it sound like the effort is ongoing. | Added text: "Note that if the KHSA ends or if the license for the dams is transferred, PacifiCorp monitoring efforts under this program will discontinue." |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 7 | Pg 292 | Phytoplankton, periphyton, and algal toxins are an important component of all monitoring plans for the Tribes and PacifiCorp. | Revised as suggested. |
| Salmon River Restoration Council | 7 | Pg 295 | Spring-run Chinook and summer steelhead census snorkel surveys have occurred on the Salmon River since 1986. Spring Chinook spawner surveys have been led by the Salmon River Restoration Council, with assistance from community volunteers, the Karuk Tribe and the Klamath National Forest when available. The SRRC has been conducting water temperature monitoring on the Salmon River since the early '90's. We are currently conducting long term temperature and flow trend analysis with the help of Riverbend Sciences. The report should be out soon.<br><br>There should be a pace holders added for water quality monitoring, and fisheries census surveys, and other fisheries monitoring for the Salmon River Restoration Council | Revised as suggested. |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 7 | Pg 301: L 19 | The Karuk Tribe conducts spawner surveys, carcass surveys, outmigrating juvenile trapping, fish disease monitoring, and runs pit tag arrays for coho. Also have done cold water refugia work and monitored off channel ponds for coho use/abundance and pit-tagged and tracked adult coho and lamprey. | Revised. |
| Quartz Valley Indian Reservation/Karuk Tribe DNR | 7 | Pg 309: L 3 | Some information on effectiveness monitoring of off-channel ponds is available in master's theses by Shari Witmore and Michelle Krall:<br>- Witmore, S.K. 2014. Seasonal Growth, Retention, and Movement of Juvenile Coho Salmon in Natural and Constructed Habitats of the Mid-Klamath River. Thesis, Humboldt State University. http://scholarworks.calstate.edu/handle/10211.3/124018. Accessed 10 Feb 2016.<br>- Krall, M.R. 2016. The Influence of Habitat Characteristics on Abundance and Growth of Juvenile Coho Salmon Oncorhynchus Kisutch in Constructed Habitats in the Middle Klamath River Basin. Thesis, Humboldt State University. http://scholarworks.calstate.edu/handle/10211.3/177109. Accessed 5 Jul 2017. | Revised. |
| The Nature Conservancy- CA | 7 | General | I didn't look at this section too closely but was curious where the groundwater monitoring fits in? I didn't see any reference to SGMA or the Scott River Watershed's Groundwater Monitoring Program. Maybe I missed it. As you likely know, SGMA divided the Shasta watershed into half- which has resulted in the part of the watershed that is the driver for cold springs being OUTSIDE of any regulation by SGMA. This a significant mistake and in the future this fractured bedrock component of the Shasta needs to be incorporated into SGMA and included in future groundwater monitoring for the Shasta. | Not included in final report |
| Salmon River Restoration Council | 7 | General | Spring-run Chinook and summer steelhead in the Salmon River snorkel surveys has occurred for since 1986, For the past several years it has occurred in one day. This type of monitoring should be discussed in the IFRMP. | Revised. |
| Salmon River Restoration Council | 7 | General | Document spanning comment: There are several Placeholders throughout the document. Difficult to provide comments in these sections. | Several attempts to gather information from individual agencies were not successful. One last attempt for each placeholder was made and if no response we just indicated the existence of the agency and their general |

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| | | | | role in monitoring where possible. |
| Karuk Tribe DNR | 8 | Pg 321: Table 8-3 | Seems like an excessive explanation of adaptive management.<br>Table 8-3 For the Klamath some of the same people for different agencies might be in both the management and technical roles<br>8.4.1 The Elwha is referenced here but have you also looked at lessons learned from dam removal published by those at the Powell Center? Chauncey Anderson from USGS would be a good contact for very recent publications on this issue.<br><br>Page 369 line 16. Recommended addition to end of second paragraph in the Develop a Data Management Plan section: "The plan should leverage existing data compilations. For example, Klamath Tribal Water Quality Consortium has compiled a database of Klamath Basin stream temperatures which includes more than 28 million individual measurements from more than 4,300 site-years, collected by entities including the U.S. Forest Service, Salmon River Restoration Council, Yurok Tribe Environmental Program, Yurok Tribe Fisheries Program, U.S. Fish and Wildlife Service, Karuk Tribe, Quartz Valley Indian Reservation, U.S. Bureau of Land Management, and the California Department of Fish and Wildlife." | Thank-you. We will review lessons from Powell Center and connect with Chauncey Anderson as we move forward with future steps in Plan development.<br><br>We agree that leveraging existing data compilations would of course be essential to any data management strategy. |
| US Geological Survey, Oregon Water Science Center | 8 | Pg 339: L 14-27 | p. 339: L 14-27. Given the various processes already underway in the basin, including especially dam removal which is looming rapidly and has large potential consequences, some timelines and proposed sequencing of these steps and associated needs would be helpful here.<br>p. 339, L 19: Key uncertainties translate to data gaps. Again with the immediacy of dam removal in mind, identifying these key uncertainties as they relate to dam removal, and how they translate to things like baseline data, are critically needed in the short run. How will this be accomplished, and what will the decision making processes be associated with prioritizing the key uncertainties? | We reviewed how the report summarizes what the specific next steps are in Plan development, and ensure this is clear. However, we will not be in a position in the Synthesis Report to provide *specific* timelines. Timelines follow in future stages of Plan development.<br><br>We completely agree that identification of data gaps and key uncertainties is essential. This is made abundantly clear at various points throughout the document, and, these steps are central to future Plan development tasks. However, specific details are beyond the scope of the Synthesis Report. |
| US Geological Survey, Oregon Water Science Center | 8 | Pg 340: L 40 | p. 340, L~40. Another benefit for the Elwha plan was the link from management consideration to monitoring actions, which helped managers understand the need for specific information.<br>p. 341. L 6-8: This is critical for the dam removal and needs to get going ASAP.<br>p. 341, L 14-17: Can you give examples why this type of error is important to managers? E.g. so that estimates of sediment evolution from the reservoirs can be accurate in evaluating how much sediment is still available for erosion, or for assessing effects on downstream habitat?<br>p. 340., L 29. Is there adequate information on expanded habitat range to assess its suitability for the fish that we think will use it?<br>p. 341, L 6-9. As you stated, this will likely be iterative. It will also likely require different, subsystem-specific conceptual models. E.g. there are several such models for dam removal that could be adapted for the Klamath Basin. These could be very different in form and content than a conceptual model for the entire "Klamath Basin".<br>p. 341, L 21-22: I agree, but there are parallel process issues, and "restoration" actions that are focused on aspects other than fish. E.g. TMDLs, and more details of water quality. It's also important for the CM's to include measureable parameters, or link specifically to them, to help identify information needs. | For points of clarification we will make these revisions / tempering or qualifying statements.<br><br>Bulk of responses are commentary and advice, largely supportive of existing themes and planned intent.<br><br>MR-1 addresses issues of water quality. |
| US Geological Survey, Oregon Water Science Center | 8 | Pg 344: L 10 - 11 | This is going to be a challenge. This particular report and process is focused on fisheries, but WQ and other aspects (tribal health) are also critical. We need a process to accommodate some of these parallel concerns. | Please refer to MR-1. |
| US Geological | 8 | Pg 349: Table | p. 349, Table 8-6. This is a decent table and set of steps. Where in this process would critical baseline data needs, | Baseline data collection needs would be identified under the definition of |

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| Survey, Oregon Water Science Center | | 8-6 | e.g. prior to the restoration action(s), be identified? In the case of dam removal, there is decreasing time, and therefore increasing urgency, to characterize baseline data. In section 2 of the table, I would also argue that scope should include topical or programmatic areas of interest and inclusion. E.g. clearly delineate and define what issues are covered and, equally important, what ones are not. Also in section 2, Alternatively, is there a specific condition that might be achieved that would allow monitoring to be scaled back or stopped, or conversely that might trigger additional monitoring and surveying? I.e. decisions based on time durations might be arbitrary.<br>Table 8-11. As an example this table is fine, but within it there are many issues, depending on what the operative questions are for the "metric" of choice.<br>p. 365. This is more easily said than done, especially where existing programs have methods that the responsible agencies are reluctant to change for fear of introducing new biases into longer term processes. | candidate restoration actions and assessments for the reference condition and planning phase. We agree that in short-run, given decreasing time, this is an important priority. There are also some parallel processes underway with the KBRC that we will coordinate with to ensure synergy and efficiency (avoid duplication of efforts).<br><br>Bulk of responses are commentary and advice, largely supportive of existing themes and planned intent.<br><br>We agree that development of a Plan of this magnitude, with the many competing objectives and high stakes is a challenging (but worthy) undertaking. |
| KBMP | 8 | Pg 359: Table 8-11 | Table 8-11 Sub-basin names needed.<br>Recommendations from Royer 2011 not updated in 2016 report so some are outdated. This chart needs to be revised. Please contact me if this is a priority so I can dedicate some KBMP resources towards this. of monitoring gaps. | Actually conducting a gap analysis is out of scope for the Synthesis Report. Table 8-11 was by design an example only. Gap assessment is proposed as an important step in future stages of Plan development. |
| Quartz Valley Indian Reservation | 8 | Pg 369: L 16 | Recommended addition to end of second paragraph in the Develop a Data Management Plan section: "The plan should leverage existing data compilations. For example, Klamath Tribal Water Quality Consortium has compiled a database of Klamath Basin stream temperatures which includes more than 28 million individual measurements from more than 4,300 site-years, collected by entities including the U.S. Forest Service, Salmon River Restoration Council, Yurok Tribe Environmental Program, Yurok Tribe Fisheries Program, U.S. Fish and Wildlife Service, Karuk Tribe, Quartz Valley Indian Reservation, U.S. Bureau of Land Management, and the California Department of Fish and Wildlife." | We agree that leveraging existing data compilations would of course be essential to any data management strategy. We have mentioned examples of existing data holdings beyond KBMP mentioned. |
| Karuk Tribe DNR | 8 | | Not supportive of the focal species focus. Focal species=only fish species proposed, no amphibians, macroinvertebrates, mussels, etc have been proposed as a focal species. By focusing on focal species, a whole part of the ecosystem is downplayed, particularly food web dynamics. For example, the responses of key macroinvertebrate and periphyton species to restoration actions might be much quicker and dramatic than waiting for a focal (fish) species to adjust. This is why there need to be a variety of response mechanisms for assessing restoration actions and adaptive management other than focal species. It will allow for more real-time adaptive management than focal species alone. | The focal species that are identified represent species we are contractually obligated to emphasize in the Synthesis Report. However, this focal species approach should not be narrowly interpreted as "only fish" (and see MR-1). To the extent that restoration actions can be compellingly linked to improvements in focal species fish condition, survival, productivity, genetic diversity and abundance -- those attributes and food web features may indeed be potential targets for restoration. There are also a variety of key research assessments that will need to be identified, pilot studies, and the associated monitoring programs established as the Plan is developed. As discussed in chapter 8, a prioritization framework also needs to be developed. Fundamentally, every natural resource management program must constrain efforts to avoid the paralysis that comes with trying to cover 'everything'. |
| Karuk Tribe DNR | 8 | | I feel like after reading through and attempting to process this giant document, I am unable to constructively comment on the proposed actions and timelines in the IFRMP. To me it feels more like before this document is final, there needs to be a meeting to discuss through the timelines and suggestions in Section 8 and how we all would envision this moving forward as a whole instead of commenting individually. | The Synthesis Report is only the beginning of the planning process. Future stages of Plan development will address priorities and timelines. |
| Hoopa Tribal Fisheries | 8 | | Section 8.2.2 on governance "best practices" has us thinking of what Buzz Holling said to us following an AFS session on adaptive management.<br><br>When we asked "why do most AM projects fail?" he responded "because there is not a fully informed, authorized and | No action is required to formally respond *in the Synthesis Report*. Section 8.2.2 and 8.5 already surface constructive suggestions on this matter. The reviewer's feedback generally supports the suggestions made. |

| Organization | Section | Page and Line | Comment | Draft Response |
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| | | | adequately resourced leader". Sounded like the truth to us.<br><br>We have for years promoted (formally proposed) a Joint Directorate for Klamath-Trinity science; this group would develop a unified approach to restoration, harnessing their combined legal authorities. Somewhere in the Plan to be written eventually, or in a parallel document, there belongs a section identifying the benefit of unified governance. To us this stands as indispensable to successful AM.<br><br>Section 8.5 speaks to a critical, first step in developing effective restoration actions | |
| Karuk Tribe DNR | 8 | General | Instead of effectiveness monitoring on a project by project basis (which is often inefficient and ineffective), the basin would benefit by prioritizing a coordinated basin-wide monitoring effort to track status and trends. This network is mostly in place for water quality through the Klamath Tribal WQ Consortium, KBMP, and other working groups but funding needs to be prioritized to support these efforts beyond the soon to end KHSA. | The Synthesis Report identifies the role and importance of both status and trend and effectiveness monitoring. Rather than "instead of", we recommend "both". Effectiveness monitoring would be targeted at classes of restoration actions rather than all individual projects. |
| Hoopa Tribal Fisheries | 1.4.4 | Pg 22: L 5 | The description of the role of the Hoopa Valley Tribe in fisheries management. We feel it is of fundamental importance to describe the Tribe's unique co-management jurisdiction regarding the Trinity River Restoration Program; the Tribe enjoys a federally-legislated concurrence authority alongside Department of Interior. The Tribe stands alone in this relationship to federal authorities. | Text modified to make it clearer the Hoopa Valley Tribe's co-management role in relationship to the Trinity River Restoration Program. |
| Bureau of Land Management - Klamath Falls Resource Area | 1.4.5/Exec. Summ | Pg 23 | The executive summary/introduction list federal agencies that manage resources within the Klamath River watershed, but doesn't mention BLM.<br>Section 1.4.5, page 23 - again need to add BLM to the federal agencies. Robert Roninger attended meeting and will be BLM representative. | Oversight. We will add BLM to the list of federal agencies and ensure Robert Roninger continues to be part of our master contact list. |
| USFWS | 1.6.3 | Pg 33 | It is the Secretary of the Interior's expectation that FERC will support the KRRC's That statement may not be true with the newly appointed Secretary of Interior | The last sentence on p. 33 has been deleted. The sentence on pg. 34 was modified to read: "It was at the time the former Secretary of the Interior's expectation (in October 2016) that FERC will support the KRRC's detailed decommissioning and removal plan once these detailed plans are further fine-tuned (USDI 2016)." |
| CDFW - Northern Region | Appendix B | Pg 414 | Habitat: Lost River ("need I say more") - comment: yes. | The table is a consolidation of participant comments from the workshop. The statement is a direct transcription. I left it in to communicate that the participant did not elaborate. |
| KBMP | Appendix B | Pg 414: Figure B-2 | If you note the proportion, I'm not seeing a description of why that is relevant. | These are simply a reporting of workshop participant comments - not statements by ESSA. |
| KBMP | Appendix B | Pg 414: Figure B-2 | These stressors don't align with the PCSRF data dictionary. This is where the disconnect with the PCSRF definition of WQ comes into play. | These are simply a reporting of workshop participant comments - not statements by ESSA. The stressor categories were intentional as part of the workshop design to facilitate discussion. |
| KBMP | Appendix B | Pg 432 | Representation and participation: Speaking of representation, I'll add a comment now that water quality issues in this document are not properly represented as a driver of fish stressors and a bottleneck to recovery. Until issues related to hypereutrophic conditions and associated algal blooms in UKL and the impacts to WQ downstream are addressed, we run the risk of introducing fish into a system that will not support temperature and dissolved oxygen requirements at critical times of the year. If a trap and haul program is proposed for Keno, this is far from the ecosystem recovery approach that is advocated in the document. | See response MR-1, found at the beginning of this appendix, which is related to overarching issues with water quality in this report. |
| CDFW - Northern Region | Appendix F | Pg 488 | "Appendix F: Line 3: federal level, - comment: Not including state law? | Appendix F focuses on Federal laws. Review of State laws is a broader subject beyond scope of Appendix F. |
| KBMP | Appendix G | Pg 445 | Data Assembly Structure and Assumptions: This is an incredibly important database and one that I hope can be shared publicly. Besides making this public, having a tool to help summarize data beyond what the PCSRF can do would be extremely helpful to fish managers, regulatory agencies, and restoration planners. If this is beyond the | This comment is out of scope of the current report but provides an appreciated perspective on how the data collected here could be leveraged in the future. |

| Organization | Section | Page and Line | Comment | Draft Response |
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| | | | scope for ESSA/IFRMP, we are working on something that could help…<br><br>The San Francisco Estuary Institute is working towards development of a dashboard for the EcoAtlas project database that has the capability of querying multiple databases to summarize all activities. This might address the issues related to the larger field of restoration data being stored in many databases that have different structures, etc. Conversations with Cedar and Joel Shinn with AFWO note the potential value of this type of web tool. The current funding for the dashboard does not cover this but it has been done for projects in Lake Tahoe. If there were funding to support a crosswalk of PCSRF fields to a set of agreed upon standardized categories related to performance measures, steps could be made to make data in this and other databases to be searched and summarized, without having to transfer data to a single database now or in the future. This would allow groups to continue to use their own databases, not have to enter data twice, and still be included in summaries. The value of this for adaptive management could be significant. Let me know if you would like a webinar presentation on the proposed dashboard. | |
| PacifiCorp | Appendix K | Pg 469 | Table: National Fish and Wildlife Foundation / PacifiCorp: This is actually out of date. As of December 2016, PacifiCorp has funded 38 projects with $3.9 million, leveraging an additional $7.4 million in matching funds. | This section has been updated with the information provided. |
| Karuk Tribe DNR | Overall | | Overall for the document: there is a lot of emphasis put on the NRC report although this report was somewhat controversial when it came out and didn't necessarily incorporate the most updated science or hypotheses about the basin. It also puts a lot of emphasis on TRRP as a template for the Klamath when I and many colleagues do not believe that the TRRP is a good model for the Klamath. | This is only a Synthesis document and was capturing available information. Also, the notion that we would use the TRRP as a model for the Klamath is not stated in the Synthesis Report. The Plan will be "made in Klamath" and developed collaboratively with local tribes, states, co-managers and interested participants. |
| Karuk Tribe DNR | Overall | | I think this was quite an undertaking and a very comprehensive document. However, I still feel as if this document is set up for the federal agencies to prioritize their habitat restoration goals instead of this being a comprehensive document that prioritizes equally water quality, water quantity, and habitat restoration to recover not only fish species but restore ecosystem health in the Klamath Basin. The use of fish only focal species adds to that narrow view. The critical role of the Tribes as watershed managers, researchers, and monitoring entities also seems to be downplayed in this document when the Tribes particularly in the mid and lower basin are conducting the majority or monitoring, research, and restoration actions. | The problems of the Klamath Basin are too large and complex for federal agencies to address alone. Independent experts have noted that restoration in the Klamath Basin has been done in "bits and pieces." The intent is to engage in a collaborative process where tribes, states, and other stakeholders have input and engagement via an adaptive management process to devise the best plan possible to restore Klamath Basin fisheries. The Synthesis Report was only a first step. The next phases are designed to address specific goals and objectives and begin to identify how best to deliver on-the-ground actions to improve Klamath Basin fisheries. |
| Hoopa Tribal Fisheries | Overall | | There is work to do in regards to Trinity, as in several sections it is apparent that Team Klamath was advising you, and Team Trinity not so much. We understand this is a huge undertaking, and that your focus was on Klamath outside of the Trinity; still, to make sense of the whole each part needs sufficient attention. | The appropriate level of integration between Trinity and Klamath will emerge during future Plan development steps, including work undertaken by subregional workgroups. |

# Appendix F: Document Library Description

The Document Library is designed to be highly searchable and user-friendly. Content can be found using text searches, Category filters and Focal Topic filters. Category filters isolate specific document types and include: Academic Articles, Conference Proceedings, Formal Agreements, Policy Reports, Presentations, Spatial Data, Statutes/Regulations, non-academic Studies, Tabular Data, Technical Memos, Technical Reports, and Websites. Focal Topic filters isolate common topics of interest (e.g., Adaptive Management, Coho, Dam Removal). Text search is also available on the main search page and searches all Titles, Focal Topics, metadata and abstract contents associated with each file. All returned results are sortable (e.g., by date, alphabetically) by clicking on the header row of the results table. Clicking on text corresponding to any Category or Focal Topic of interest filters the database accordingly. Selecting any record title will open a new page providing metadata and an abstract about the file as well as a hyperlink for full download if available. Some documents (e.g., academic articles, books) are copyright protected – in these cases we provided URLs to the source material so users can access if they have accounts or wish to pay for a file. Spatial data are a special case requiring adherence to the Federal Geographic Data Committee's Content Standard for Geospatial Metadata (FGDC-STD-001-1998) (NDSI 1998). Where these metadata are required, a separate file containing the information is provided. Figure A-1 shows the main search page of the Document Library, which is hosted by the Pacific States Marine Fisheries Commission (PSMFC) and can be accessed at: http://kbifrm.psmfc.org/document-library/

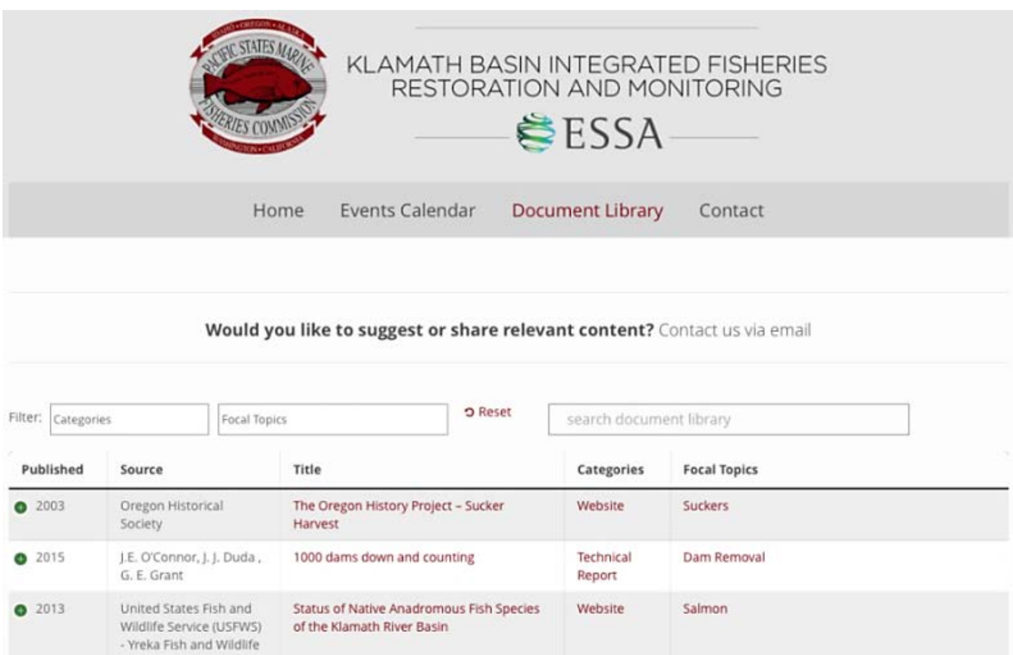



Figure A-1. Klamath Basin Integrated Fisheries Restoration and Monitoring Web-based Document Library

# Appendix G: Legislative Frameworks & Statutory Authorities for Fisheries

At the federal level, many U.S. laws have been passed by Congress that affect fisheries management issues in the Klamath Basin. These statutes are wide-ranging and give agencies the authority to engage in their conservation-oriented missions and fisheries management. Activities range from protecting endangered species, to promoting the sustainability of commercial fishing and the management of invasive species. There are laws that help the agencies (see Section 1.4) fulfill tribal trust responsibilities as well as those that help enhance recreational fishing and other public benefits of aquatic species. Some of the more notable legal and regulatory tools used by the federal agencies are briefly summarized below.

## *Endangered Species Act*

The U.S. Endangered Species Act (ESA) is the most comprehensive law any nation has enacted to protect imperiled species (Malcom and Li 2015) and it has been called the world's gold standard for environmental protection. President Richard Nixon signed the Act into law in 1973, where since it has strengthened federal protections for animals that had been nearly wiped out by humans, and has been the backbone of many success stories including enabling recovery of bald eagles, humpback whales and California condors. When Congress passed the Endangered Species Act (ESA) in 1973, it recognized that a rich natural heritage is of "esthetic, ecological, educational, recreational, and scientific value to our Nation and its people." It further expressed dire concern that many of the nation's native plants and animals were in danger of becoming extinct. The purpose of the ESA is to protect and recover imperiled species and the ecosystems upon which they depend. Achieving the balance between human interests and the needs of non-human communities' in some situations necessities restricting degradation and interference with certain critical habitats and lands that provide essential ecosystem services to the imperiled species.

The Interior Department's U.S. Fish and Wildlife Service (USFWS) and the Commerce Department's National Marine Fisheries Service (NMFS) administer the ESA. The FWS has primary responsibility for terrestrial and freshwater organisms, while the responsibilities of NMFS are mainly marine wildlife such as whales and anadromous fish such as salmon. Under the ESA, species may be listed as either endangered or threatened. "Endangered" means a species is in danger of extinction throughout all or a significant portion of its range. "Threatened" means a species is likely to become endangered within the foreseeable future. In the Upper Klamath Basin, two native fish, Lost River and shortnose suckers, are listed as endangered. The U.S. Fish and Wildlife Service oversees the management and regulation of these species. In the Lower Klamath Basin, coho salmon are also federally protected. They are a threatened species under ESA and are managed by NMFS.

Section 7 of the ESA requires all federal agencies to ensure that the actions they fund, authorize, or carry out are not likely to "jeopardize" a listed species or "destroy or adversely modify" critical habitat. Critical habitat includes geographic areas that contain the physical or biological features that are essential to the conservation of the species and that may need special management or protection. Federal agencies must consult with the FWS or the NMFS to fulfill this mandate. Consultations typically start as discussions between the Service and a federal agency to determine whether the agency's proposed actions may affect a listed species. This "informal consultation" ends if the Service determines that the activity is "not likely to adversely affect" a species. Otherwise, "formal consultation" is required. During formal consultation, the Service evaluates whether the proposed action will violate the prohibitions on jeopardy or destruction/adverse modification. If neither of these outcomes is likely but take is expected, then the Service will prescribe "reasonable and prudent measures" (RPMs) that are designed to minimize the effects of the action and the amount of take. If either jeopardy or destruction/adverse modification is likely, the Service must suggest "reasonable and prudent alternatives" (RPAs)—conservation measures that reduce or partly offset the harm from the proposed action, to avoid jeopardy or adverse modification. If no such alternatives are available, the action cannot proceed without violating the Act unless it is exempted by a special committee known as the "God Squad" (Malcom and Li 2015). Formal consultations end with a Service "biological opinion," which must be finalized within 135 d after formal consultation begins, unless an extension is agreed on.

In the Klamath Basin, the Bureau of Reclamation's Klamath Irrigation Project is an example of where Section 7 has come into play. This federal irrigation project was authorized by the Interior Secretary in 1905. The Project essentially involves the storage and conveyance of water in the Upper Klamath Basin. However, these operations impact listed fish – endangered suckers in the Upper Basin, and threatened coho salmon in the Lower Basin. Reclamation, however, must consult with FWS and NMFS to ensure these operations do not harm the listed species. During consultation the "action" agency receives a "biological opinion" or concurrence letter addressing the proposed action.

## *The Federal Power Act*

The Federal Power Act (FPA), 16 U.S.C. § 791-828(c), passed in 1920 and amended in 1935 and 1986, created the Federal Energy Regulatory Commission (FERC), an independent regulatory agency that provides licenses for non-federal hydroelectric plants, and addresses environmental matters. The agency is governed by a five-member commission appointed by the President with the advice and consent of the Senate, 16 U.S.C. § 792. The FPA authorizes FERC to issue exemptions or licenses to construct, operate and maintain dams, water conduits, reservoirs, and transmission lines to improve navigation and to develop power from streams and other bodies of water over which it has jurisdiction. 16 U.S.C. § 797(e). Most of the licenses issued by FERC before 1986 were issued with little or no attention to environmental protection (Hydroreform 2017). Consequently, many of the dam rental agreements in effect today were written decades ago when scientists and engineers did not understand the damage that poorly operated flow regimes and blocked passage did to aquatic organisms that depend on natural flow variation and bi-directional migration through the river corridor. A rich body of scientific theory and evidence now supports the natural flow paradigm which treats flow as the "master variable" needed to drive natural variation of hydrologic regimes to protect native biodiversity and the evolutionary potential of aquatic and riparian ecosystems (Arthington et al. 1991, 2006; Richter et al. 1996, 1997; Stanford et al. 1996; Poff et al. 1997; IFC 2002; Postel and Richter 2003; Tharme 2003; Petts 2009; Fleenor et al. 2010; Carlisle et al. 2010; Poff and Zimmerman 2010; Poff et al. 2010; Alexander et al. 2014).

Amendments to the FPA since 1986 have mandated several fish and wildlife provisions that require licenses to include conditions that protect, mitigate and enhance fish and wildlife affected by the project in consultation with the USFWS and NMFS and other state fish and wildlife agencies. Section 18 of the FPA states that FERC "shall require the construction, maintenance, and operation by a licensee at its own expenses of such…fishways as may be prescribed by the Secretary of the Interior or the Secretary of Commerce, as appropriate." 16 U.S.C. § 811. Section 18 gives authority to prescribe a fishway that, in FERC's judgment, is necessary to maintain all life stages of the fish impacted by the project (Hydroreform 2017).

Because FERC licenses are issued for terms between 30-50 years, relicensing is characterized as a "once in a lifetime" opportunity to restore many of the environmental and social values that characterized a river prior to existence of a dam. The Federal Power Act's requirements to including consideration of public and environmental values in licensing proceedings has provided river advocates with a major tool for conservation and restoration (Hydroreform 2017).

## *Magnuson-Stevens Fishery Conservation and Management Act (MSA)*

The Magnuson-Stevens Act (MSA) is the primary law governing marine fisheries management in U.S. federal waters. First passed in 1976, the Magnuson-Stevens Act (NOAA 2017) fosters long-term biological and economic sustainability of our nation's marine fisheries out to 200 nautical miles from shore. Key objectives of the Magnuson-Stevens Act are to (1) prevent overfishing; (2) rebuild overfished stocks; (3) increase long-term economic and social benefits; and (4) ensure a safe and sustainable supply of seafood. Prior to the MSA, waters beyond 12 nautical miles were international waters and fished by fleets from other countries. The 1976 law extended U.S. jurisdiction to 200 nautical miles and established eight regional fishery management councils (Councils) with representation from the coastal states and fishery stakeholders. The Councils' primary responsibility is development of fishery management plans (FMPs).

U.S. fisheries management is designed to be a transparent and robust process of science, management, innovation, and collaboration with the fishing industry. A scientific analysis of the abundance and composition of a fish stock (stock assessment) evaluates the stock to determine if a fish population is subject to overfishing or overfished. Using scientific data, Councils set annual escapement goals, catch limits, and if they are exceeded in a fishing year, accountability measures pre-determine the mechanism to respond.

For example, in the Klamath, the MSA updated the conservation objective for Klamath River **fall Chinook salmon**. Previously the conservation objective required at least 35,000 natural-area adult spawners. This was changed to a conservation objective reflecting the maximum sustainable yield escapement level of 40,700 natural-area adult spawners (PFMC 2012). Under the amendment, Klamath River fall Chinook salmon are considered overfished when the 3-year geometric mean spawning escapement falls below 30,525 natural-area adult spawners (PFMC 2012). The stock is managed through the implementation of a new control rule specifying that the predicted exploitation rate cannot exceed 68%, which represents a 5% reduction from the maximum fishing mortality rate threshold to account for scientific uncertainty. The control rule also specifies further reductions in the annual exploitation rate as abundance forecasts decrease (PFMC 2012).

As a result of the Magnuson-Stevens Act, the United States is working towards ending and preventing overfishing in federally-managed fisheries, actively rebuilding stocks, and providing fishing opportunities and economic benefits for both commercial and recreational fishermen as well as fishing communities and shoreside businesses that support fishing and use fish products.

## *Other Federal Statutes*

Other federal acts that may be relevant to the Klamath Basin fisheries management include the following:

**Anadromous Fish Conservation Act** (16 USC 757a-757g; 79 Stat. 1125) as amended -- Public Law 89-304, October 30, 1965, authorizes the Secretaries of the Interior and Commerce to enter into cooperative agreements with the States and other non-Federal interests for conservation, development, and enhancement of anadromous fish, including those in the Great Lakes, and to contribute up to 50 percent as the Federal share of the cost of carrying out such agreements.

**Central Valley Project, California** (16 U.S.C 695d-695j). The Emergency Relief Appropriations Act (Chapter 48, April 8, 1935; 49 Stat. 115) authorized expenditures of funds for various types of public works projects, including water conservation and irrigation. The Central Valley Project (CVP), a series of dams, reservoirs and canals in the San Joaquin Valley of California, was first established under this authority. This authority has been subsequently amended, with particular interest in fish issues as follows:

Public Law 674, enacted in 1954, declared use of water for fish and wildlife as a project purpose in addition to all other previously stated purposes.

P.L. 102-575, signed October 30, 1992 (106 Stat. 4600) included provisions to protect, restore, and enhance fish and wildlife and their habitats in the Central Valley and Trinity River basins. Objectives include addressing the impacts of the CVP on fish and wildlife resources and achieving a "reasonable balance among competing" water uses. (For more detail, see the entry on P.L. 102-575, the Reclamation Projects Authorization and Adjustment Act of 1992, particularly Title XXXIV, the Central Valley Project Improvement Act.)

**Central Valley Project Improvement Act Title 34** (Public Law 102-575). The purposes of this title are:

- to protect, restore, and enhance fish, wildlife, and associated habitats in the Central Valley and Trinity River basins of California;
- to address impacts of the Central Valley Project on fish, wildlife and associated habitats;
- to improve the operational flexibility of the Central Valley Project;
- to increase water-related benefits provided by the Central Valley Project to the State of California through expanded use of voluntary water transfers and improved water conservation;

- to contribute to the State of California's interim and long-term efforts to protect the San Francisco Bay/Sacramento-San Joaquin Delta Estuary;
- to achieve a reasonable balance among competing demands for use of Central Valley Project water, including the requirements of fish and wildlife, agricultural, municipal and industrial and power contractors.

**Coastal Wetlands Planning, Protection and Restoration Act** (16 U.S.C. 3951-3956) - Title III of P.L. 101-646 (16 U.S.C. 3951 et seq.; 104 Stat. 4779; enacted November 29, 1990) engages the Fish and Wildlife Service in interagency wetlands restoration and conservation planning in Louisiana. It also expands the administration of Federal grants to acquire, restore, and enhance wetlands of coastal States and the Trust Territories and authorizes the Director of the Fish and Wildlife Service to participate in the development and oversight of a coastal wetlands conservation program, and lead in the implementation and administration of a National coastal wetlands grant program.

**Estuaries and Clean Waters Act of 2000** (P.L. 106-457) - The act encourages the restoration of estuary habitat through more efficient project financing and enhanced coordination of Federal and non-Federal restoration programs. The Fish and Wildlife Service plays a role through the estuary habitat restoration partnership component. The law creates a Federal interagency council that includes the Director of the Fish and Wildlife Service, the Secretary of the Army for Civil Works, the Secretary of Agriculture, the Administrator of the Environmental Protection Agency and the Administrator for the National Oceanic and Atmospheric Administration.

**Federal Aid in Sport Fish Restoration Act** (16 U.S.C. 777-777k, 64 Stat. 430), as amended. This August 9, 1950, Act has been amended several times and is commonly called the Dingell-Johnson Act or Wallop-Breaux Act. It provides Federal aid to the States for management and restoration of fish having "material value in connection with sport or recreation in the marine and/or fresh waters of the United States." In addition, amendments to the Act provide funds to the states for aquatic education, wetlands restoration, boat safety and clean vessel sanitation devices (pumpouts), and a nontrailerable boat program. Funds distributed to states for the various programs funded in the Act are collected in an account known as the Sport Fish Restoration Account, one of two accounts in the Aquatic Resources Trust Fund established under the authority of the internal revenue code (26 U.S.C. 9504(a)). Unless otherwise specified in the Act, funds are permanently appropriated (see P.L. 136, August 31, 1951; 65 Stat. 262).

**Fish and Wildlife Conservation Act** ("Nongame Act"; 16 U.S.C. 2901-2911; 94 Stat. 1322) -- Public Law 96-366, approved September 29, 1980, authorizes financial and technical assistance to the States for the development, revision, and implementation of conservation plans and programs for nongame fish and wildlife.

**Fish and Wildlife Coordination Act** (16 U.S.C. 661-667e. The amendments enacted in 1946 require consultation with the Fish and Wildlife Service and the fish and wildlife agencies of States where the "waters of any stream or other body of water are proposed or authorized, permitted or licensed to be impounded, diverted . . . or otherwise controlled or modified" by any agency under a Federal permit or license. Consultation is to be undertaken for the purpose of "preventing loss of and damage to wildlife resources." The amendments authorize the transfer of funds to the Fish and Wildlife Service to conduct related investigations

**Fish and Wildlife Improvement Act of 1978** (16 U.S.C. 742l. Approved November 8, 1978, authorizes the Secretaries of the Interior and Commerce to establish, conduct, and assist with national training programs for State fish and wildlife law enforcement personnel. The law provides authority to the Secretaries to enter into law enforcement cooperative agreements with State or other Federal agencies, and authorizes the disposal of abandoned or forfeited items under the fish, wildlife, and plant jurisdictions of these Secretaries. It strengthens the law enforcement operational capability of the Service by authorizing the disbursement and use of funds to facilitate various types of investigative efforts.

**Fishery Conservation and Management Act of 1976** (Public Law 94-265, approved April 13, 1976 16 U.S.C. 1801-1882; 90 Stat. 331) as amended by numerous subsequent public laws listed and identified in the U.S. Code. Also known as Magnuson Fishery Conservation and Management Act, this law established a 200-mile fishery conservation zone, effective March 1, 1977, and established Regional Fishery Management Councils comprised of Federal and State officials, including the Fish and Wildlife Service. The concept of a fishery conservation zone was subsequently dropped by amendment and the geographical area of coverage was changed to the Exclusive Economic Zone (EEZ), with the inner boundary being the seaward boundary of the coastal States. The Act provides for management of fish and other species in the EEZ under plans drawn up by the Regional Councils and reviewed and approved by the Secretary of Commerce. It provides for regulation of foreign fishing in the management zone under GIFA's (governing international fishing agreements) and vessel fishing permits. It also provides a mechanism for pre-emption of State law by the Secretary of Commerce.

**Interjurisdictional Fisheries Act of 1986** Public Law 99-659, approved November 14, 1986 (100 Stat. 3731; 16 U.S.C. 4101 note), as amended, repealed the Commercial Fisheries Research and Development Act and substituted for it the Interjurisdictional Fisheries Act of 1986. The Act provides for grants by the Secretary of Commerce to States for management of interjurisdictional commercial fishery resources.

**Federal Water Pollution Control Act (Clean Water Act)** (33 U.S.C. 1251 - 1376; Chapter 758; P.L. 845, June 30, 1948; 62 Stat. 1155), as amended. The original 1948 statute, the Water Pollution Control Act, authorized the Surgeon General of the Public Health Service, in cooperation with other Federal, state and local entities, to prepare comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries and improving the sanitary condition of surface and underground waters. The Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500) stipulated broad national objectives to restore and maintain the chemical, physical, and biological integrity of the Nation's waters (33 U.S.C. 1251). Provisions included a requirement that the Federal Power Commission not grant a license for a hydroelectric power project to regulate streamflow for the purpose of water quality unless certain conditions are satisfied (33 U.S.C. 1252). The 1977 amendments, the Clean Water Act of 1977 (P.L. 95-217), again extensively amended the Act. Of particular significance were the following provisions:

Development of a "Best Management Practices" Program as part of the state area wide planning program (33 U.S.C. 1288).

Authority for the Fish and Wildlife Service to provide technical assistance to states in developing "best management practices" as part of its water pollution control programs (33 U.S.C. 1288(i)(1))

Procedures for State assumption of the regulatory program, including a requirement that the Director of the Fish and Wildlife Service be involved in an advisory role regarding transfer of the program to the State (33 U.S.C. 1344 (g-m))

**Klamath River Basin Fishery Resources Restoration Act** -- Public Law 99-552 (100 Stat. 3081, October 27, 1986), as amended by P.L. 100-580 (102 Stat. 2935, October 31, 1988) and P.L. 100-653 (102 Stat. 3829, November 14, 1988; 16 U.S.C. 460ss), requires the Secretary to formulate, establish, and implement a 20-year program to restore and maintain anadromous fish populations of the Klamath River basin. Note that the Klamath Act expired on October 1, 2006, and was not reauthorized by Congress. The funding for this program was eliminated and the charter was discontinued.

**National Environmental Policy Act of 1969** as amended. Title I of the 1969 National Environmental Policy Act (NEPA) requires that all Federal agencies prepare detailed environmental impact statements for "every recommendation or report on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. The 1969 statute stipulated the factors to be considered in environmental impact statements, and required that Federal agencies employ an interdisciplinary approach in related decision-making and develop means to ensure that unquantified environmental values are given appropriate consideration, along with economic and technical considerations. Title II of this statute requires annual reports on environmental quality from the President to the Congress, and established a Council on Environmental Quality in the Executive Office of the President with specific duties and functions.

**National Wildlife Refuge System Administration Act of 1966** (16 U.S.C. 668dd-668ee) The 1966 Act constitutes an "organic act" for the National Wildlife Refuge System and provides guidelines and directives for administration and management of all areas in the system, including "wildlife refuges, areas for the protection and conservation of fish and wildlife that are threatened with extinction, wildlife ranges, game ranges, wildlife management areas, or waterfowl production areas." It was amended by P.L. 105-57, "The National Wildlife Refuge System Improvement Act of 1997" to ensure that the National Wildlife Refuge System is managed as a national system of related lands, waters, and interests for the protection and conservation of our Nation's wildlife resources.

**Salmon and Steelhead Conservation and Enhancement Act** (Public Law 96-561, approved December 22, 1980 (94 Stat. 3299; 16 U.S.C. 3301-3371) Established a salmon and steelhead enhancement program to be jointly administered by the Departments of Commerce and Interior, with appropriations authorized at $126,500,000. The Act established a Washington State and Columbia River conservation area and directed the Secretary of Commerce to establish an advisory committee of representatives from Washington and Oregon, the Washington and Columbia River tribal bodies, the Pacific Fisheries Management Council, and the National Marine Fisheries Service. It also directed that a report be submitted to the Secretary of Commerce and Congress, and the Secretary of the Interior was authorized to establish a grant program for each conservation area. Title II, entitled the "American Fisheries Promotion Act," authorized emergency assistance loans, accelerated fisheries research and development, extended the Federal fishing vessel obligation guarantee program under Title XI of the Merchant Marine Act, and redefined regulations governing foreign fishing in U.S. waters for steelhead and salmon.

**Sikes Act** (16 USC 670a-670o, 74 Stat. 1052), as amended, Public Law 86-797, approved September 15, 1960, provides for cooperation by the Departments of the Interior and Defense with State agencies in planning, development and maintenance of fish and wildlife resources on military reservations throughout the United States. Public Law 93-452, signed October 18, 1974, (88 Stat. 1369) authorized conservation and rehabilitation programs on AEC (now DOE), NASA, Forest Service and BLM lands. These programs are carried out in cooperation with the States by the Secretary of the Interior, and on Forest Service lands by the Secretary of Agriculture.

# Appendix H: Sources and Methods of Project Information Synthesis

The following table captures the major public grant- and project-tracking databases consulted to compile a collection of ***major*** grant-driven restoration and monitoring projects that have taken place in the Klamath Basin to date. While many of these databases are tied to specific grants or states, others such as the Pacific Northwest Salmon Habitat Project Database and California Habitat Restoration Project Database aim to capture all relevant restoration projects taking place in the region regardless of funding source or implementing agency. While these databases do not contain complete information on every project ever pursued in the basin, they together provide useful insight into the major restoration priorities of grant-driven restoration work, which comprise a large share of the restoration work done in the Klamath Basin.

Table G-1: Major restoration and monitoring grant and project tracking databases consulted to compile information on *major* grant-driven Klamath activities. For entries marked with a *, raw data was provided directly courtesy of data stewards.

| Agency | Database | Coverage | No. Projects** |
|---|---|---|---|
| Environmental Protection Agency (EPA)* | Grants Reporting and Tracking System (GRTS), encompassing<br>• 319(h) Nonpoint Source Management Grant Program<br>https://iaspub.epa.gov/apex/grts/f?p=grts:95 | National | 6 |
| UC Davis* | National Restoration Project Inventory (NRPI), encompassing:<br>• The California Watershed Projects Inventory (CWPI),<br>• The California Ecological Restoration Projects Inventory (CERPI), and<br>• The California Dept. of Conservation Noxious Weeds Projects Inventory (CNWPI).<br>http://www.ice.ucdavis.edu/nrpi/home.aspx | California / Southern Oregon | 258 |
| NOAA* | NOAA Restoration Atlas<br>https://restoration.atlas.noaa.gov/src/html/index.html | National | 18 |
| NOAA | NOAA National Estuaries Restoration Inventory<br>• Note that only 1 project was retained from the broader suite of Klamath projects in this database, which were already captured in other databases<br>https://neri.noaa.gov/neri/ | National | 1 |
| NOAA* | Pacific Coastal Salmon Recovery Fund (PCSRF) Project and Performance Metrics Database<br>• Federal, state, private, and NGO salmonid restoration projects<br>https://www.webapps.nwfsc.noaa.gov/apex/f?p=309:13 | Washington, Oregon, California | 474 (at level of work site) |
| NOAA* | Pacific Northwest Salmon Habitat Project Database, encompassing:<br>• Federal, state, private, and NGO salmonid restoration projects<br>https://www.webapps.nwfsc.noaa.gov/apex/f?p=409:13 | Washington , Oregon | 610 (at level of work site) |
| CalFish | California Habitat Restoration Project Database (CHRPD), includes:<br>• CDFW Fisheries Restoration Grant Program (FRGP) Projects<br>• Wildlife Conservation Board (WCB) Approved Projects<br>http://www.calfish.org/ProgramsData/ConservationandManagement/RestorationProjects.aspx | California | 494 (at level of work site) |
| CalTrout | California Trout Online Keystone Initiatives Explorer<br>http://caltrout.org/state-map/ | California | 3 |

| Agency | Database | Coverage | No. Projects** |
|---|---|---|---|
| California State Coastal Conservancy | Coastal Conservancy Project Map<br>www.mapcollaborator.org/sccpv/prod/ | California | 4 |
| Oregon Watershed Enhancement Board (OWEB) | Oregon Watershed Restoration Inventory (ORWI) Database<br>Restoration and Technical Assistance Grant Slates<br>• Older information captured in PCSRF content of Oregon Watershed Restoration Inventory projects<br>• Current information entered manually from records of recent grant awardees<br>http://www.oregon.gov/OWEB/GRANTS/pages/index.aspx | Oregon | 107 |
| Klamath County* | Klamath Decision Support System (DSS) Database, encompassing:<br>• U.S. Forest Service Watershed Improvement Tracking (WIT) Database<br>http://www.klamathdss.org/Klamathdss_datasources.php | Klamath Basin | 18 |
| U.S. FWS | U.S. Fish and Wildlife Service Yreka Ecosystem Restoration (ERO) Projects<br>• Information entered manually from https://www.fws.gov/yreka/fr-ehrp.htm<br>U.S. Fish and Wildlife Service Partners for Fish and Wildlife Projects<br>• Provided on request by the USFWS and coded manually for PCSRF restoration types | Klamath Basin | 72<br><br>936 |
| National Fish and Wildlife Foundation (NFWF) | Klamath River Coho Habitat Restoration Grant Program (2015-2016)<br>http://www.nfwf.org/klamathcoho/Pages/home.aspx<br>Klamath River Coho Enhancement Fund (2009-2015)<br>http://www.nfwf.org/klamathriver/Pages/home.aspx<br>• Information entered manually from records of recent grant awardees<br>Upper Klamath Basin Initiative<br>http://www.nfwf.org/upperklamath/Pages/home.aspx<br>• Information provided on request and entered manually from records of recent grant awardees | Klamath Basin | 38 |
| Trout Unlimited | • Information provided on request and entered manually from records of recent grant awardees | Upper Klamath Basin | 27 |
| Klamath Tracking and Accounting Program | Encompasses projects drawn from the databases above (pruned for duplicates) as well as project information submitted directly to KTAP.<br>• Provided on request from KTAP | Klamath Basin | 39 |
| Trinity River Restoration Program (TRRP)* | Channel Rehabilitation Project Summary Sheets (2005-2015)<br>• Information entered manually from channel rehabilitation factsheets | Trinity River Subbasin | 10 |

***Note that the number of entries in the database is larger than the total number of projects, as each project is split into multiple entries for each type of restoration action involved as described below.*

## Data Assembly Structure and Assumptions

Because each agency structures data in its own unique way, assembling these databases into a single collection of restoration and monitoring project data required following a single standard and making some assumptions to convert data into that standard. These standards and assumptions are outlined here:

- Spatial databases with broader geographical extents were clipped to the HUC6 boundaries of the Klamath Basin.
- Key information fields retained from each database included the source of the project data, the implementing agency, and project type, description, cost, timeframe, and explicit location in the basin identified by latitude and longitude or simply by HUC8 sub-basin where specific coordinates were not available or withheld to maintain partner privacy.
- As each new data set was integrated into the master database, it was manually ***checked for duplicates*** against existing entries and the duplicate entry with the least amount of information was removed. Duplicates were identified using Excel's internal duplicate identification tools to highlight duplicates, and then scanning the database row-by row to identify entries with identical internal project ID numbers, titles, or funding amounts. We also checked for duplicates across projects within subsets of projects with the same lead agency or with the same sub-basin to identify identical projects with slightly different entry characteristics, such as differing project titles. Over 500 duplicate projects were pruned out in this way.
- For retained projects, data on project activity types were standardized across all databases to match the NOAA PCSRF Data Dictionary hierarchy of restoration actions (detailed in Appendix J).
- Where projects included more than one type of restoration action, each action type was included as a separate row in the database under the same project name to allow for simple summaries by action type.
- Where only a single lump project cost was available for projects with multiple action types, the total cost was assumed to be split evenly across each action type following the example set by the NOAA PCSRF database. For projects where the dollar value of in-kind contributions was estimated (e.g., from volunteer labour), this was added to the total project cost to reflect the true cost of the work being done.
- All costs were adjusted for inflation to 2017 $ using the Consumer Price Index for All Urban Consumers (CPIAUCSL) compiled by the U.S. Bureau of Labour Statistics and available for download via the Federal Reserve Bank of St. Louis Economic Research Department (https://fred.stlouisfed.org/series/CPIAUCSL)
- The database includes some activities tangential to concrete restoration actions, such as planning, outreach, and education. We have retained these in our collection of projects, but excluded them from our summaries which focus on boots-on-the-ground restoration actions which more directly benefit fish. We have also excluded monitoring activities from the analyses in this section, as monitoring is examined separately in Section 7.
- Analysis and data visualization was carried out using the open-source R statistical software suite to maximize the ability to reproduce and update these analyses and visualizations using new information.

# Appendix I: Partial List of Entities involved in Restoration of Klamath Basin Fisheries

This is a table to catalogue major entities involved in restoring ecosystem elements related to fish populations (which includes water quality) in the Klamath Basin, although many other smaller organizations have also contributed to restoration programs to date. Entities are grouped by the type of organization and listed alphabetically within each group.

| Interested Parties | Type of Organization |
|---|---|
| National Parks Service - Lava Beds National Monument | Federal Government |
| National Parks Service - Redwood National Park | Federal Government |
| National Parks Service - Department of Environmental Quality | Federal Government |
| Regional Ecosystem Office | Federal Government |
| Six Rivers National Forest | Federal Government |
| U.S. Bureau of Indian Affairs | Federal Government |
| U.S. Bureau of Land Management | Federal Government |
| U.S. Bureau of Reclamation | Federal Government |
| U.S. Department of Justice - Indian Resource Section | Federal Government |
| U.S. Department of the Interior | Federal Government |
| U.S. Fish and Wildlife Service - Arcata Falls Office | Federal Government |
| U.S. Fish and Wildlife Service - Klamath Falls Office | Federal Government |
| U.S. Fish and Wildlife Service - Yreka Office | Federal Government |
| U.S. Forest Service Happy Camp Ranger District | Federal Government |
| U.S. Forest Service Klamath National Forest | Federal Government |
| U.S. Forest Service Klamath National Forest Salmon River Ranger District | Federal Government |
| U.S. Forest Service Klamath National Forest, Happy Camp / Oak Knoll Ranger District | Federal Government |
| U.S. Forest Service Klamath National Forest, Salmon River Ranger District | Federal Government |
| U.S. Forest Service Klamath National Forest, Scott River Ranger District | Federal Government |
| U.S. Forest Service Modoc National Forest | Federal Government |
| U.S. Forest Service Oak Knoll Ranger District | Federal Government |
| U.S. Forest Service Shasta-Trinity National Forest Weaverville Ranger District | Federal Government |
| U.S. Forest Service Shasta-Trinity National Forest, Weaverville Ranger District | Federal Government |
| U.S. Forest Service Six Rivers National Forest | Federal Government |
| U.S. Forest Service Six Rivers National Forest, Lower Trinity Ranger District | Federal Government |
| U.S. Forest Service Six Rivers National Forest, Orleans Ranger District | Federal Government |
| U.S. Geological Service | Federal Government |
| U.S. Timberlands | Federal Government |
| California Conservation Corps | State Government |
| California Department of Fish and Wildlife | State Government |
| California Department of Justice | State Government |

| Interested Parties | Type of Organization |
|---|---|
| California Department of Transportation | State Government |
| California Department of Water Resources | State Government |
| California Natural Resources Agency | State Government |
| California Public Utilities Commission | State Government |
| California State Coastal Conservancy | State Government |
| California State Water Resources Control Board | State Government |
| Caltrans | State Government |
| Klamath Basin National Wildlife Refuge Complex | State Government |
| Oregon Department of Environmental Quality | State Government |
| Oregon Department of Fish and Wildlife | State Government |
| Oregon Department of Forestry | State Government |
| Oregon Water Resources Department | State Government |
| Oregon Watershed Enhancement Board | State Government |
| Ahtanum Irrigation District | County Government |
| County of Del Norte | County Government |
| County of Siskiyou | County Government |
| County of Trinity | County Government |
| Del Norte County | County Government |
| Humboldt County - Natural Resources | County Government |
| Humboldt Fish Action Council | County Government |
| Humboldt State University Foundation | County Government |
| Humboldt State University Sponsored Programs Foundation | County Government |
| Jackson Soil and Water Conservation District | County Government |
| Klamath County | County Government |
| Klamath County Weed Control | County Government |
| Klamath Drainage District | County Government |
| Klamath Soil and Water Conservation District | County Government |
| Montague Water Conservation District | County Government |
| North Coast Environmental Center | County Government |
| North Coast Regional Water Board | County Government |
| North Coast Regional Water Quality Control Board | County Government |
| Scott Valley Resource Conservation District | County Government |
| Shasta Valley Resource Conservation District | County Government |
| Siskiyou County Air Pollution Control District | County Government |
| Siskiyou County Department of Agriculture | County Government |
| Siskiyou County Department of Public Works | County Government |
| Siskiyou County Office of Education | County Government |
| Siskiyou County Resource Conservation District | County Government |
| Siskiyou Gardens, Parks and Greenways Association | County Government |
| Siskiyou Land Trust | County Government |
| Siskiyou Resource Conservation District | County Government |
| Trinity County Department of Transportation | County Government |

| Interested Parties | Type of Organization |
|---|---|
| Trinity County Planning Department, Natural Resources Division | County Government |
| Trinity County Resource Conservation District | County Government |
| Trinity County Waterworks | County Government |
| Tulelake Irrigation District | County Government |
| City of Etna | Municipal Government |
| City of Weed | Municipal Government |
| City of Yreka | Municipal Government |
| Jacoby Creek Canyon Community | Municipal Government |
| Weaverville Sanitary District | Municipal Government |
| Willow Creek Community Services District | Municipal Government |
| Grenada Irrigation District | Utility |
| Klamath Water and Power Agency | Utility |
| Hoopa Valley Tribe - Business Council | Tribe |
| Hoopa Valley Tribe - Environmental Protection Agency | Tribe |
| Hoopa Valley Tribe - Fisheries Department | Tribe |
| Hoopa Valley Tribe - Forestry Department | Tribe |
| Karuk Tribe | Tribe |
| Karuk Tribe - Department of Natural Resources | Tribe |
| Klamath Tribes | Tribe |
| Quartz Valley Indian Reservation | Tribe |
| Resighini Rancheria | Tribe |
| Yurok Tribal Fisheries Program | Tribe |
| Yurok Tribe | Tribe |
| Yurok Tribe Natural Resources Department | Tribe |
| Yurok Tribe Watershed Restoration Department | Tribe |
| American Fishing Foundation | NGO |
| American Forests | NGO |
| American Rivers | NGO |
| Bonneville Environmental Foundation | NGO |
| California Trout, Inc. | NGO |
| California Waterfowl Association | NGO |
| Center for Education and Manpower Resources | NGO |
| Ducks Unlimited, Inc. | NGO |
| Endangered Species Coalition | NGO |
| Five Counties Salmonid Conservation Program | NGO |
| Fort Klamath Critical Habitat Landowners Inc. | NGO |
| Klamath Basin Ecosystem Foundation | NGO |
| Klamath Basin Rangeland Trust | NGO |
| Land Partners Through Stewardship (Landpaths Inc.) | NGO |
| Lomakatsi Restoration Project | NGO |
| National Fish and Wildlife Foundation | NGO |
| Native American Rights Fund | NGO |

| Interested Parties | Type of Organization |
|---|---|
| North Coast Regional Land Trust | NGO |
| Northern California Resource Center | NGO |
| Oregon Wild | NGO |
| Pacific Coast Fish Wildlife and Wetlands Restoration Association | NGO |
| Redwood Community Action Agency | NGO |
| Rocky Mountain Elk Foundation | NGO |
| Rural Human Services | NGO |
| Salmon River Restoration Council | NGO |
| Salmonid Restoration Federation | NGO |
| Save-the-Redwoods League | NGO |
| Scott River Water Trust | NGO |
| Scott River Watershed Council | NGO |
| Smith River Alliance | NGO |
| Sprague River Water Resource Foundation | NGO |
| Sustainable Nothwest | NGO |
| The Freshwater Trust | NGO |
| The Nature Conservancy | NGO |
| The Watershed Center | NGO |
| The Wilderness Land Trust | NGO |
| Trinidad Fishermen's Salmon Enhancement | NGO |
| Trinity Fisheries Improvement Association | NGO |
| Trout Unlimited Inc. | NGO |
| Water for Life Foundation | NGO |
| California State University, Humboldt Foundation | Research Organization |
| Coordinated Resource Management Plan Group - Shasta River | Research Organization |
| Institute for Fisheries Resources | Research Organization |
| Klamath River Basin Fisheries Task Force | Research Organization |
| Monterey Bay Salmon and Trout Project | Research Organization |
| National River Restoration Science Synthesis | Research Organization |
| North Carolina State University | Research Organization |
| Pacific States Marine Fisheries Commission | Research Organization |
| Regents of the University of California Berkeley | Research Organization |
| Trinity River Restoration Program | Research Organization |
| UC Davis | Research Organization |
| Watershed Research and Training Center | Research Organization |
| Etna Elementary School District | School / Academic |
| French Creek Outdoor School/Etna Elementary School | School / Academic |
| Kidder Creek Outdoor School/Etna Elementary School | School / Academic |
| Scott Valley Unified School District | School / Academic |
| French Creek Watershed Advisory Group | Community Organization |
| Harbor Isles Condominium Owners Association | Community Organization |
| High Desert Trail Riders | Community Organization |

| Interested Parties | Type of Organization |
|---|---|
| Klamath Water Users Association | Community Organization |
| Klamath Watershed Council | Community Organization |
| Klamath Watershed Partnership | Community Organization |
| Lake County Umbrella Watershed Council | Community Organization |
| Mid Klamath Watershed Council | Community Organization |
| Northern California Council Federation of Fly Fishers | Community Organization |
| Northern California Indian Development Council | Community Organization |
| Northwest California Resource Conservation & Development Council | Community Organization |
| Orleans Karok Council | Community Organization |
| Orleans Rod and Gun Club | Community Organization |
| Orleans/Soames Bar Fire Safe Council | Community Organization |
| Shasta River Coordinated Resources Management and Planning | Community Organization |
| Shasta Water Association | Community Organization |
| The Orleans/Soames Bar Fire Safe Council | Community Organization |
| Upper Klamath Water Users Association | Community Organization |
| Alexandre Dairy | Farm or Ranch |
| Ausaymas Cattle Company and Hawkins Cattle Company | Farm or Ranch |
| Deming Ranches | Farm or Ranch |
| Double K Ranch | Farm or Ranch |
| Eagle Ranch | Farm or Ranch |
| Gerber Ranch | Farm or Ranch |
| Goold's Sprague River Ranch | Farm or Ranch |
| Harlowe Ranch LLC | Farm or Ranch |
| Hawkins Cattle Company | Farm or Ranch |
| Indian Creek Ranch | Farm or Ranch |
| Lonesome Duck Ranch | Farm or Ranch |
| Arcata Redwood Company | Industry |
| Bill Parry Construction | Industry |
| Boise Cascade | Industry |
| Clearwater Biostudies, Inc. | Industry |
| Coastal Stream Restoration Group | Industry |
| Crown Pacific Partners | Industry |
| Davids Engineering, Inc. | Industry |
| Emmerson Investments, Inc. | Industry |
| ENT Forestry | Industry |
| Eternal Hills Cemetery | Industry |
| Fruit Growers Supply Company | Industry |
| Great Northern Corporation | Industry |
| Inland Fiber Group LLC | Industry |
| JELD-WEN Timber and Ranches | Industry |
| Klamath Guides Association | Industry |
| Kuhler-Dobson LLC | Industry |

| Interested Parties | Type of Organization |
|---|---|
| McBain and Trush | Industry |
| North Coast Fisheries Restoration | Industry |
| Northwest Biological Consulting | Industry |
| Northwest Hydraulic Consultants, Inc. | Industry |
| Ouzel Enterprises | Industry |
| Pacific Coast Federation of Fishermen's Associations | Industry |
| PacifiCorp | Industry |
| R & R Backhoe Service | Industry |
| Rabe Consulting | Industry |
| Ranch and Range Consulting | Industry |
| River Design Group, Inc. | Industry |
| Roseburg Resources Co. | Industry |
| Ross Taylor and Associates | Industry |
| Schlumpberger Consulting Engineers | Industry |
| Scott Valley Builders | Industry |
| Shasta-Cascade Ops | Industry |
| SHN Consulting Engineers & Geologists | Industry |
| Somach Law | Industry |
| Stillwater Sciences | Industry |
| Stoel Rives LLP | Industry |
| The Great Northern Corporation | Industry |
| Timber Resource Services | Industry |
| Trinity Fisheries Consulting | Industry |
| Trinity River Consulting | Industry |
| Water and Power Law Group PC. | Industry |
| Wiley Rein LLP | Industry |
| William Huber & Associates | Industry |
| Winzler & Kelly Consulting Engineers | Industry |
| Woods Rogers, Inc. | Industry |

# Appendix J: NOAA PCSRF Data Dictionary of Restoration Actions and Definitions

The PCSRF Data Dictionary (v20 as of 04-08-2013) has a hierarchical structure with Categories (e.g., Habitat, Planning/Assessment, RM&E, etc.); Sub-Categories (e.g., the type of project, so within the Habitat Category it includes Instream Flow, Riparian, Upland, etc.); Work Type (e.g., type of treatment); and, Metrics. This version of the data dictionary has been trimmed to include only restoration activities assessed in this synthesis report. The full version is available at: https://www.webapps.nwfsc.noaa.gov/j/Docs/PCSRF%20Data%20Dictionary%20ver20%2004-08-13.xlsx

| Sub-Category Name | Work Type or Attribute Name | Definition |
|---|---|---|
| *Fish Screening* | | *Projects that result in the installation, improvement or maintenance of screening systems that prevent salmonids from passing into areas that do not support salmonid survival; for example, into irrigation diversion channels.* |
| | Fish screens installed | New fish screens installed where no screen had existed previously. |
| | Fish screens replaced or modified | Pre-existing fish screens that are replaced, repaired or modified. |
| *Fish Passage Improvement* | | *Projects that improve or provide anadromous salmonid migration up and down stream including fish passage at road crossings (bridges or culverts), barriers (dams or log jams), fishways (ladders, chutes or pools), and weirs (log or rock).* |
| | Fish passage blockages removed or altered | Removal or alteration of blockages, impediments or barriers to allow or improve salmonid passage (other than road crossings). |
| | Fishway chutes or pools Installed | Placement of an engineered bypass for salmonids to pass more safely around or over a barrier (other than fish ladder). This includes bedrock chutes, weirs, rock boulder step pools, chutes constructed/roughened in bed rock, and engineered channel structures. |
| | Fish ladder Installed / improved | Installation or modification (upgrade/improvement) of a fish ladder. |
| | Culvert installed or Improved at road stream crossing | Installation or improvement/upgrade (including replacement) of a culvert to a standard that provides juvenile and adult salmonid passage. |
| | Bridge installed or improved at road stream crossing | Installation, improvement/upgrade or replacement of a bridge over a stream to provide/improve salmonid passage under a road. The bridge could be replacing a culvert. |
| | Rocked ford - road stream crossing | Placement of a crushed gravel reinforced track through stream that still allows unimpeded stream flow. This could replace a dysfunctional culvert. |

| Sub-Category Name | Work Type or Attribute Name | Definition |
|---|---|---|
| | Road stream crossing removal | Removal of stream road crossing and the affiliated road structures so that the stream flows unimpeded. This would include removal of culverts and other material in the channel. |
| | Unspecified or other fish passage project | Other unspecified or other fish passage project. |
| *Instream Flow Project* | | *Projects that maintain and/or increase the flow of water to provide needed salmonid habitat conditions. This can include water rights purchases/leases, or irrigation practice improvements (reduced flow into fields) including water conservation projects to reduce stream diversions or extractions.* |
| | Water flow gauges | Water gauges installed to measure and regulate water use. |
| | Irrigation practice improvement | Improvement of irrigation practices (where water is removed from a stream) to protect fish. This includes: reducing withdrawals; installing a headgate with water gauge to control water flow into irrigation canals and ditches; regulating flow on previously unregulated diversions; installing a well to eliminate a diversion; or, replacing open canals with pipes to reduce water loss to evaporation. |
| | Water leased or purchased | Water that is leased or purchased, and thus not withdrawn from the stream. This includes the purchase of water rights. |
| | Maintaining adequate flow or reducing withdrawals | Preventing or reducing water withdrawals from stream. |
| | Unspecified or other instream flow project | Other unspecified or other instream flow project. |
| *Instream Habitat Project* | | *Projects that increase or improve the physical conditions within the stream environment (below the ordinary high water mark of the stream) to support increased salmonid population.* |
| | Channel reconfiguration and connectivity | Changes in channel morphology, sinuosity or connectivity to off-channel habitat, wetlands or floodplains. This includes instream pools added/created; removal of instream sediment; meanders added; former channel bed restored; removal or alteration of levees or berms (including setback levees) to connect floodplain; and, creation of off-channel habitat consisting of side channels, backwater areas, alcoves, oxbows, ponds, or side-pools. |
| | Channel structure placement | Placement of large woody debris or rocks/boulders (including deflectors, barbs, weirs) to collect and retain gravel for spawning habitat; deepen existing resting/jumping pools; create new pools above and/or below the structure; trap sediment; aerate the water; channel roughening; or, promote deposition of organic debris. This includes floodplain roughening or fencing. |
| | Streambank stabilization | Stabilization of the streambank through resloping and/or placement of rocks, logs, or other material on streambank. |

| Sub-Category Name | Work Type or Attribute Name | Definition |
|---|---|---|
| | Spawning gravel placement | Addition of spawning gravel to the stream. |
| | Plant removal/control | Removal or control of aquatic non-native plants, invasive species or noxious weeds growing in the stream channel. |
| | Beavers | Introduction or management of beavers to add natural stream complexity (beaver dams, ponds, etc.). |
| | Predator/competitor removal | Control or removal of salmonid predators or competitors (e.g., northern pike minnow, non-native fish, invasive animals) from the instream habitat. |
| *Riparian Habitat Project* | | *Projects that change areas (above the ordinary high water mark of the stream and within the flood plain of streams) in order to improve the environmental conditions necessary to sustain salmonids throughout their life cycle. This includes lakeshores of connected lakes.* |
| | Riparian planting | Riparian planting or native plant establishment. |
| | Fencing | Creation of livestock exclusion or other riparian fencing. |
| | Riparian exclusion | Preventing or removing access to riparian areas by means other than fencing. |
| | Water gap development | Installation of a fenced livestock stream crossing or livestock bridge. |
| | Conservation grazing management | Alteration of agricultural land use practices to reduce grazing pressure for conservation (e.g., rotate livestock grazing to minimize impact on riparian areas). |
| | Riparian plant removal / control | Removal and/or control (treatment) of non-native species, noxious weeds and other plants or invasive species that adversely affect the riparian zone or water table. |
| | Forestry practices / stand management | Treating or managing trees and undergrowth in riparian area including prescribed burnings, stand thinning, stand conversions, and silviculture. |
| *Upland Habitat and Sediment Project* | | *Landscape level projects implemented above the elevation of the riparian zone (above the floodplain) that are intended to benefit salmonid habitat (for example, reducing/eliminating sediment flow from upland areas into streams).* |
| | Road drainage system improvements and reconstruction | Road projects that reduce or eliminate sediment transport into streams. This includes placement of structures to contain/ control runoff from roads, road reconstruction or reinforcement, surface and peak-flow drainage improvements, and roadside vegetation. These roads may extend into or are in the riparian zone. |
| | Road closure / abandonment | Closure (abandonment), relocation, decommissioning or obliteration of existing roads (including pavement such as parking areas) to diminish sediment transport into stream and/or improve riparian habitat. These roads/pavement may extend into or are in the riparian zone. |

| Sub-Category Name | Work Type or Attribute Name | Definition |
|---|---|---|
| | Erosion control structures installed | Construction/placement of sediment basins, sediment collection ponds, sediment traps, or water bars (other than road projects or upland agriculture). |
| | Planting for erosion and sediment control | Upland projects that control erosion through planting and revegetation or grassed waterways. |
| | Slope stabilization | Implementation of slope/hillside stabilization or slope erosion control methods including landslide reparation and non-ag terracing. |
| | Upland vegetation management | Upland vegetation treatment or removal projects for water conservation or sediment control including plant removal (e.g., juniper removal or noxious weeds), selective tree thinning, undergrowth removal, prescribed burnings, stand conversions, and silviculture. |
| | Upland agriculture management | Implementation of best agricultural management practices such as low or no till agriculture, conservation land management; or, upland irrigation water management for water conservation. |
| | Upland livestock management | Upland livestock management action designed to control sediment flow into a stream or riparian area. This includes livestock watering schedules; grazing management plans; upland exclusion and fencing; and, livestock water development (also called off-channel watering or livestock water supply) including installation of upland ditches, wells, and ponds. |
| *Water Quality Project* | | *Projects that improve instream water quality conditions for salmonids or reduce impacts of instream point/non-point pollution. This includes improved water quality treatment; nutrient enhancement through carcass placement; return flow cooling; removal or prevention of toxins, sewage or refuse; or, the reduction or treatment of sewage outfall and/or stormwater.* |
| | Sewage clean-up | Reduction or clean-up of sewage outfall including failed septic systems. |
| | Toxin reduction | Clean-up or prevention of mine or dredge tailings, herbicides, pesticides, or toxic sediments. |
| | Carcass or nutrient placement | Placement of salmonid carcasses, fish meal bricks, or other fertilizer in or along the stream for nutrient enrichment. |
| | Livestock manure management | Relocation or modification of livestock manure holding structures and/or manure piles to reduce or eliminate drainage into streams. |
| | Stormwater / wastewater modification or treatment | Modifications to stormwater/wastewater and drainage into stream to improve water quality. Includes bioswales and rain gardens. |
| | Return flow cooling | Return flow cooling projects where extracted water that has heated during use is cooled before it is returned to the stream. This can occur in power plants, large industry, and smaller applications which generally consist of replacing old open return ditches with underground PVC pipe (purpose is eliminate to thermal loading by filtering flows underground where they can cool). |

| Sub-Category Name | Work Type or Attribute Name | Definition |
|---|---|---|
| *Wetland Project* | | *Projects designed to improve connected wetland, meadow or floodplain areas (wetlands that are connected to the stream/riparian area) that are known to support salmonid production.* |
| | Wetland planting | Planting of native wetland species in wetland areas. |
| | Wetland plant removal / control | Removal and/or control (treatment) of non-native species, noxious weeds and other plants or invasive species that adversely affect the wetland area or water table. |
| | Wetland improvement/ restoration | Improvement, reconnection, or restoration of existing or historic wetland (other than vegetation planting or removal). |
| | Artificial wetland created | New (artificial) wetland created in an area not formerly a wetland. This is wetland area created where it did not previously exist.. |
| *Hatchery Production* | | *Operations that collect and spawn adult salmon; incubate eggs; rear and maintain fry/smolt in a hatchery facility or pond; or, outplant fry/smolt.* |
| | Salmonids reared/released | Salmonid fry/smolt that are produced and released. Report number produced by species. |
| | Hatchery operations - facility or equipment | Purchase, replacement or modification of hatchery facility equipment or structures necessary for salmonid production (not for marking/tagging fish - see D.2.c). This includes acclimation ponds, pumps, fish transport, traps, weirs, and costs for design/construction. |
| | Salmonids outplanted | Salmonid fry/smolt by species that are outplanted to re-establish salmonids to an area or to supplement a wild population. Report number produced by species. |
| | Native/wild broodstock collection/relocation | Collection of native/wild broodstock for hatchery production or for relocation above barriers or other streams |

## PCSRF action work types with corresponding conceptual model stage used to produce colour-coded figure in Section 6.

| Activity Type | Conceptual Model Category |
|---|---|
| **Fish Passage Improvement - Bridge Installed Or Improved** | Habitat |
| **Fish Passage Improvement - Culvert Installed Or Improved** | Habitat |
| **Fish Passage Improvement - Fish Ladder Installed / Improved** | Habitat |
| **Fish Passage Improvement - Fish Passage Blockages Removed Or Altered** | Habitat |
| **Fish Passage Improvement - Fishway Chutes Or Pools Installed** | Habitat |
| **Fish Passage Improvement - Road-Crossing Removal** | Habitat |
| **Fish Screening - Fish Screens Replaced or Modified** | Habitat |
| **Fish Screening - New Fish Screens Installed** | Habitat |
| **Fish Rearing - Fish Rearing** | Biological Response |

| Activity Type | Conceptual Model Category |
|---|---|
| **Instream Flow - Irrigation Practice Improvement** | Fluvial Processes |
| **Instream Flow - Water Flow Gauges** | Fluvial Processes |
| **Instream Flow - Water Leased Or Purchased** | Fluvial Processes |
| **Instream Habitat - Beavers** | Habitat |
| **Instream Habitat - Channel Reconfiguration And Connectivity** | Habitat |
| **Instream Habitat - Channel Structure Placement** | Habitat |
| **Instream Habitat - Predator/competitor removal** | Biological Response |
| **Instream Habitat - Spawning Gravel Placement** | Habitat |
| **Instream Habitat - Streambank Stabilization** | Habitat |
| **Riparian Habitat - Riparian Plant Removal/Control** | Habitat |
| **Riparian Habitat - Fencing** | Habitat |
| **Riparian Habitat - Forestry Practices / Stand Management** | Habitat |
| **Riparian Habitat - Riparian Plant Removal / Control** | Habitat |
| **Riparian Habitat - Riparian Planting** | Habitat |
| **Riparian Habitat - Water Gap Development** | Habitat |
| **Upland Habitat And Sediment - Erosion Control Structures** | Watershed Inputs |
| **Upland Habitat And Sediment - Road Closure/Abandonment** | Watershed Inputs |
| **Upland Habitat And Sediment - Road Drainage System Improvements And Reconstruction** | Watershed Inputs |
| **Upland Habitat And Sediment - Slope Stabilization** | Watershed Inputs |
| **Upland Habitat And Sediment - Upland Agriculture Management** | Watershed Inputs |
| **Upland Habitat And Sediment - Upland Livestock Management** | Watershed Inputs |
| **Upland Habitat And Sediment - Upland Vegetation Management** | Watershed Inputs |
| **Water Quality - Livestock Manure Management** | Watershed Inputs |
| **Water Quality - Stormwater / Wastewater Modification Or Treatment** | Watershed Inputs |
| **Wetland - Artificial Wetland Created** | Habitat |
| **Wetland - Wetland Improvement/ Restoration** | Habitat |

# Appendix K: Partial List of Klamath Basin Management and Restoration Plans

| Included in Crosswalk Table | Agency | Category | Date | Area | Plan Name | Link |
|---|---|---|---|---|---|---|
| | Klamath National Forest | Fire Management | 2014 | Lower | Western Klamath Restoration Partnership - Plan for Restoring Fire Adapted Landscapes (Klamath National Forest 2014) | http://karuk.us/images/docs/dnr/2014%20Western%20Klamath%20Restoration%20Partnership_Restoration%20Plan_DRAFT_FINA%20%20%20.pdf |
| | USFW | Fire Management | 2001 | Upper | Wildland Fire Management Plan Klamath Basin National Wildlife Refuge Complex (USFWS 2001) | https://www.fws.gov/fire/fmp/region1/oregon/klamath_basin_nwr_complex.pdf |
| X | ODFW | Fish Reintroduction | 2008 | Upper | A Plan for Reintroduction of Anadromous Fish in the Upper Klamath Basin (ODFW, Hooton & Smith 2008) | http://www.dfw.state.or.us/agency/commission/minutes/08/05_may/C_2_Draft%20Plan%20for%20the%20Reintroduction%20of%20Anadromous%20Fish%20in%20the%20Upper%20Klamath%20Basin.pdf |
| | ODFW | Fish Reintroduction | 2017 | Upper | Salmon Reintroduction Implementation Plan for the Upper Klamath Basin | Under Development |
| X | USFWS | Fisheries Management | 1991 | Whole | Long Range Plan For The Klamath River Basin Conservation Area Fishery Restoration Program (1991) | http://www.krisweb.com/biblio/gen_usfws_kierassoc_1991_lrp.pdf |
| | ODFW | Fisheries Management | 1997 | Upper | Klamath River Basin Fish Management Plan (ODFW 1997) | https://nrimp.dfw.state.or.us/nrimp/information/docs/fishreports/Klamath%20Basin%20Fish%20Management%20Plan%201997.pdf |
| | CDFW | Fisheries Management | 2003 | National | STRATEGIC PLAN for TROUT MANAGEMENT: A plan for 2004 and beyond (CDFW 2003) | https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=9631 |
| | CDFW/PSFMC | Fisheries Management | 2010 | Lower | Scott River Spawning Gravel Evaluation and Enhancement Plan (CDFW/PSFMC 2010) | www.fishsciences.net/reports/download_report.php?rid=5349 |
| X | Pacific Fishery Management Council | Fisheries Management | 2016 | National | Pacific Coast Salmon Fishery Management Plan (PSMFC 2016 - Coho / Chinook) | http://www.pcouncil.org/wp-content/uploads/2016/03/FMP-through-A-19_Final.pdf |
| | CDFW | Fisheries Management | 2016 | Upper | Upper Klamath River Fishery Management Plan (California Natural Resource Agency - Department of Fish and Wildlife 2016) | https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=121271 |
| | Klamath Tribes | Forest Management | 2008 | Upper | A Plan for the Klamath Tribes' Management of the Klamath Reservation Forest | http://www.klamathtribes.org/documents/Klamath_Plan_Final_May_2008.pdf |
| | KRITFWC / Hoopa | Forest Management | 2014 | Lower | Hoopa Tribal Forestry Forest Management Plan (2014) | http://www.hoopaforestry.com/planning.html |
| X | KRITFWC / Yurok | Habitat Restoration | 2000 | Lower | Lower Klamath River Sub-basin Watershed Restoration Plan (Gale and Randolph 2008, Yurok Tribal Fisheries Program) | http://www.yuroktribe.org/departments/fisheries/documents/LowerKlamathRestorationPlanFINAL2000_000.pdf |
| X | USFS/SRRC | Habitat Restoration | 2002 | Lower | Salmon River Subbasin Restoration Strategy (Elder, D. et al, 2002, US Forest Service and Salmon River Restoration Council) | https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5110056.pdf |
| | Yurok | Habitat Restoration | 2004 | Lower | Habitat Assessment and Restoration Planning in the Salt Creek Watershed, Lower Klamath River Sub-Basin, California (Yurok Tribal Fisheries Program 2004) | http://www.yuroktribe.org/departments/fisheries/documents/2004RestorationPlanningSaltCreekFINAL_000.pdf |
| | Green Diamond Resource Company | Habitat Restoration | 2006 | Lower | Green Diamond Resource Company Aquatic Habitat Conservation Plan and Candidate Conservation Agreement with Assurances (applied to privately owned land in the Lower Klamath sub-basin) | http://www.swrcb.ca.gov/northcoast/board_info/board_meetings/10_2012/pdf/green_diamond/GD_AHCP_Vol1_Final_1006.pdf |
| | KRITFWC / Yurok | Habitat Restoration | 2008 | Lower | Cooperative Restoration of Tribal Trust Fish and Wildlife Habitat in Lower Klamath River Tributaries (Yurok Tribal Fisheries Program. Klamath, CA, Beesley, S. and R. Fiori. 2008) | http://www.yuroktribe.org/departments/fisheries/documents/YTFP2008CooperativeRestorationofLKTribsFINALReport_PartI.pdf |

| Included in Crosswalk Table | Agency | Category | Date | Area | Plan Name | Link |
|---|---|---|---|---|---|---|
| | Yurok | Habitat Restoration | 2008 | Lower | Restoration Planning in Lower Blue Creek, Lower Klamath River: Phase I | http://www.yuroktribe.org/departments/fisheries/documents/YTFP_2008_BlueCreekRestorationPlan-PhaseIFINAL_001.pdf |
| | KRITFWC / Yurok | Habitat Restoration | 2011 | Lower | Yurok Tribe Environmental Program Wetlands Program Plan (YTEP 2011) | http://www.yuroktribe.org/departments/ytep/documents/wetlands_plan.pdf |
| | USFWS | Habitat Restoration | 2012 | Whole | Partners for Fish and Wildlife & Coastal Programs Strategic Plan - California/Nevada Operations incl Klamath Basin (USFWS 2012c) | https://www.fws.gov/partners/docs/783.pdf https://www.fws.gov/coastal/Regions/Region_8_strategic_plan_0830.pdf |
| X | CDFW | Hatchery Management | 2014 | Mid | Hatchery and Genetic Management Plan For Iron Gate Hatchery Coho Salmon (USDFW 2014) | https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=111176 |
| X | ODFW | Hatchery Management | 2017 | Upper | Klamath Hatchery Program Management Plan (ODFW 2017) | http://www.dfw.state.or.us/fish/HOP/Klamath%20HOP.pdf |
| | US Forest Service | Multi-Objective | 1992 | Upper | Environmental Assessment & River Management Plan - Sycan Wild & Scenic River / Fremont Nat'l Forest (US Forest Service 1992) | https://www.rivers.gov/documents/plans/sycan-plan-ea.pdf |
| | BLM | Multi-Objective | 1995 | Upper | Klamath Falls Resource Area Record of Decision and Resource Management Plan / Rangeland Program Summary (BLM 1995) | https://www.blm.gov/or/plans/files/Kfalls_RMP_1995.pdf |
| X | SRCRMPC | Multi-Objective | 1997 | Lower | Shasta Watershed Recovery Plan (Shasta River Coordinated Resource Management and Planning Committee 1997) | http://www.krisweb.com/biblio/klamath_srcrmp_xxxx_1997_plan.pdf |
| | OWEB | Multi-Objective | 1997 | Upper | The Oregon Plan for Salmon and Watersheds (aka Oregon Coastal Salmon Restoration Initiative, Oregon Legislature, 1997) (focused on watersheds other than Klamath - Rogue, South Coast, etc) | https://www.oregon.gov/OPSW/Pages/archived.aspx |
| X | BLM | Multi-Objective | 2003 | Upper | Upper Klamath River Management Plan Environmental Impact Statement and Resource Management Plan (BLM 2003) | https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB2009108339.xhtml |
| | BLM | Multi-Objective | 2003 | Upper | Lakeview Resource Area Record of Decision and Resource Management Plan (BLM 2003) | https://www.blm.gov/or/districts/lakeview/plans/lakeviewrmp.php |
| | USDA-NRCS | Multi-Objective | 2004 | Whole | WORK PLAN FOR ADAPTIVE MANAGEMENT Klamath River Basin Oregon & California (USDA-NRCS 2004) | https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/home/?cid=nrcs143_023463 |
| X | Scott River Watershed Council | Multi-Objective | 2005 | Lower | Initial Phase of the Scott River Watershed Council Strategic Action Plan (SRWC 2005, extensive goals and objectives) | http://kbifrm.psmfc.org/wp-content/uploads/2017/01/2005_0165_SRWC_StrategicActionPlan_Update.pdf |
| | Karuk | Multi-Objective | 2006 | Lower | Karuk Tribe Department of Natural Resources - DRAFT Eco-Cultural Resources Management Plan (Karuk 2006) | http://www.klamathwaterquality.com/documents/Karuk_Ecological_Plan.pdf |
| | ODFW | Multi-Objective | 2006 | Upper | Oregon Conservation Strategy, ODFW, 2006 | http://www.oregonconservationstrategy.org/oregon-conservation-strategy-help/ |
| X | USFWS | Multi-Objective | 2006 | Whole | Klamath River Basin Conservation Area Restoration Plan (in fulfillment of the Klamath Act) (USFWS 2006) | https://www.fws.gov/yreka/PDF/KRBCARP_Activities.pdf |
| | BLM | Multi-Objective | 2008 | Upper | Klamath Falls Resource Area Record of Decision and Resource Management Plan (BLM 2008) | https://www.blm.gov/or/districts/lakeview/plans/lakeviewrmp.php |
| X | Karuk Tribe | Multi-Objective | 2008 | Mid | Mid-Klamath Subbasin Fisheries Resource Recovery Plan (Karuk Tribe 2008) | http://mkwc.org/old/publications/subbasinplanning/Mid-Klamath%20Subbasin%20Fisheries%20Resource%20Recovery%20Plan.pdf |
| | BLM | Multi-Objective | 2008 | Upper | Record of Decision and Resource Management Plan - Klamath Falls Resource Area (BLM 2008 update) | https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB2009108339.xhtml |
| | NFWF | Multi-Objective | 2008 | Upper | Draft Business Plan for the Upper Klamath Basin (NFWF 2008) | http://www.nfwf.org/upperklamath/Documents/Upper_Klamath_Biz_Plan.pdf |
| X | Klamath National Forest | Multi-Objective | 2010 | Lower | Klamath National Forest Land and Resource Management Plan (Klamath National Forest 2010) (Chapter 4) | https://www.fs.usda.gov/main/klamath/landmanagement/planning |
| X | Multi-Party | Multi-Objective | 2010 | Whole | Klamath Basin Restoration Agreement (2010, Terminated) | https://www.doi.gov/sites/doi.gov/files/migrated/news/pressreleases/upload/Klamath-Basin- |

| Included in Crosswalk Table | Agency | Category | Date | Area | Plan Name | Link |
|---|---|---|---|---|---|---|
| | | | | | | Restoration-Agreement-2-18-10.pdf |
| | Multi-Party | Multi-Objective | 2010 | Whole | Klamath Hydroelectric Settlement Agreement (KHSA) (2010, Amended 2016) | https://www.doi.gov/sites/doi.gov/files/uploads/FINAL%20KHSA%20PDF.pdf |
| | Bureau of Reclamation | Multi-Objective | 2011 | Whole | Reservoir Area Management Plan for the Secretary's Determination on Klamath River Dam Removal and Basin Restoration (2011) | https://klamathrestoration.gov/sites/klamathrestoration.gov/files/Reservoir_Site_Management_Plan_Final.pdf |
| X | Klamath Tribes | Multi-Objective | 2014 | Upper | Wetland and Aquatic Resources Program Plan 2015 – 2018 (Klamath Tribes 2014) | https://www.epa.gov/sites/production/files/2015-10/documents/tkt_final_warpp.pdf |
| | Multi-Party | Multi-Objective | 2014 | Upper | Upper Klamath Basin Comprehensive Agreement (2014, active but unfunded due to termination of KBRA) | http://klamathtribes.org/wp-content/uploads/2014/08/2014-4-18-UPPER-KLAMATH-BASIN-COMPREHENSIVE-AGREEMENT.pdf |
| | Bureau of Reclamation | Multi-Objective | 2015 | Lower | Draft Long-Term Plan for Protecting Late Summer Adult Salmon in the Lower Klamath River | https://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=22021 |
| | Karuk | Multi-Objective | 2015 | Lower | Karuk Department of Natural Resources Strategic Plan for Organizational Development (Karuk DNR 2015) | http://www.karuk.us/images/docs/dnr/Karuk%20DNR_Strategic%20Plan_FINAL_12172015.pdf |
| | KRITFWC | Multi-Objective | 2016 | Mid | Middle Klamath Restoration Candidate Actions Plan (Spreadsheet provided by Toz Soto, updated in 2016) | Document not online |
| | KTAP | Multi-Objective | 2016 | Whole | Klamath Tracking and Accounting Program (KTAP / Willamette Partnership 2016) | http://willamettepartnership.org/wp-content/uploads/2014/09/KTAP-Stewardship-Reporting-Protocol-Final-Draft_2016-02-09.pdf |
| | USFWS | Multi-Objective | 2017 | Upper | Final Comprehensive Conservation Plan/Environmental Impact Statement (CCP/EIS) for Lower Klamath, Clear Lake, Tule Lake, Upper Klamath and Bear Valley National Wildlife Refuges (USFWS 2017) | https://www.fws.gov/refuge/Tule_Lake/what_we_do/planning.html |
| | Klamath Tribes, Trout Unlimited, The Nature Conservancy, USFWS Klamath Falls Partners for Fish and Wildlife Program, ODEQ, Klamath Watershed Partnership, and the North Coast Regional Water Board | Multi-Objective | 2017 | Upper | Upper Klamath Basin Watershed Action Plan | Under Development |
| X | CDFW | Species Conservation/ Recovery Plan | 1996 | Lower | Steelhead Restoration and Management Plan for California (CDFW 1996) | https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=3490 |
| | CDFW | Species Conservation/ Recovery Plan | 2003 | Lower | Shasta and Scott River Pilot Program for Coho Salmon Recovery: with recommendations relating to Agriculture and Agricultural Water Use (CDFW 2003) | http://calfish.ucdavis.edu/files/110057.pdf |
| | CDFW | Species Conservation/ Recovery Plan | 2004 | Lower | Recovery Strategy for California Coho Salmon (CDFW 2004) | https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=99401&inline |
| | CDFW | Species Conservation/ Recovery Plan | 2005 | Upper | Upper Klamath River Wild Trout Area Fisheries Management Plan (CDFW 2005) | https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=56382&inline |
| X | NMFS | Species Conservation/ Recovery Plan | 2010 | National | Federal Recovery Outline - North American Green Sturgeon Southern Distinct Population Segment (NMFS 2010b) | http://www.westcoast.fisheries.noaa.gov/publications/protected_species/other/green_sturgeon/green_sturgeon_sdps_recovery_outline2010.pdf |
| X | USFWS | Species Conservation/ | 2012 | Upper | Revised Lost River Sucker and Shortnose Sucker Recovery Plan (2012) | https://www.fws.gov/klamathfallsfwo/suckers/sucker_news/FinalRevLRS- |

| Included in Crosswalk Table | Agency | Category | Date | Area | Plan Name | Link |
|---|---|---|---|---|---|---|
| | | Recovery Plan | | | | SNSRecvPln/FINAL%20Revised%20LRS%20SNS%20Recovery%20Plan.pdf |
| X | PacifiCorp | Species Conservation/ Recovery Plan | 2012 | Upper | PacifiCorp Klamath Hydroelectric Project Interim Operations Habitat Conservation Plan for Coho Salmon (PacifiCorp 2012) | www.nfwf.org/klamathriver/Documents/PacifiCorpHCP_Feb162012Final.pdf |
| X | PacifiCorp | Species Conservation/ Recovery Plan | 2013 | Upper | PacifiCorp Klamath Hydroelectric Project Interim Operations Habitat Conservation Plan for Lost River and Shortnose Suckers (PacifiCorp 2013) | https://www.pacificorp.com/content/dam/pacificorp/doc/Energy_Sources/Hydro/Hydro_Licensing/Klamath_River/2013Sucker-HCP(11-20-2013)V2F.pdf |
| X | USFW | Species Conservation/ Recovery Plan | 2014 | National | Revised draft recovery plan for the coterminous United States population of bull trout (*Salvelinus confluentus*) (USFW 2014) | https://www.fws.gov/oregonfwo/documents/RecoveryPlans/Bull_Trout_RevisedDraftRP.pdf |
| X | NOAA/NMFS | Species Conservation/ Recovery Plan | 2014 | Whole | Recovery Plan for Southern Oregon/Northern California Coast Coho Salmon (SONCC) (National Marine Fisheries Service, Arcata, CA, 2014) | http://www.nmfs.noaa.gov/pr/recovery/plans/cohosalmon_soncc.pdf |
| X | NMFS | Species Conservation/ Recovery Plan | 2016 | National | Endangered Species Act Recovery Plan for the Southern Distinct Population Segment of Eulachon (*Thaleichthys pacificus*) (NMFS 2016a) | http://www.nmfs.noaa.gov/pr/recovery/plans/draft_eulachon_recovery_plan_draft_public_review.pdf |
| X | Interior Redband Conservation Team | Species Conservation/ Recovery Plan | 2016 | Upper | Conservation Strategy for Interior Redband (Oncorhynchus mykiss subsp.) - (Upper Klamath Pops) (Interior Redband Conservation Team 2016) | https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd525054.pdf |
| X | USDA Forest Service | Water Quality | 2003 | Upper | Water Quality Restoration Plan - Upper Klamath Basin (USDA FS 2003) | https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5288818.pdf |
| | Yurok | Water Quality | 2004 | Lower | Water Quality Control Plan For the Yurok Indian Reservation (2004) | http://www.klamathwaterquality.com/documents/Yurok_Res_WQ_Plan_08-24-04.pdf |
| | KRITFWC / Hoopa | Water Quality | 2008 | Lower | Water Quality Control Plan Hoopa Valley Indian Reservation (2008) | http://www.klamathwaterquality.com/documents/Final_Hoopa_WQCP_20080311-5083(18890575).pdf |
| | ODEQ | Water Quality | 2010 | Upper | Upper Klamath and Lost River Subbasins Total Maximum Daily Load (TMDL) and Water Quality Management Plan (WPMP) (Oregon Department of Environmental Quality 2010) | http://www.deq.state.or.us/wq/TMDLs/docs/klamathbasin/uklost/KlamathLostTMDLWQMP.pdf |
| X | CA Regional Water Quality Control Board | Water Quality | 2011 | Lower | North Coast Regional Water Quality Control Board Watershed Planning Chapter - Klamath Watershed Management Area (CA NC RWQCB 2011) | http://www.waterboards.ca.gov/northcoast/water_issues/programs/basin_plan/083105-bp/basin_plan.pdf |
| | Scott Valley Watershed Council | Water Quality | 2013 | Lower | Voluntary Groundwater Management & Enhancement Plan for Scott Valley Advisory Committee approved 10-22-12 (Scott Valley Watershed Council 2013) | https://www.co.siskiyou.ca.us/sites/default/files/natural-resources/ScottValleyGroundwaterMgmtPlan2012_0.pdf |
| | Karuk | Water Quality | 2014 | Lower | Karuk Tribe Water Quality Control Plan (Karuk 2014) | http://www.klamathwaterquality.com/documents/Karuk_WQCP_Main_final20140220.pdf |
| | ODA | Water Quality | 2015 | Upper | Klamath Headwaters Agricultural Water Quality Management Area Plan (Oregon Dept. of Agriculture / Klamath SWCD, 2015) | https://www.oregon.gov/ODA/shared/Documents/Publications/NaturalResources/KlamathAWQMAreaPlan.pdf |
| | ODA | Water Quality | 2015 | Upper | Lost River Subbasin Agricultural Water Quality Management Area Plan (Oregon Dept. of Agriculture / Klamath SWCD, 2015) | https://www.oregon.gov/ODA/shared/Documents/Publications/NaturalResources/LostRiverAWQMAreaPlan.pdf |
| X | Klamath Tribal Water Quality Consortium | Water Quality | 2016 | Upper | Upper Klamath Basin Nonpoint Source Pollution Assessment and Management Program Plan (KTWQC 2016) | http://www.klamathwaterquality.com/documents/DRAFT_KlamConsortium_nps_plan_20160819.pdf |
| | KBMP | Water Quality | 2016 | Whole | Klamath Basin Water Quality Monitoring Plan (KBMP 2016) | http://kbifrm.psmfc.org/wp-content/uploads/2016/12/Royer-et-al_2016_0029_Klamath-Basin-Water-Quality-Monitoring-Plan.pdf |

# Appendix L: Partial List of Watershed Restoration Grants Applicable to the Klamath Basin

## Major Sources of Restoration Funding

Numerous sources of funding are available to support fish and habitat restoration work in the Klamath Basin. The primary sources of funding for these activities to date have been federal and state restoration grant programs, some of which are specific to the Klamath Basin.

- The Klamath River Coho Habitat Restoration Grant Program is administered jointly by the National Fish and Wildlife Foundation (NFWF), the Bureau of Reclamation (BoR), and NOAA. This program awards roughly $1 million in BoR funding per year to projects helping to meet the requirements of the 2013 Biological Opinion on Klamath Project Operations. Priority projects focus on stream bank and habitat revegetation, address access improvements for spawning and rearing habitat and refuge improvement to increase the viability of cold-water plumes to the benefit of SONCC coho salmon (NFWF 2016a).
- The Klamath River Coho Enhancement Fund is administered by NFWF and PacifiCorp and funds projects that help to attain the conservation objectives contained in PacifiCorp's Klamath Hydroelectric Project Interim Operations Habitat Conservation Plan for Coho Salmon. Priority projects are those that will restore, enhance, and improve habitat, flows, and fish passage for SONCC coho salmon in the Klamath River and its tributaries downstream of Iron Gate Dam (NFWF 2016b).
- Four separate grant programs relevant to Klamath fish are administered by the California Department of Fish and Wildlife (CDFW) using funding by the NOAA Pacific Coastal Salmon Recovery Fund (PCSRF) with additional contribution of state funds. Together, these programs award roughly $17 million of funding per year benefitting fish and fish habitat in California (CDFW 2016a). These programs are:
    - The Fisheries Restoration Grant Program (FRGP), which supports projects that restore, enhance, or protect anadromous salmonid habitat in anadromous watersheds of California, with up to $7 million allocated specifically for coho, Chinook, and Steelhead in the lower Klamath Basin region;
    - The Steelhead Report and Restoration Card (SHRRC), which provides roughly $180,000 per year to support projects focused on steelhead in anadromous coastal and inland watersheds in California. Of note, only projects below barriers impeding anadromy are eligible.
    - The Forest Land Anadromous Restoration (FLAR), which provides roughly $2 million per year to be used on forested watersheds to address the legacy impacts of forest management on non-federal lands and restore conditions beneficial to

State and/or federally listed anadromous salmonids. The Scott River and Lower Klamath watersheds are highlighted as regions of interest for this work.

- The Commercial Salmon Stamp (CSS), which provides roughly $500,000 generated from the sale of commercial salmon stamps to restore salmon populations through habitat improvement, hatchery management, or public outreach, with a particular focus on Chinook salmon. As with the SHRRC program, only projects below barriers impeding anadromy are eligible.

- The Watershed Restoration Grant Program is administered by the California Department of Fish and Wildlife (CDFW) and funded by the Water Quality, Supply, and Infrastructure Improvement Act of 2014 (Proposition 1). This program provides roughly $30 million of funding per three-year cycle for projects that contribute to water quality, river, and watershed protection outside of the San Francisco Delta, which is covered by a different grant program, with the exception of planning and land acquisition projects (CDFW 2016b).
- The Oregon Watershed Enhancement Board administers a variety of grant programs, including Restoration Grants, Monitoring Grants, and Technical assistance Grants[57]. These grants are awarded to projects which help to restore and enhance watershed and ecosystem functions and processes and support community needs. Several grants have been awarded to projects in the Klamath watershed.
- The USDA administers several major conservation programs funded through the 2002 Farm Bill that are intended to assist private landowners in implementing conservation projects on agricultural or ranch lands[58]. Among these are:
  - The Environmental Quality Incentives Program (EQIP) funds projects that improve soil, water, plant, animal, air and related natural resources on agricultural land and non-industrial private forestland. Overall, an estimated $100 million of Farm Bill Program Funds were distributed in the Klamath Basin through to 2007 alone (NRCS 2007).
  - The Wildlife Habitat Incentives Program (WHIP) was repealed in 2014, but once helped conservation-minded landowners who wanted to develop and improve wildlife habitat on agricultural land, nonindustrial private forest land, and Indian land. Some portion of this former program have now been rolled into EQIP.
  - The Conservation Stewardship Program (CSP) funds projects that help private landowners improve their land management practices in ways that benefit wildlife and ecosystems.
- The EPA administers the Section 319(h) Nonpoint Source Management Program established under the Clean Water Act to distribute an estimated $200 million per year in funding to states, territories, and tribes to support projects that help to reduce sources of

[57] https://www.oregon.gov/OWEB/GRANTS/pages/grant_faq.aspx
[58] https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/

nonpoint pollution and improve water quality[59]. Many of the water quality improvement projects in the Upper Klamath Basin to date have been funded through this program.

A number of other smaller grant programs available for supporting restoration work that are not specific to the Klamath Basin are detailed in the following table.

### *Sources of Funding*

California Department of Fish and Wildlife (CDFW). 2016a. 2016 Proposition 1 Watershed Restoration & Delta Water Quality and Ecosystem Restoration Grant Programs Proposal Solicitation Notice. 56 pp. Available at: https://www.wildlife.ca.gov/Conservation/Watersheds/Restoration-Grants

California Department of Fish and Wildlife (CDFW). 2016b. Fisheries Habitat Restoration 2016 Proposal Solicitation Notice. 126 pp.

National Fish and Wildlife Foundation (NFWF). 2016a. Klamath River Coho Habitat Restoration Grant Program 2016 Grant Slate. 4 p. Available at: http://www.nfwf.org/klamathcoho/Pages/home.aspx

National Fish and Wildlife Foundation (NFWF). 2016b. Klamath River Coho Enhancement Fund Request for Pre-Proposals and Full Proposals 2016. 8 p. Available at: http://www.nfwf.org/klamathriver/Pages/home.aspx

[59] https://www.epa.gov/nps/319-grant-program-states-and-territories

| Awarding Agency | Grant Program | Purpose | Funding Category |
|---|---|---|---|
| Oregon Watershed Enhancement Board | Oregon Watershed Restoration Project Grants | The Oregon Watershed Enhancement Board (OWEB) strives to help create and maintain healthy watersheds and natural habitats that support thriving communities and strong economies. | Habitat Restoration |
| Oregon Watershed Enhancement Board | OWEB Small Grants Program | The Small Grant Program is an easy-to-engage-in, competitive grant program that awards funds of up to $10,000 for on-the-ground restoration projects.<br><br>OWEB's Small Grant Program funds projects principally carried out on private lands across Oregon. The Small Grant Program responds to a need for local decision-making about watershed restoration opportunities on a shorter timeframe than is available under OWEB's regular grant program.<br><br>The Small Grant Program enables landowners across the state to contribute to the Oregon Plan for Salmon and Watersheds and the Oregon Conservation Strategy by committing "small acts of kindness" on their properties for the benefit of water quality, water quantity, and fish and wildlife. From planting native plants along stream sides to reducing sedimentation and erosion from upland farms and ranches, citizens everywhere can make a difference. | Habitat Restoration |
| California Department of Fish and Wildlife | Fisheries Restoration Grant Program (FRGP) Project | The Fisheries Restoration Grant Program (FRGP) was established in 1981 in response to rapidly declining populations of wild salmon and steelhead trout and deteriorating fish habitat in California. This competitive grant program has invested millions of dollars to support projects from sediment reduction to watershed education throughout coastal California. Contributing partners include federal and local governments, tribes, water districts, fisheries organizations, watershed restoration groups, the California Conservation Corps, AmeriCorps, and private landowners. | Habitat Restoration<br>Capacity Building |
| State of California Wildlife Conservation Board | Wildlife Conservation Board (WCB) Approved Projects | The Wildlife Conservation Board (WCB) was created by legislation in 1947 to administer a capital outlay program for wildlife conservation and related public recreation. Originally created within the California Department of Natural Resources, and later placed with the Department of Fish and Wildlife, WCB is a separate and independent board with authority and funding to carry out an acquisition and development program for wildlife conservation (California Fish and Wildlife Code 1300, et seq.). WCB consists of the President of the Fish and Game Commission, the Director of the Department of Fish and Wildlife and the Director of the Department of Finance. Legislation that created WCB also established a Legislative Advisory Committee consisting of three members of the Senate and three members of the Assembly, which meet with WCB, providing legislative oversight.<br><br>The primary responsibilities of WCB are to select, authorize and allocate funds for the purchase of land and waters suitable for recreation purposes and the preservation, protection and restoration of wildlife habitat. WCB approves and funds projects that set aside lands within the State for such purposes, through acquisition or other means, to meet these objectives. WCB can also authorize the construction of facilities for recreational purposes on property in which it has a proprietary interest. | Land and Water Acquisition |
| Bureau of Reclamation | Klamath River Coho Habitat Restoration Program | The goal of this competitive grant program is to meet requirements outlined in the 2013 Biological Opinion on Klamath Project Operations by providing support for projects in the Klamath Basin in California that address limiting factors facing SONCC coho salmon, have the greatest impact on promoting survival and recovery, and provide sustainable and lasting ecological benefits. In FY 2016, approximately $1 million in Reclamation funds will be available to implement coho habitat restoration actions within the Klamath River and its tributaries. Successful proposals will address access improvement and fish passage barrier removal, habitat improvement and access to cold water refugia, as well as design, planning and monitoring activities, always making sure to demonstrate direct benefits for SONCC coho salmon. | Habitat Restoration |
| National Fish and | Klamath River Coho | PacifiCorp, which owns and operates the Klamath Hydroelectric Project, developed a Habitat Conservation Plan for coho salmon. As part of | Habitat Restoration |

| Awarding Agency | Grant Program | Purpose | Funding Category |
|---|---|---|---|
| Wildlife Foundation / PacifiCorp | Enhancement Fund | PacifiCorp's conservation strategy, the Klamath River Coho Enhancement Fund was developed to fund projects that will restore, enhance, and improve habitat, flows, and fish passage for the SONCC coho salmon in the Klamath River and/or its tributaries downstream of Iron Gate Dam. In order to be eligible for funding, projects must have a direct benefit to SONCC coho salmon and address one or more of PacifiCorp's Habitat Conservation Plan for Coho Salmon goals.<br><br>As of December 2016, PacifiCorp has funded 38 projects with $3.9 million, leveraging an additional $7.4 million in matching funds.. The projects awarded meet the Habitat Conservation Plan goals, including the improvement of fish passage and connectivity, spawning and rearing habitat enhancements, and flow augmentation through water transactions.<br><br>This program is a conservation partnership between NFWF and PacifiCorp Energy to assist PacifiCorp in meeting the environmental commitments in its Habitat Conservation Plan for Coho Salmon. In most cases, projects funded under this project also support NFWF's Lower Klamath Basin conservation priorities. | |
| National Fish and Wildlife Foundation / OWEB/USFWS/USFS | Upper Klamath Basin Initiative Grants Program | The goal of Upper Klamath Basin initiative is to restore watershed and water flow conditions in order to support increased distribution and abundance of federally-listed Lost River sucker and shortnose sucker, as well as state sensitive redband trout. | Capacity-Building, Habitat Restoration, Research |
| U.S. Fish and Wildlife Service | Watershed Restoration Priority for Lower Klamath Tributaries | Funds under this award are to assist the Yurok Tribal Fisheries to plan and implement priority watershed enhancement activities in the Lower Klamath River. The Yurok Tribes¿¿s restoration actions in the Lower Klamath are focused on reducing sedimentation of high value aquatic habitats, protecting and enhancing cold water tributaries, and increasing habitat complexity and watershed resiliency to climate change affects. Specifically, YTWRD is focused on decommissioning roads and stream crossings to reduce sedimentation and water quality/quantity impacts by restoring more natural flow paths and removing unstable fill. The project also helps the USFWS fulfill tribal trust obligations to the tribe. This award is made under the authority of: Fish and Wildlife Act of 1956, as amended, 16 U.S.C. 742a-742j. | Habitat Restoration |
| National Forest Foundation / US Forest Service | Community Capacity and Land Stewardship (CCLS) program | he National Forest Foundation is working in partnership with the USDA Forest Service, Natural Resources Conservation Service and conservation leaders in Pacific coast states to help community-based organizations remove barriers to watershed-scale restoration projects .<br><br>The Community Capacity and Land Stewardship (CCLS) program provides operations grants of up to $24,000 to provide capacity building support for local efforts that work toward improving their effectiveness implementing watershed restoration projects with long-term economic benefits. The grant program provides support for organizations to develop restoration plans, come to collaborative consensus around watershed priorities, conduct restoration workshops and trainings, and complete other activities that can help organizations achieve restoration and economic development objectives.<br><br>At present, CCLS funding is only available to support work benefiting National Forests and Grasslands in California, Oregon, Washington, and in Southeast Alaska. The NFF anticipates offering the program more broadly if additional funding becomes available. | Capacity-building and Administrative Support |
| California Department of Water Resources | Integrated Regional Water Management (IRWM) Program Grants (Prop 84) | Proposition 84, Safe Drinking Water, Water Quality and Supply, Flood Control, River and Coastal Protection Bond Act of 2006 provides $900 million in regional funds to be allocated to 11 California Funding Areas. The North Coast's allocation is $37 million with approximately $11M remaining. On March 13, 2015 the California Department of Water Resources (DWR) released the 2015 Integrated Regional Water Management (IRWM) Program Guidelines and 2015 Proposal Solicitation Package (PSP) for the last round of Proposition 84 funding. The final DWR 2015 IRWM Guidelines and 2015 PSP can be found at http://www.water.ca.gov/irwm/grants/p84implementation.cfm. | Habitat Restoration |
| International Federation of Fly | Conservation Grants Program | Conservation is one of the founding principles of the International Federation of Fly Fishers. Contributing over 40 years of conservation work, the IFFF is proud to continue protecting our fisheries and angling opportunities for the future. | Habitat Restoration |

| Awarding Agency | Grant Program | Purpose | Funding Category |
|---|---|---|---|
| Fishers | | To support our mission the Conservation Small Grants Program was started in 2011 by Dr. Rick Williams, VP-Conservation, and Bob Tabbert, FFF Conservation Director. With the approval of the IFFF Board of Directors, the Conservation Committee began the process of setting guidelines and promoting the program to Clubs and Councils throughout the IFFF organization. The IFFF Board of Directors approved $22500 to support the program in 2011. Two rounds of grants were awarded in 2011 and will continue to be awarded two times each year until further notice. To accomplish this goal, applications will be accepted all year long. | |
| CA Department of Conservation | Resource Conservation District (RCD) Capacity Building Financial Assistance Program | Grants to fund RCD projects that improve the health of can watershed san build RCD capacity to promote and support conservation with landowners and communities within watersheds | Capacity-building and Administrative Support |
| CA Department of Conservation | Watershed Coordinator Grant Program | The Department of Conservation awarded competitive grants to special districts, nonprofit groups, and local governments to promote watershed management and local watershed improvements. The grant program supported watershed coordinator positions that facilitated collaborative efforts to improve and sustain the health of California's watersheds. | Capacity-building and Administrative Support |
| CA Department of Parks and Recreation | Habitat Conservation Fund Grant | Local governments only. Can be used for wetland and riparian acquisition or restoration, among other categories. Public access required | Capacity-building and Administrative Support, Acquisition of Lands |
| CA State Water Resources Control Board | Agricultural Water Quality Grant Program | Reduce or eliminate non-point source pollution discharge to surface waters from irrigated agricultural lands | Water Quality Management |
| CA State Water Resources Control Board | Non-point Source Pollution Control and Watershed Protection / Implementation Grants (Operates under the FEDERAL CWA 319(H) PROGRAM) | This program is an annual federally funded nonpoint source pollution control program that is focused on controlling activities that impair beneficial uses and on limiting pollutant effects caused by those activities. States must establish priority rankings for waters on lists of impaired waters and develop action plans, known as Total Maximum Daily Loads (TMDLs), to improve water quality. Project proposals that address TMDL implementation and those that address problems in impaired waters are favored in the selection process. There is also a focus on implementing management activities that lead to reduction and/or prevention of pollutants that threaten or impair surface and ground waters. | Water Quality Management |
| California Department of Forestry and Fire Protection (CAL FIRE) | Vegetation Management Program (VMP) | The Vegetation Management Program (VMP) is a cost-sharing program that focuses on the use of prescribed fire, and some mechanical means, for addressing wildland fire fuel hazards and other resource management issues on State Responsibility Area (SRA) lands. The use of prescribed fire mimics natural processes, restores fire to its historic role in wildland ecosystems, and provides significant fire hazard reduction benefits that enhance public and firefighter safety. VMP allows private landowners to enter into a contract with CAL FIRE to use prescribed fire to accomplish a combination of fire protection and resource management goals. | Fire Management, Water Quality Management |
| California Department of Forestry and Fire Protection (CAL FIRE) | Cal Forest Improvement Program (CFIP) | The purpose of the California Forest Improvement Program (CFIP) program is to encourage private and public investment in, and improved management of, California forest lands and resources. This focus is to ensure adequate high quality timber supplies, related employment and other economic benefits, and the protection, maintenance, and enhancement of a productive and stable forest resource system for the benefit of present and future generations. The program scope includes the improvement of all forest resources including fish and wildlife habitat, and soil and water quality. Cost-share assistance is provided to private and public ownerships containing 20 to 5,000 acres of forest land. Cost-shared activities include management planning, site preparation, tree purchase and planting, timber stand improvement, fish and wildlife habitat improvement, and land conservation practices. | Fire Management, Water Quality Management |

| Awarding Agency | Grant Program | Purpose | Funding Category |
|---|---|---|---|
| Common Council Foundation | The Acorn Foundation | Community based projects which preserve and restore habitat, advocate for environmental justice, particularly for low-income and indigenous people, and prevent or remedy toxic pollution | Capacity-Building, Habitat Restoration |
| Conservation Alliance | Conservation Alliance Grants | The Conservation Alliance seeks to protect threatened wild places throughout North America for their habitat and recreational values. As a group of outdoor industry companies, we recognize our responsibility to help protect the wild lands and waterways on which our customers recreate and wildlife thrives. To achieve that goal, we make grants to nonprofit organizations working to protect the special wild lands and waters in their backyards. | Capacity-Building, Habitat Restoration |
| Environmental Protection Agency | Environmental Education Grant Program | Under the Environmental Education Grants Program, EPA seeks grant proposals from eligible applicants to support environmental education projects that promote environmental awareness and stewardship and help provide people with the skills to take responsible actions to protect the environment. This grant program provides financial support for projects that design, demonstrate, and/or disseminate environmental education practices, methods, or techniques. Since 1992, EPA has distributed between $2 and $3.5 million in grant funding per year, supporting more than 3,600 grants. | Education |
| Trout Unlimited | Embrace a Stream Program Grants | Embrace-A-Stream (EAS) is a matching grant program administered by TU that awards funds to TU chapters and councils for coldwater fisheries conservation. Since its inception in 1975, EAS has funded more than 1,000 individual projects for a total of $4.4 million in direct cash grants. Local TU chapters and councils contributed an additional $13 million in cash and in-kind services to EAS funded projects, for a total investment of more than $17 million. | Habitat Restoration |
| American Sport fishing Association | FishAmerica Foundation | Since 1983, the FishAmerica Foundation has awarded $12.1 million to 1,007 projects in all fifty states and Canada to enhance fish populations, restore fishery habitats, improve water quality and advance fishery research to improve sportfishing opportunities and help ensure recreational fishing's future. | Habitat Restoration |
| National Fish and Wildlife Foundation / Partners | Bring Back the Natives Initiative (BBN) | The Bring Back the Natives/More Fish program invests in conservation activities that restore, protect, and enhance native populations of sensitive or listed fish species across the United States, especially in areas on or adjacent to federal agency lands. The program emphasizes coordination between private landowners and federal agencies, tribes, corporations, and states to improve the ecosystem functions and health of watersheds. The end result is conservation of aquatic ecosystems, increase of instream flows, and partnerships that benefit native fish species throughout the U.S. This funding opportunity also provides grants to implement the goals of the National Fish Habitat Action Plan (www.fishhabitat.org). | Habitat Restoration |
| USDA Natural Resources Conservation Service | Regional Conservation Partnership Program | The Regional Conservation Partnership Program (RCPP) offers new opportunities for the NRCS, conservation partners and agricultural producers to work together to harness innovation, expand the conservation mission and demonstrate the value and efficacy of voluntary, private lands conservation. | Land Use Practices |
| USDA Natural Resources Conservation Service | Environmental Quality Incentives Program (EQIP) | The Environmental Quality Incentives Program (EQIP) is a voluntary program that provides financial and technical assistance to agricultural producers to plan and implement conservation practices that improve soil, water, plant, animal, air and related natural resources on agricultural land and non-industrial private forestland. EQIP may also help producers meet Federal, State, Tribal, and local environmental regulations. | Land Use Practices |
| USDA Natural Resources Conservation Service | Conservation Innovation Grants (CIG) | Conservation Innovation Grants (CIG) are competitive grants that stimulate the development and adoption of innovative approaches and technologies for conservation on agricultural lands. CIG uses Environmental Quality Incentives Program (EQIP) funds to award competitive grants to non-Federal governmental or nongovernmental organizations, American Indian Tribes, or individuals. Producers involved in CIG funded projects must be EQIP eligible. | Land Use Practices |
| USDA Natural Resources Conservation Service | Conservation Stewardship Program | The Conservation Stewardship Program (CSP) helps landowners build on their existing conservation efforts while strengthening operations. Whether landowners are looking to improve grazing conditions, increase crop yields, or develop wildlife habitat, we can custom design a CSP plan to help you meet those goals. This program helps landowners schedule timely planting of cover crops, develop a grazing plan that will improve the forage base, implement no-till to reduce erosion or manage forested areas in a way that benefits wildlife habitat. | Land Use Practices |
| California Department of Fish and Wildlife | Watershed Restoration Grant Programs | CDFW established two new grant programs to fund multi-benefit ecosystem and watershed protection and restoration projects, as outlined in the Water Quality, Supply, and Infrastructure Improvement Act of 2014 (Proposition 1). The Watershed Restoration Grant Program focuses on water | Habitat Restoration |

| Awarding Agency | Grant Program | Purpose | Funding Category |
|---|---|---|---|
| | (Proposition 1) | quality, river, and watershed protection and restoration projects of statewide importance outside of the Sacramento-San Joaquin Delta (Delta). The Delta Water Quality and Ecosystem Restoration Grant Program focuses on water quality, ecosystem restoration and fish protection facilities that benefit the Delta.<br><br>Proposition 1 provides funding to meet three broad objectives of the California Water Action Plan: more reliable water supplies; the restoration of important species and habitat; and a more resilient, sustainably managed water resources system (water supply, water quality, flood protection, and environment) that can better withstand inevitable and unforeseen pressures in the coming decades. | |

# Appendix M: Required Information to Develop a Sampling Design

The following list of questions is modified from (Paige et al. 2014) and is a guide for developing sampling design. The order of the questions is not absolute; rather an iterative approach is required. Some questions will be revisited and refined in response to answers to other questions:

1. Clearly state the study objective.

2. Identify Performance Measures (PMs)
    - *What information do you need in order to assess the objectives?*

3. Identify data needs
    - *What data do you need to collect in order to generate the PM?*
        - *Age-structure,*
        - *Natural:hatchery,*
        - *Harvest,*
        - *Escapement, etc… in order to estimate recruitment.*

4. Describe how the data will be analyzed
    - *What would you do with the data if you had it?*
        - *Trend analysis.*
        - *Before/after comparisons.*
        - *Control vs. Rehab sites.*
        - *Formal experiments of different hydrographs or gravel regimes.*
        - *Multiple regression analyses.*

5. Identify baseline data
    - *How much baseline data is available, if any?*
    - *What is the quality of the data?*
    - *Can it be used for before/after comparisons?*
    - *Can it be used to provide initial estimates of variability for power analyses or sample size calculations?*

6. Identify key uncertainties
    - *What are key uncertainties that need to be addressed within each assessment?*

7. Clarify protocols
    - *What are existing/proposed protocols?*
    - *Is there much controversy about the methods (if so, describe), or are they well established?*
    - *What monitoring is done now?*
    - *How is it done?*
    - *How much effort?*
    - *What is the estimated cost*?

8. Describe any important life history characteristics or logistical constraints.
    - *Are there any life history characteristics or logistical constraints that will affect the sampling design?*
        - *Behaviour*
        - *Timing*
        - *Logistical difficulties due to flows…etc.*

9. Define the target population.
    - *Consider space and time – be explicit.*
    - *Consider seasonality (e.g., habitat availability in summer vs. winter)*
    - *Are there any exclusion criteria (i.e., locations you aren't interested in for some reason)?*

10. Define an appropriate sampling unit.
    - *The size and shape of a sampling unit can affect the efficiency of the estimate, both in a statistical sense (minimizing confidence intervals) and a logistical sense (minimizing effort).*
    - *Consider the following:*
        - *Convenience*
        - *Efficiency*
        - *Minimization of variability among sampling units*
        - *Ease of obtaining sampling frame*

11. Determine how sampling units should be positioned
    - *Stratified, systematic?*
    - *Is stratification appropriate? (i.e., is between strata variability > within stratum variability?)*
    - *How is the attribute distributed?*
    - *Are there any known gradients in the target population? This information can be used to help determine between a random, systematic, or Generalized Random-Tessellation Stratified (GRTS) design*

12. Determine an appropriate sample size at each step of the design
    - *What size change do you wish to detect?*
    - *What existing data do you to do preliminary power analyses?*

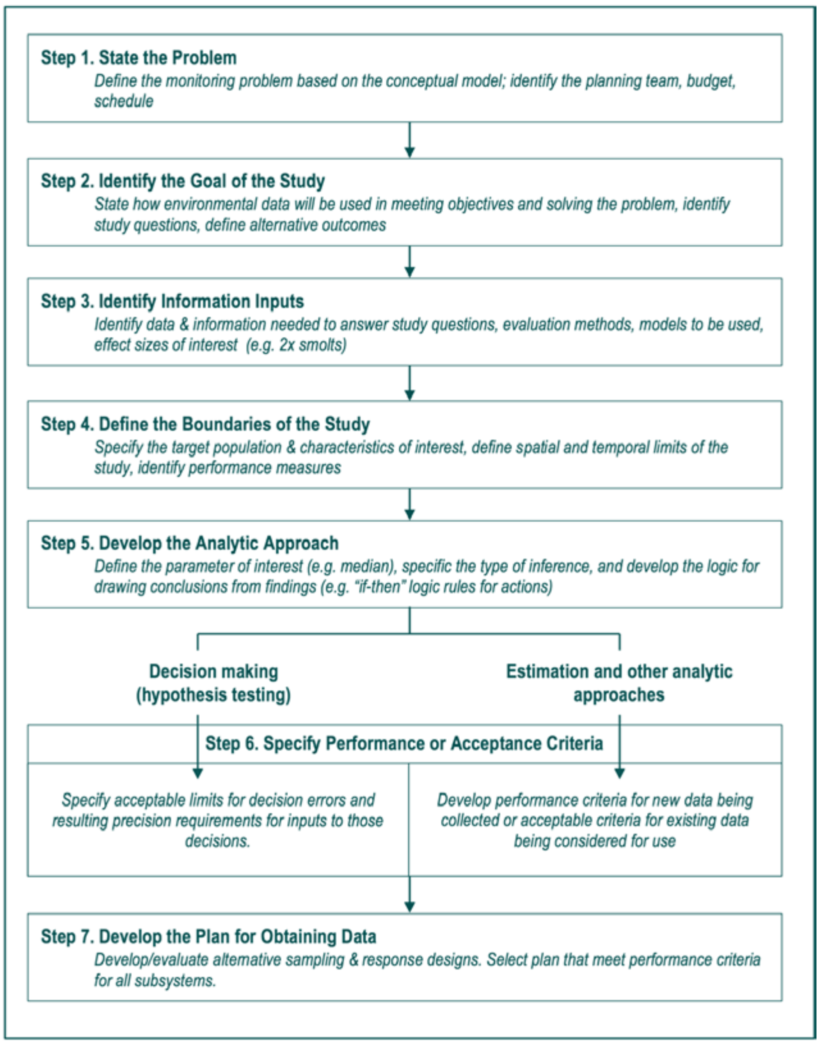
13. Determine an appropriate sampling frequency
    - *Frequency/timing of sampling 1) within a year, and 2) across years?*
    - *What time of day should you sample?*
    - *What time of year should you sample?*
    - *Do you need multiple measurements in time (i.e., monthly or daily mean)?*
    - *Should you use permanent or temporary sites (or some combination)?*

14. Integrate with other assessments
    - *What other assessments should be integrated to get better information?*
    - *How will this be accomplished?*
    - *Who is dependent on the data produced by the assessment?*
    - *What data collected by other assessments are required?*
    - *Is overlap desired (e.g., rehabilitation sites, non-rehabilitation sites, confined, unconfined)?*

# Appendix N: Determining Precision Requirements for Monitoring

The Environmental Protection Agency's (EPA) Data Quality Objectives (DQO) process provides a logical decision pathway to guide the development and evaluation of alternative study designs, including determining precision requirements for monitoring projects (EPA 2006). The process involves 7 steps, each associated with a series of qualitative and quantitative statements that help to clarify monitoring program objectives, define the appropriate types of data to collect/analyze and specify the tolerable limits on potential decision errors. Responding to each step helps characterize the quality and quantity of data needed to support decisions. Steps 5 and 6 offer a useful guide for determining required levels of precision; more details can be found in the full EPA report.

Figure M-1. EPA's Data Quality Objective's Process




Source: Adapted from EPA (2006)

# Appendix O: Summary of proposed roles and responsibilities of major entities implementing the Missouri River Recover Program

Table N-1: Summary of proposed roles and responsibilities of major entities implementing the Missouri River Recover Program (MRRP). See Figure 8-7 of this report for the general relationships among entities. Source: Fischenich et al. 2016a (with clarifications of acronyms).

| Entity | Composition | Primary Roles and Responsibilities |
|---|---|---|
| Technical Team | Independent experts, agency staff, and contractors supporting the MRRP in a non-decision, technical role; organized similar to the Effects Analysis Teams | • Conduct monitoring and assessment of projects<br>• Analyze and evaluate data and hypotheses<br>• Develop and apply models as needed<br>• Interpret results and present findings in reports and at biannual science meetings<br>• Assess potential courses of action and outcomes<br>• Conduct research and/or undertake focused studies as directed |
| Bird and Fish Teams | Implementation Project Managers (PMs) for each species<br>USFWS species representatives<br>Adaptive Management Project Manager (AM PM)<br>Water Management representative<br>Engineering Division representative<br>Planning Division representative<br>Coordinators of the Independent Science Program (ISP)<br>MRRIC[60] Bird and Fish Work Groups (WGs) | • Review research, monitoring, and assessment results and make related recommendations<br>• Identify needed research, technical assessments, etc.<br>• Resolve issues related to project siting, construction, operations, etc.<br>• Develop recommendations on prioritizations for management action implementation based on discussions at AM Workshop<br>• Manage contracts, and conduct other "on-the-ground" tasks necessary for implementation |
| Human Considerations Team (HC Team) | MRRIC PM<br>AM PM<br>USFWS representative<br>Water Management representative<br>USACE technical staff<br><br>MRRIC HC WG | • Review research, monitoring, and assessment results for HC-related concerns<br>• Make recommendations for monitoring, assessment or special studies related to HCs<br>• Identify needed changes in monitoring or assessment protocols |

[60] MRRIC = Missouri River Recovery Implementation Committee, a 75-person stakeholder committee that provides recommendations to implementing agencies, and includes representatives from 9 federal agencies, 8 states, 29 tribes and 14 different interests, each represented by two people. These interests include flood control, navigation, agriculture, recreation, thermal power, hydro power, irrigation, fish and wildlife, waterway industries, water quality, water supply, conservation districts, major tributaries, local government, environment and conservation organizations, and at large/other interests.

| Entity | Composition | Primary Roles and Responsibilities |
|---|---|---|
| Management Team | Special Assistant – Missouri River Basin Programs (Northwestern Division, NWD)<br>MRRP Senior PM<br>USFWS Missouri River Coordinator<br>MRRIC PM<br>AM PM<br>Implementation PMs for each species<br>Manager of Independent Science Program<br>Water Management Representative | • Make decisions regarding allocation of budget, staff, and material<br>• Make recommendations on action and research prioritization and flow modifications<br>• Prepare Draft Work Plans<br>• Recommend changes to program components and governance |
| Executive Steering Committee (ESC) | Special Assistant – Missouri River Basin Programs (NWD)<br>Chiefs of Programs and Project Management (Omaha and Kansas City Districts, NWO and NWK)<br>Chief of CW (NWO and NWK)<br>Chief of Planning (NWO and NWK)<br>Chief of Missouri River Basin Water Management District | • Review and recommendations on Draft WP<br>• Ensures that the MRRP is implemented according to the direction and guidance provided by the Oversight level<br>• Ensures regional, systems perspective<br>• Resolves district and cross-district disputes<br>• Approves/decides on budget and staffing issues |
| Oversight Level | NWD Commander<br>USACE District Commanders<br>NWD Director of Programs<br>USFWS Region 6 Director<br>USFWS Assistant Regional Director<br><br>MRRP Senior PM<br>USFWS MR Coordinator<br>Chief of NWD Water Management | • Make decisions about priorities<br>• Make decisions regarding flow actions<br>• Make decisions about targets and objectives<br>• Make decisions about program structure and changes<br>• Resolve disputes |
| MRRIC | Plenary As defined in Charter | • Provides input to AM Plan development and subsequent adjustments to the plan<br>• Make recommendations on WPs<br>• Make recommendations on research needs and priorities<br>• Provide feedback and input on HC assessments/issues of concern |
| | Bird and Fish Work Groups | • Works in conjunction with agency staff on Bird/Fish Teams to prioritize the research, project implementation, monitoring, evaluation, and adaptive actions of the MRRP.<br>• Provide information to the full body of MRRIC regarding insights based on science findings, and assist with MRRIC recommendations |
| | Human Considerations Work Group (HC WG) | • Works in conjunction with agency staff on HC Team to guide recommendations on HC |

| Entity | Composition | Primary Roles and Responsibilities |
|---|---|---|
| | | monitoring and assessment priorities<br>• Provide information to the full body of MRRIC regarding insights based on HC effects, and assist with MRRIC recommendations |
| Independent Advisory Panel | As defined in enabling documentation | • Participate in biannual science and AM meetings; review substantive products.<br>• Provide independent scientific and technical advice and recommendations to MRRIC and the lead agencies |
| Integrated Science Program (ISP) | ISP Manager<br>AM PM<br>Terrestrial Science Coordinator<br>Aquatic Sciences Coordinator<br>Support Staff (including partners) | • Oversee monitoring and assessment<br>• Oversee research and focused studies<br>• Oversee the Technical Team<br>• Provide program advice to senior leadership and represent the program on science matters |
| Issue Resolution Board | NWD Director of Programs<br>USFWS Assistant Regional Director<br>Special Assistant – Missouri River Basin Programs (NWD)<br>USFWS MR Coordinator | • Resolves disputes |
| Tribes | As recognized | • Provide input into the process through communication participation, coordination, and consultation with MRRP |
| Agencies Outside MRRIC | State and other Federal agency departments with defined roles outside MRRIC process | • Regulatory compliance and recommendations on site-specific projects |
| Public | Refers to individuals acting outside the above categories | • Provide input to the MRRP in response to any public notice related to the Program |