IMPLEMENTATION PLAN FOR THE REINTRODUCTION OF ANADROMOUS FISHES INTO THE OREGON PORTION OF THE UPPER KLAMATH BASIN

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Prepared by

Oregon Department of Fish and Wildlife

The Klamath Tribes

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For Information regarding the Klamath Hydroelectric Project dam removal:

- Lower Klamath Hydropower Project Dam removal information (Klamath River Renewal Corporation website) – www.klamathrenewal.org/

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Cover photo: Klamath River in Oregon between J.C. Boyle Dam and Copco 1 Dam by Mark E. Hereford, ODFW

ACRONYMS AND ABBREVIATIONS

BLM	U.S. Bureau of Land Management
CDFW	California Department of Fish and Wildlife
CDWR	California Department of Water Resources
CWT	Coded-wire tag
DIDSON	Dual-Frequency Identification Sonar
DNA	Deoxyribonucleic acid
DO	Dissolved oxygen
DPS	Distinct Population Segment
DRE	Dam Removal Entity
eDNA	Environmental DNA
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
FERC	Federal Energy Regulatory Commission
IFRMP	Klamath Basin Integrated Fisheries Restoration and Monitoring Plan
IUCN	International Union for the Conservation of Nature
KBRA	Klamath Basin Restoration Agreement
KHP	Klamath Hydroelectric Project
KHSA	Klamath Hydroelectric Settlement Agreement
KRRC	Klamath River Renewal Corporation
KRTT	Klamath River Technical Team
NHD	National Hydrography Dataset
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
OAR	Oregon Administrative Rule
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
OFWC	Oregon Fish and Wildlife Commission
PFMC	Pacific Fishery Management Council
PIT	Passive Integrated Transponder
rkm	river kilometers
rm	river miles
SMU	Species Management Unit
SNP	Single-nucleotide polymorphism
SONCC	Southern Oregon/Northern California Coast
UKB	Upper Klamath Basin
UKBCA	Upper Klamath Basin Comprehensive Agreement
UKL	Upper Klamath Lake
UKTR	Upper Klamath-Trinity River
USBR	U.S. Bureau of Reclamation
USDC	U.S. Department of Commerce
USDI	U.S. Department of Interior
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WAP	Watershed Action Plan

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EXECUTIVE SUMMARY

The construction of Copco 1 Dam in October of 1912 on the Klamath River, near the town of Hornbrook, California resulted in blocking the migration of anadromous fishes (fish that spend time in the ocean for growth and migrate to freshwater to reproduce) to all waters in the Klamath River Basin upstream of Copco 1 Dam. Consequently, all anadromous fish runs above Copco 1 Dam were extirpated. Prior to the construction of Copco 1 Dam, fall and spring-run Chinook Salmon, Coho Salmon, steelhead trout, and Pacific Lamprey were documented to have occurred in the Upper Klamath Basin (see Hamilton et al. 2005 and Hamilton et al. 2016 for historical description and characteristics of anadromous fishes in the Upper Klamath Basin). Subsequent construction of Copco 2 Dam, J.C. Boyle Dam, and Iron Gate Dam on the Klamath River further blocked migration of these fish.

The license to operate the Klamath Hydroelectric Project (FERC Project No. 2082), owned and operated by PacifiCorp located on the Klamath River in California and Oregon expired in 2006. The Klamath Hydroelectric Project includes the four Klamath River mainstem hydroelectric dams (Iron Gate Dam, Copco 1, Copco 2, and J.C. Boyle Dam), along with several additional hydropower facilities (e.g., Fall Creek, East Side, West Side and Keno Dam). The relicensing of these dams requires the owners of the project to include volitional passage of anadromous fishes and associated water quantity and quality measures for passage. The passage requirement resulted in the owner of the dams along with stakeholders to pursue an alternative to relicensing the project in the form of an agreement to remove the dams. The 2010 Klamath Hydroelectric Settlement Agreement (KHSA) set in motion the removal of the four mainstem hydroelectric dams located on the Klamath River in California and Oregon. On September 23, 2016, the Klamath River Renewal Corporation (KRRC), a non-profit organization formed to serve as the party responsible for the dam removal, applied to the Federal Energy Regulatory Commission (FERC) to remove the four dams and associated facilities that together form the Lower Klamath Project (FERC Project No. 14803) which is currently part of the Klamath Hydroelectric Project (FERC Project No. 2082). The current timeline for dam removal and subsequent fish passage is 2023.

In 2008 Oregon Department of Fish and Wildlife wrote *A Plan for the Reintroduction of Anadromous Fish in the Upper Klamath Basin* (Reintroduction Plan). The Reintroduction Plan sought and obtained approval from the Oregon Fish and Wildlife Commission to authorize amendments to the Klamath River Basin Fish Management Plan regarding the reintroduction and management of anadromous fishes. The purpose of the Reintroduction Plan was to initiate the efforts to re-establish anadromous fishes in the Oregon portion of the Klamath River Basin, assuming volitional fish passage is provided throughout the Klamath River corridor. The Reintroduction Plan and the associated Oregon policy (OAR 635-500-3890) state that a Reintroduction Implementation Plan (this document) shall be prepared to guide the reintroduction of Chinook Salmon, Coho Salmon, steelhead trout, and Pacific Lamprey into the Oregon portion of the Klamath River Basin, with the goal of establishing self-sustaining, naturally produced populations.

The Reintroduction Implementation Plan recommends species-specific approaches to guide the reintroduction of historically present anadromous fishes. Fall-run Chinook, Coho Salmon, steelhead trout, and Pacific Lamprey are all found in habitat immediately below Iron Gate Dam. When the dams are removed there is a high degree of confidence that individuals of these species will repopulate newly available habitat on their own. Therefore, this plan recommends a volitional approach to reintroduction of these fishes, in which no active measures will initially be taken to assist in repopulating habitat in the Upper Klamath Basin. The only remaining populations of spring-run Chinook Salmon in the Klamath Basin are located in the Trinity River and Salmon River sub-basins (150 and 128 miles downstream of Iron Gate Dam, respectively). Because of the long distance from Iron Gate Dam, and even further distance to newly available habitat, to the source populations of spring-run Chinook Salmon (Trinity River and Salmon River sub-basins), these fish are unlikely to repopulate habitat in the upper basin on their own. This plan recommends and outlines the approaches for an active reintroduction program to repopulate suitable habitat in the Upper Klamath Basin with spring-run Chinook Salmon through the use of releasing pathogen-screened, hatchery reared juveniles from an in-basin source (most likely from the Trinity River sub-basin).

The Reintroduction Implementation Plan includes a recommended strategy for monitoring re-establishment of anadromous fishes following the removal of the four Klamath Hydroelectric dams. The strategy for monitoring will be focused on fundamental questions. Immediately following the availability of passage, monitoring will focus on determining if anadromous fishes are migrating into habitat immediately above the dams. As fish populations become more widely established, monitoring will be more specific and focused on management objectives, such as determining adult escapement, juvenile productivity, and spatial distribution within each sub-basin. This plan recommends monitoring facilities and activities, such as the use of PIT and telemetry tags, visual surveys, video weirs, and downstream juvenile traps, while also recognizing that monitoring should be adaptable to other technologies and methods to help answer monitoring questions.

The content of the material in this plan was written by staff from Oregon Department of Fish and Wildlife and The Klamath Tribes. Multiple meetings and document reviews with staff from California Department of Fish and Wildlife, National Marine Fisheries Service (NOAA), U.S. Fish and Wildlife Service, U.S. Geological Survey, Yurok Tribe, Karuk Tribe, Hoopa Tribe, Oregon State University, Humboldt State University, University of California (Davis), Trout Unlimited, and Wild Salmon Center helped inform the material in this document.

Although The Klamath Tribes' staff participated in the development of this document, they do not waive any sovereign rights or associated abilities of The Klamath Tribes.

1. INTRODUCTION

The following Reintroduction Implementation Plan recommends efforts to be undertaken within the Oregon portion of the Upper Klamath Basin to reintroduce anadromous fishes to suitable, historically occupied areas above the site of Iron Gate Dam (river kilometer; rkm 312; river mile 194). The recommended efforts shall take place within a science-based, adaptive framework that will be incorporated into other efforts to restore key aquatic environments across the Klamath Basin as a whole. Other, simultaneous efforts are separate from those described in this Implementation Plan but will affect the overall success of reintroduction and will require a coordinated effort among Klamath Basin agencies, Tribes, and various other interested organizations.

Key Considerations

- Removing the lower four Klamath Hydroelectric Project (KHP) dams (J.C. Boyle Dam, Copco 1 and 2 Dams, and Iron Gate Dam) on the mainstem Klamath River or providing volitional fish passage at these dams and the reservoirs behind them is essential to meeting the objectives of this Reintroduction Implementation Plan.
    - The reintroduction strategies developed in this plan are in response to the removal of the four lower hydroelectric dams and do not include strategies under a "dams remain" scenario.

    - For more information regarding the dam removal process visit the Klamath River Renewal Corporation website at klamathrenewal.org.

- We use the International Union for the Conservation of Nature (IUCN 1998) definition of **reintroduction** as "an attempt to establish a species in an area which was once part of its historical range, but from which it has been extirpated or become extinct." Within this broad definition we consider two approaches to reintroduction:
    - **Natural repopulation** (sometimes referred to as volitional repopulation or re-establishment), where individuals from a nearby source population repopulate newly available habitat on their own, without human assistance following barrier removal. The available literature sometimes refers to this approach as recolonization.

      and

    - **Active repopulation** (sometimes referred to as active reintroduction) where individuals are actively transplanted from a distant source population into newly available habitat above removed barriers.

The Reintroduction Implementation Plan begins with a description of the Klamath Basin and its historical runs of anadromous fishes. It then outlines key issues and uncertainties that may affect successful reintroduction of these fishes into the Oregon portion of the basin once fish passage is restored through the Klamath Hydroelectric Project (KHP). The Reintroduction Implementation Plan then sets forth species-specific approaches to reintroducing anadromous fishes to Oregon waters within the basin, followed by sections describing strategies for monitoring and evaluating volitional repopulation and tactics for actively repopulating habitat with spring-run Chinook Salmon.

1.1 History

1.1.1 Hydrology, Ecology, Climate, and Native Fishes

The Klamath River drains a 40,610 km^2 (15,680 square miles) basin in southern Oregon and northern California that flows directly into the Pacific Ocean on the California coast (Figure 1-1). The ecological landscape of the basin reflects its diverse geology. The upper-most portion of the basin has been shaped by the activity of large volcanoes and faulting that have created broad valleys containing the largest natural lakes and wetlands in the area. Due to its location on the east side of the Cascade Range, the upper portion of the Klamath Basin has a relatively dry, high desert climate (NRC 2004). Streams in the Upper Klamath Basin (defined as the Klamath Basin above the site of Iron Gate Dam, rkm 312; rm 193.9) include low gradient, meandering channels fed by groundwater-spring sources and steep montane tributaries that get much of their water from snow melt. Three major stream systems in the upper basin, Wood River, Williamson River, and Sprague River (the Williamson's largest tributary), discharge into the north end of Upper Klamath Lake (UKL, the basin's largest waterbody). Water exits the south end of UKL through Link River near the town of Klamath Falls, Oregon, and then flows into Lake Ewauna and Keno Impoundment, from which it exits as the Klamath River. Below Keno Impoundment, the Klamath River flows through predominantly steep terrain as it passes through the southern Cascade Range and then the Siskiyou Mountains, the Trinity Alps, and the Coast Range (collectively, the Klamath Mountains) on its way to the ocean. Within lower portions of the Klamath Basin, below Iron Gate Dam and particularly nearer the coast, the river has more seasonally variable discharge patterns than upstream. This is due to changes in climate toward a wetter and milder (warmer in the winter) coastal regime and a declining influence of the upper basin's profuse groundwater (NRC 2004).

The varied landscape of the Klamath Basin supports diverse populations of fishes, each expressing life histories adapted to specific aquatic habitats. These populations include anadromous runs of spring and fall-run Chinook Salmon (*Oncorhynchus tshawytscha*), Coho Salmon (*Oncorhynchus kisutch*), steelhead trout (*Oncorhynchus mykiss*), Pacific Lamprey (*Entosphenus tridentatus*), Eulachon (*Thaleichthys pacificus*), and Green Sturgeon (*Acipenser medirostris*). Anadromous fishes of the Klamath Basin are found in marine waters off California, Oregon, and Washington. These fish provide opportunities for Tribal, commercial, and recreational fishing, and support fishing-based tourism along their coastal and inland migration routes. Southern Oregon/Northern California Coast (SONCC) Coho Salmon, which includes populations in the Klamath Basin, are listed as Threatened under the federal Endangered Species

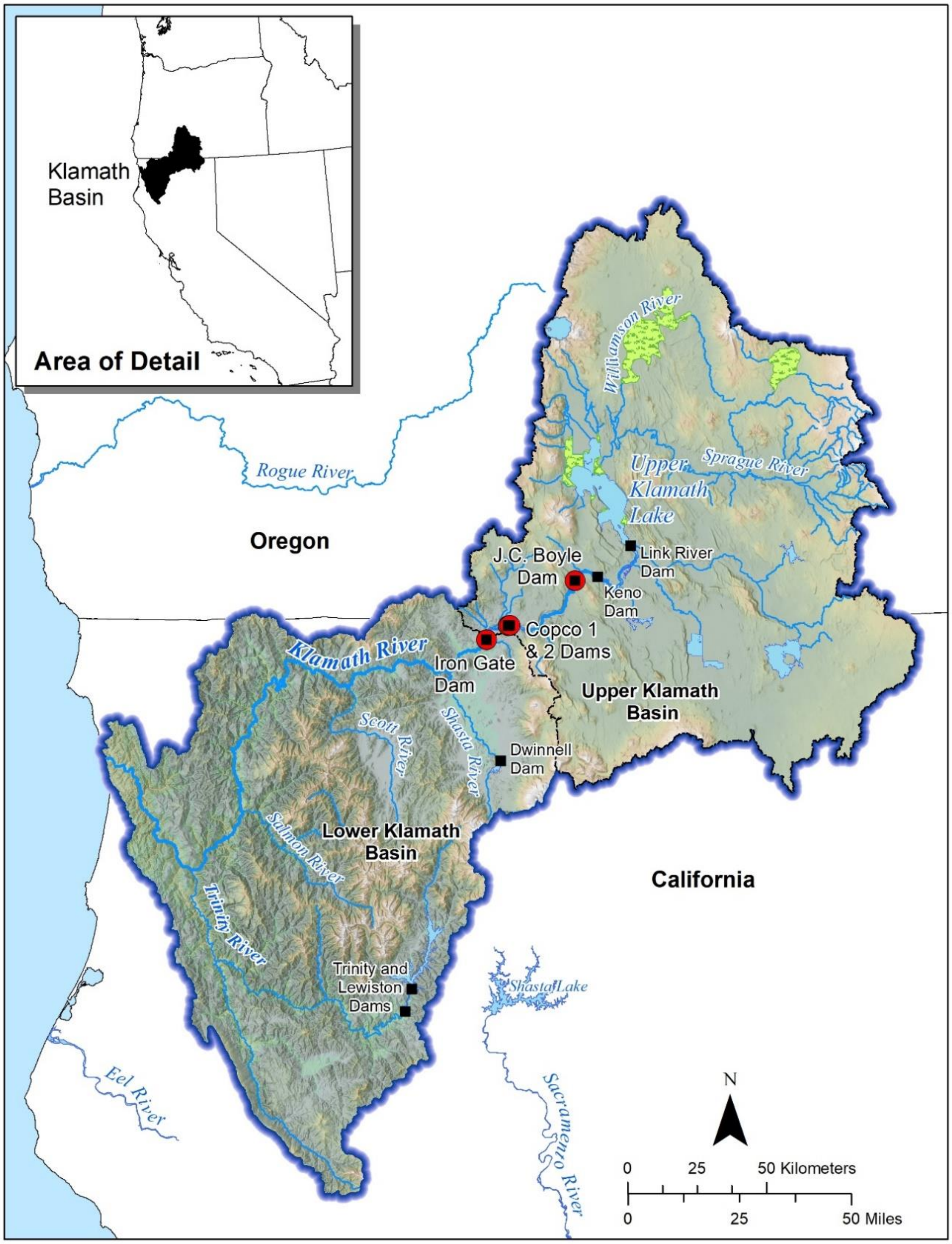


Figure 1-1. Selected hydrography of the Klamath Basin, including the distinction between the upper (upstream of Iron Gate Dam) and lower basin (downstream of Iron Gate Dam). Locations of dams in the Klamath Hydroelectric Project that are to be removed in 2023 (Iron Gate Dam, Copco1 and 2 Dams, and J.C. Boyle Dam) are highlighted in red, and other major dams in the Klamath Basin are shown. The current upstream extent of anadromous fishes is Iron Gate Dam.

Act (ESA). In some years, low abundance of Chinook Salmon escapement to the Klamath Basin have caused offshore fishery restrictions or closures along as much as 700 miles of the West Coast (PFMC 2006).

The Klamath Basin also supports a unique fauna of resident fishes, most notably in the upper basin where spring-fed streams, large waterbodies, and vast wetlands, provide a mix of aquatic environments not found in the lower basin. Resident fishes of the upper basin, such as the Lost River Sucker (*Deltistes luxatus*) and Shortnose Sucker (*Chasmistes brevirostris*), which are currently listed as Endangered under the ESA, have high cultural value. These species played an important role in sustaining The Klamath Tribes (Federally recognized tribe that includes Klamath, Modoc, and Yahooskin Peoples) for thousands of years. Due to extreme declines in sucker populations, the tribal fishery for suckers ceased in 1988. Multiple life histories of Redband Trout (*Oncorhynchus mykiss newberrii;* also referred at inland Rainbow Trout; Great Basin Redband Trout; resident Rainbow Trout found east of the Cascade Range) are present in the upper basin and support an important recreational and tribal fishery.

Adfluvial Redband Trout mature and feed in UKL and spawn in the numerous spring-fed tributaries of the lake, while stream-resident Redband Trout exist in the headwater tributaries of Upper Klamath Lake and the Klamath River. Other native resident fishes of the upper basin include: Bull Trout (*Salvelinus confluentus*), Klamath Smallscale Sucker (*Catostomus rimiculus*), Klamath Largescale Sucker (*Catostomus snyderi*), Klamath Speckled Dace (*Rhinichthys osculus klamathensis*), Blue Chub (*Gila coerulea*), Tui Chub (*Siphateles bicolor bicolor*), three species of sculpins (*Cottus* sp.), and five species of land-locked lampreys (*Entosphenus* sp.). A list of prominent native fishes, their status, and the dominant habitat they are found in is given in Table 1-1.

Non-native fish have been advertently and inadvertently introduced into the basin for various reasons, including for sport, and for use as bait to catch other fish. A list of prominent non-native fishes, their status, and the dominant habitat they are found in is given in Table 1-2. In the Upper Klamath Basin’s warmer systems Yellow Perch and Fathead Minnows are the most prominent non-native fishes; Brook Trout are the most prominent non-native in the cold, headwater systems.

Dam construction, in combination with historical land and water use practices, has altered the connectivity and quality of aquatic habitats in the Klamath Basin (NRC 2004). These changes have greatly affected the freshwater distributions and abundances of anadromous fishes in the basin. Migrations of anadromous fishes into most of the upper basin (the entirety of the basin within Oregon) have been blocked since October 1912 when construction of Copco 1 Dam began at rkm 324.9 (river mile; rm 201.9) on the Klamath River (Hamilton et al. 2016) (Figure 1-1). Copco 1 Dam was completed in 1918 without a fishway despite assurances to upstream stakeholders (Tribes, others) that one would be constructed (Lane and Lane 1981; Hamilton et al. 2016). Subsequent completion of additional KHP dams, including Copco 2 Dam at rkm 324.4 (rm 201.6) in 1925, J.C. Boyle Dam at rkm 366.9 (rm 228.0) in 1958, and Iron Gate Dam at rkm 312.0 (rm 193.9) in 1962, further blocked fish migrations (Figure 1-1; Table 1-3).

Table 1-1. Prominent native fishes currently found in the Upper Klamath Basin (Klamath River Basin above Iron Gate Dam).

Species	Adult habitat[a]	Status[b]	Comments
Shortnose Sucker, *Chasmistes brevirostris*	L	FE, SE	Adults are common but juvenile recruitment is essentially zero
Lost River Sucker, *Deltistes luxatus*	L	FE, SE	Adults are common but juvenile recruitment is essentially zero
Klamath Largescale Sucker, *Catostomus snyderi*	S, L	FSOC	Some level of hybridization with Shortnose Sucker
Klamath Smallscale Sucker, *Catostomus rimiculus*	S	C	Found in Klamath River below UKL; Isolated population in Jenny Creek above falls (Jenny Creek Sucker)
Slender Sculpin, *Cottus tenuis*	S, L	FSOC	Found in tributaries of UKL and springs of UKL
Klamath Lake Sculpin, *Cottus princeps*	L	A	Common in UKL
Klamath Marbled Sculpin, *Cottus klamathensis*	L, S	C	Common throughout Upper Klamath Basin
Blue Chub, *Gila coerulea*	L, S	A	Common throughout Upper Klamath Basin
Klamath Tui Chub, *Siphateles bicolor*	L, S	A	Common throughout Upper Klamath Basin
Klamath Speckled Dace, *Rhinichthys osculus*	L, S	C	Common throughout Upper Klamath Basin; likely a unique subspecies
Pit-Klamath Brook Lamprey, *Entosphenus lethophagus*	S	C	Found in tributaries to UKL, Klamath River
Northern California (modoc) Brook Lamprey, *Entosphenus folletti*	S	U	Lost River sub-basin
Miller Lake Lamprey, *Entosphenus minimus*	L	S	Miller Lake watershed and headwaters of Williamson River and Sycan River
Klamath River Lamprey, *Entosphenus similis*	S	C	Upper Klamath Lake, Klamath River below Keno Dam and tributaries
Klamath Lake Lamprey, *Entosphenus* (unresolved)	L	C	Found in UKL, possibly a landlocked form of Pacific Lamprey
Redband Trout/Rainbow Trout, *Oncorhynchus mykiss newberii*	S, L	FSOC, S	Fluvial and adfluvial (UKL) resident life histories present; locally abundant; also known as Great Basin Redband Trout
Bull Trout, *Salvelinus confluentus*	S	FT, SC	Restricted to a few headwater streams; likely widespread historical fluvial populations

[a] Habitats are listed in order of likeliness for each species: L, Lakes, ponds, and reservoirs; S, streams.
[b] Status in Upper Klamath Basin: A, abundant; C, common; FE, Federally Endangered; FT, Federally Threatened; FSOC, Federal Species of Concern; SE, State Endangered; S, State Sensitive; SC, State Sensitive Critical; U, unknown distribution and status.

Iron Gate Dam is currently the upstream limit of anadromous fish migration on the Klamath River. Because no effort was made to provide fish passage when Iron Gate Dam was completed in 1962, a hatchery was constructed to mitigate the loss of anadromous fish production between

Table 1-2. Prominent non-native fishes currently found in the Upper Klamath Basin (Klamath River Basin above Iron Gate Dam).

Species	Adult habitat[a]	Status[b]	Comments
Goldfish, *Carassius auratus*	L	C	Locally common in impoundments associated with Klamath River and Lost River
Fathead Minnow, *Pimephales promelas*	L, S	A	Very abundant in UKL and larger rivers, and irrigation canals
Brown Bullhead, *Ameiurus nebulosus*	L, S	A	Abundant in warm-water lakes and rivers
Kokanee, *Oncorhynchus nerka*	L	C	Localized populations in UKL and Fourmile Lake
Rainbow Trout (hatchery origin), *O. mykiss*	L, S	U	likely localized introgression with native Redband Trout
Brown Trout, *Salmo trutta*	S	C	Common in cold-water streams
Brook Trout, *Salvelinus fontinalis*	S	A	Abundant in headwater streams
Sacromento Perch, *Archoplites interruptus*	L	C	Common in Lost River sub-basin, rare in UKL
Green Sunfish, *Lepomis cyanellus*	L	R	Occasionally found in Impoundments associated with Klamath River and Lost River
Pumpkinseed, *L. gibbosus*	L, S	C	Common in warm-water lakes and streams
Largemouth Bass, *Micropterus salmoides*	L, S	R	Occasionally found in Sprague River and northern UKL
Yellow Perch, *Perca flavescens*	L, R	A	Abundant in warm-water lakes and streams

[a] Habitats are listed in order of likeliness for each species: L, Lakes, ponds, and reservoirs; S, streams.
[b] Status in Upper Klamath Basin: A, abundant; C, common (if locally common, denoted in comments); U, unknown distribution and status.

this dam and the two Copco dams 7.5 miles upstream. Iron Gate Hatchery currently raises and releases fall-run Chinook Salmon, Coho Salmon, and steelhead trout (steelhead trout have not been produced and released since 2013; Wade Sinnen, CDFW, Personal communication) under terms of its hydropower license with the Federal Energy Regulatory Commission (FERC).

In the early to mid-1900's the U.S. Bureau of Reclamation's Klamath Irrigation Project (KIP) was developed to divert water from Upper Klamath Lake to irrigate what is now approximately 97,100 hectares of land in the Upper Klamath Basin. Irrigation water is diverted via Link River Dam (completed at rkm 414.4; rm 257.5, in 1921) at the outlet of Upper Klamath Lake (though initial diversions at the outlet began in the late 1800s) and at several locations along Keno Impoundment (known also as Keno Reservoir). The Keno Impoundment was a natural impoundment of the Klamath River below Lake Ewauna formed by the level topography of the area and several rock reefs in the river. Keno Impoundment is now regulated by Keno Dam (rkm 380.5; rm 236.4), constructed in 1966 following the destructive 1964 flood, which destroyed Needle Dam (constructed in 1931 for hydropower for the town of Keno, Oregon). Both Link River and Keno Dams have fish ladders that allow passage of Redband Trout. The fish ladder at Link River Dam is specifically designed to allow passage of ESA listed suckers.

Table 1-3. Summary of major dams in the Klamath Basin including their distance from the Pacific Ocean (river kilometer). J.C. Boyle, Copco 1 and 2, and Iron Gate Dams make up the Klamath Hydroelectric Project (KHP) and are planned to be removed in 2023 (in bold). Iron Gate Dam is the upstream limit to anadromous fishes.

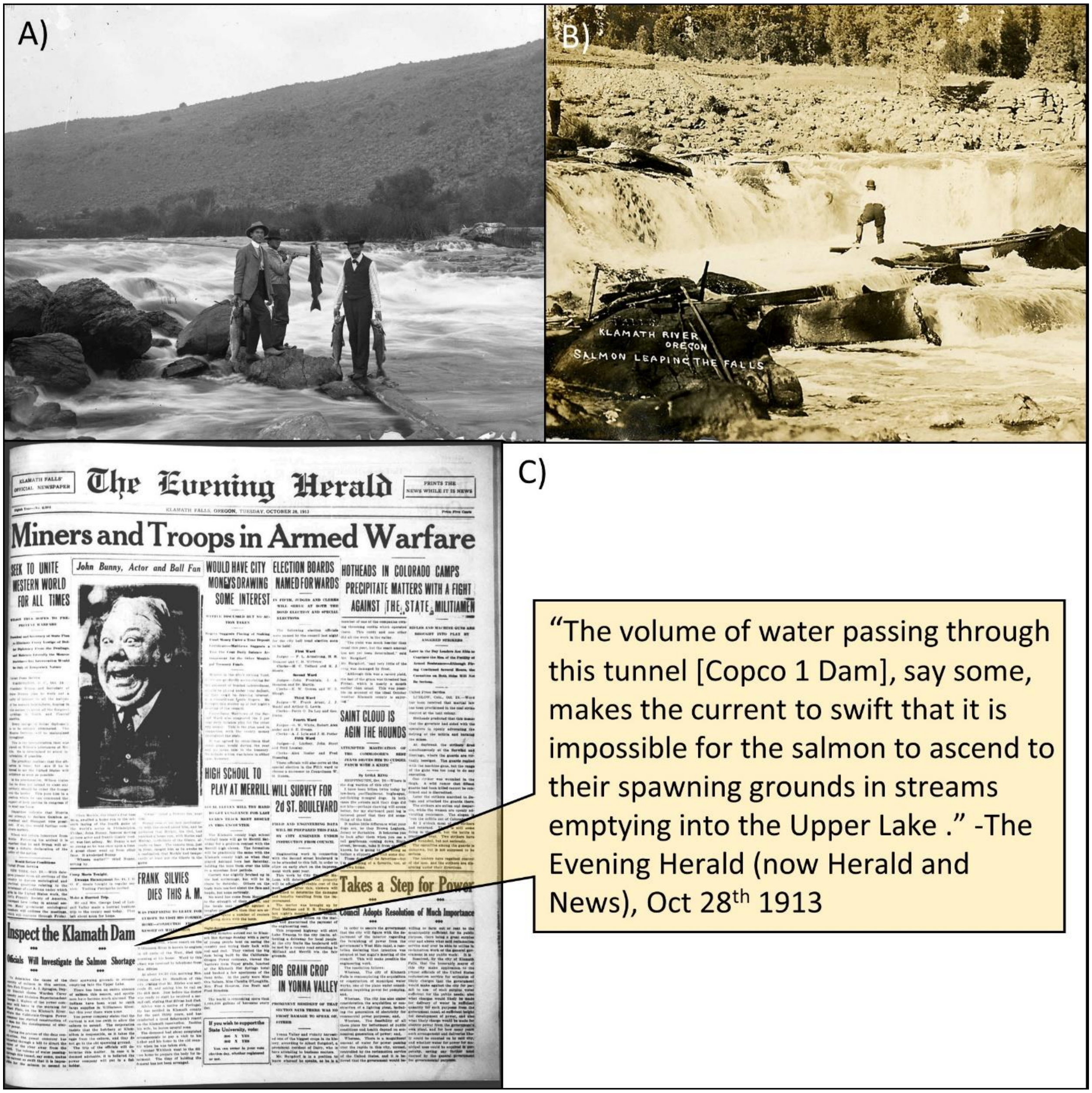
Dam	Stream	State	River kilometer (rkm)	River mile (rm)	Year completed	Dam height (m)
Link River Dam	Link River (head of Klamath R.)	Oregon	414.4	257.5	1927	4.6
Keno Dam	Klamath River	Oregon	380.5	236.4	1966	7.6
J.C. Boyle Dam	**Klamath River**	**Oregon**	**366.9**	**228.0**	**1958**	**20.7**
Copco 1 Dam	**Klamath River**	**California**	**324.9**	**201.9**	**1918**	**38.4**
Copco 2 Dam	**Klamath River**	**California**	**324.4**	**201.6**	**1925**	**10.1**
Iron Gate Dam	**Klamath River**	**California**	**312**	**193.9**	**1962**	**52.7**
Dwinnell Dam	Shasta River	California	65	40.4	1928	na
Trinity Dam	Trinity River	California	193	119.9	1962	164

1.1.2 Anadromous Fisheries of the Klamath Basin

Historically, the Klamath River supported the third largest migrations of Chinook Salmon on the West Coast (Hamilton et al. 2005). Prior to European colonization, runs of adult Pacific salmon in the Klamath Basin have been estimated at 650,000 to 1,000,000 individuals (Gresh et al. 2000). This abundance provided the main subsistence to tribal groups along the river and substantial commercial and recreational harvests (Snyder 1931; Lane and Lane 1981). Anadromous fishes utilized the mainstem Klamath River as well as its many tributaries, both above and below the current site of Iron Gate Dam (Snyder 1931; Fortune et al. 1966; Lane and Lane 1981; Hamilton et al. 2005; Hamilton et al. 2016). Historical anadromous fishes that occupied the Upper Klamath Basin and their current status are summarized in Table 1.4.

Summaries of what is known about historical anadromous fish populations above Iron Gate Dam, especially those of Chinook Salmon, can be found in Hamilton et al. (2005) and Hamilton et al. (2016). The authors used historical photos, reports, personal communications, testimonies, newspaper articles, and archeological evidence, to describe in detail the accounts of anadromous fishes in the Upper Klamath Basin. Before the construction of KHP dams, Chinook Salmon were known to spawn in the mainstem Klamath River, its numerous tributaries, and streams above Upper Klamath Lake (see Figure 1-2). The construction of Copco 1 Dam blocked access to the entire habitat previously accessible upstream of rkm 324.9 (rm 201.9) on the Klamath River (Figure 1-3). The "Frain Ranch", located near rkm 350 (rm 217) on the Klamath River in Oregon, was known as a popular spearing location and potential spawning area for Chinook Salmon (Coots 1965). Prior to the construction of Iron Gate Dam, Chinook Salmon were known to spawn in Jenny, Fall, Shovel Creeks, and Spencer Creeks (Figure 1-3) (BLM 1995). The KHP dams block access to over 751 km (over 466 miles; see Table 3-1) of existing spawning, incubation, rearing, and migration habitat for anadromous fishes of the Klamath Basin and potentially more if restored to historical conditions (Figure 1-3). The majority of the existing, historical habitat is located in streams above Upper Klamath Lake (Huntington et al. 2006).

The 1.25-mile-long Link River, which flows out of Upper Klamath Lake and into Lake Ewauna near the town of Klamath Falls (Figure 1-3), is known to have been a place where Native Americans and others once caught Chinook Salmon. Catches there were documented in journals, the local newspaper, and by numerous late-1800s photos (Hamilton et al. 2005; Hamilton et al. 2016; Figure 1-2). Numerous documents indicate that spring and fall-run Chinook Salmon were once present in the tributaries (Wood River, Williamson River, Sprague River) of Upper Klamath Lake (Lane and Lane 1981; Moyle 2002; Hamilton et al. 2005; Hamilton et al. 2016). During his visit to the outlet Upper Klamath Lake in May of 1846, the explorer John C. Fremont observed many salmon migrating up into the lake, fish that were likely spring-run Chinook Salmon (Lane and Lane 1981). The Klamath Tribes have provided numerous accounts of historical salmon fishing locations on the Sprague and Williamson rivers, highlighting locations on the Sprague River near the towns of Beatty and Bly as some of the most important, most likely because the fish spawned in or near these areas (Lane and Lane 1981). The furthest upstream extent of historic spawning of Chinook Salmon in the Sprague River system was known to occur on the South and North Fork Sprague rivers (Fortune et al. 1966). The upstream limit of spawning in the Williamson River occurred below Williamson River Falls at rkm 32, a short distance downriver from the outlet of Klamath Marsh (Spier 1930; Lane and Lane 1981).



"The volume of water passing through this tunnel [Copco 1 Dam], say some, makes the current to swift that it is impossible for the salmon to ascend to their spawning grounds in streams emptying into the Upper Lake ." -The Evening Herald (now Herald and News), Oct 28th 1913

Figure 1-2. Examples of the many historical photos and newspaper articles available that describe the details of the historical presence of anadromous fishes in the Upper Klamath Basin in Oregon prior to the construction of Copco 1 Dam on the Klamath River in California. **A)** Gentlemen display their catch while salmon fishing on the rapids of Link River, Oregon, 1891. Photo courtesy of the Klamath County Historical Society. **B)** Salmon leaping Moonshine Falls (current site of J.C. Boyle Dam) on the Klamath River, Oregon. Photo courtesy of the Klamath County Historical Society. **C)** Front page of The Evening Herald October 28th, 1913, the local newspaper from Klamath Falls, Oregon (now The Herald and News). The story is about local and state officials inspecting the construction of Copco 1 Dam on the Klamath River in California, as it was believed this was the reason for "an entire absence of salmon" in tributaries of Upper Klamath Lake. For further information on the historical characteristics of anadromous fishes in the Upper Klamath Basin see Hamilton et al. 2005 and 2016.

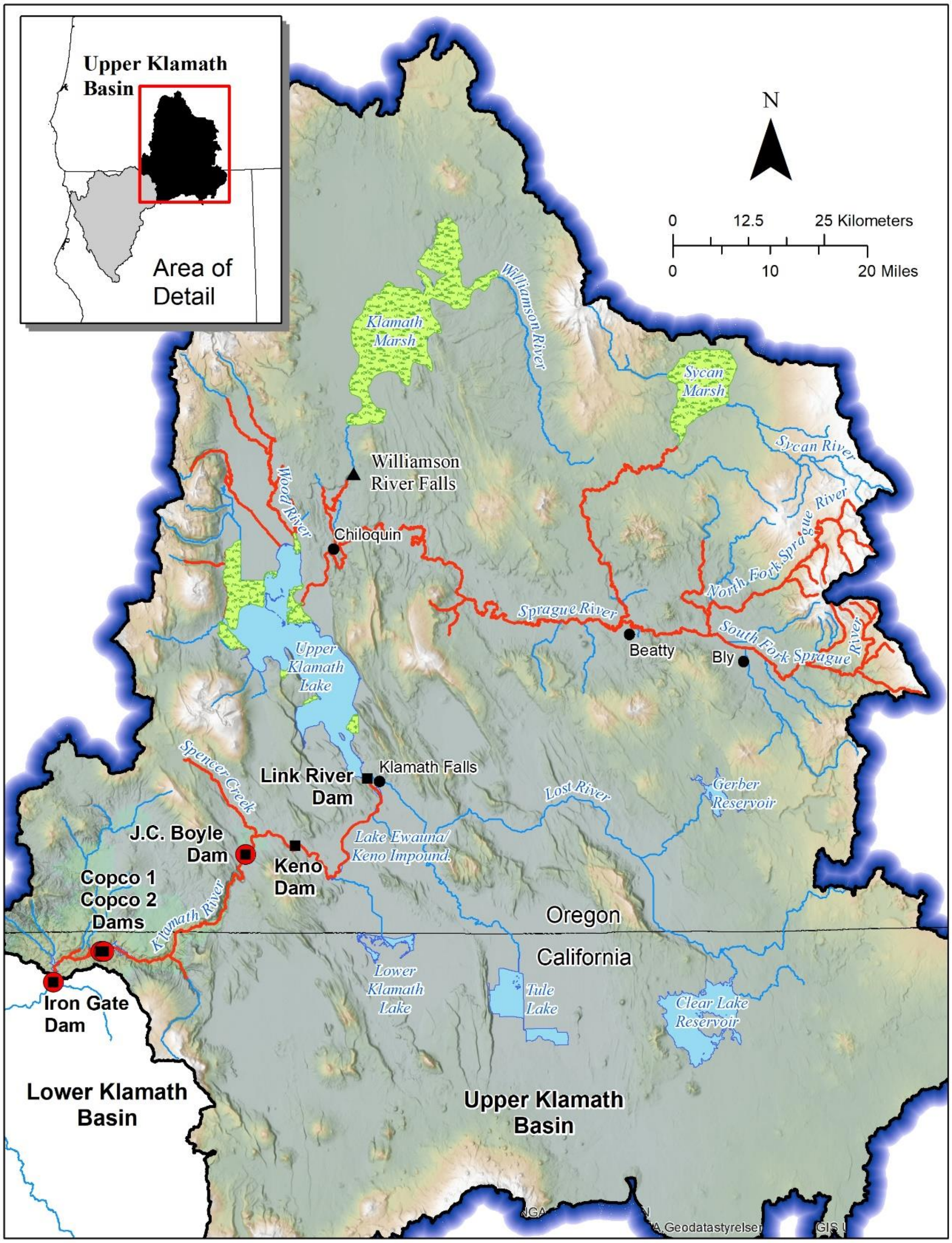
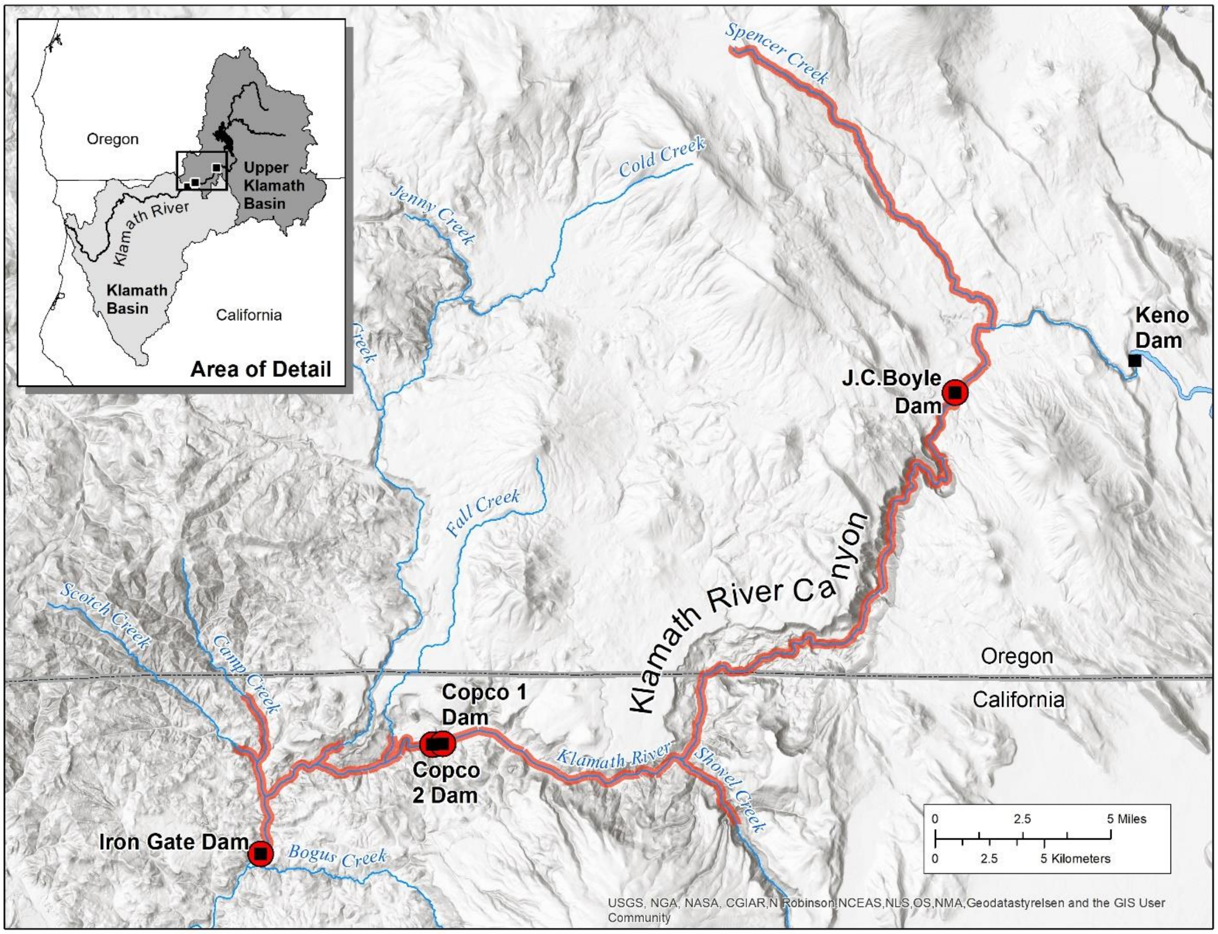


Figure 1-3. Selected hydrography of the Upper Klamath Basin with Klamath River mainstem dams. The Upper Klamath Basin is defined as that portion of the Klamath Basin above the site of Iron Gate Dam, which excludes anadromous fishes. Dams (Iron Gate, Copco 1 and 2, and J.C. Boyle Dam) planned to be removed in 2023 are highlighted in red. Potential existing streams with suitable anadromous fish habitat are highlighted in red (from Huntington et al. 2006).

Due to the difficulty of distinguishing between large resident Redband Trout from Upper Klamath Lake and steelhead trout migrating from the Pacific Ocean, the historical record of steelhead trout in the Upper Klamath Basin is not as detailed as for Chinook Salmon. However, it is known that steelhead trout spawned in Spencer Creek (BLM 1995), Shovel Creek (Fortune et al. 1966), and Camp Creek (King et al. 1977), all tributaries to the mainstem Klamath River, prior to completion of the Klamath River dams. The Klamath River and tributaries below the KHP dams support populations of steelhead trout that demonstrate multiple life history strategies (Hodge et al. 2016). Typically, in watersheds that contain Chinook Salmon and steelhead trout, the geographic distribution of steelhead trout is broader than that of the salmon, leading to the conclusion that steelhead trout once spawned in the tributaries of Upper Klamath Lake (Hamilton et al. 2005). Genetic analysis of Redband Trout in the Upper Klamath Basin and coastal Rainbow Trout/steelhead trout suggests that the Redband Trout population was invaded by the coastal lineage when the Lower Klamath River connected with Upper Klamath Lake and provided an outlet to the Pacific Ocean (Currens 1997; Currens et al. 2009). Results of a genetic study by Pearse et al. (2011) suggest that adfluvial Redband Trout in Upper Klamath Lake are a distinct native form of Redband Trout, while genetic similarities exist between coastal and inland *O. mykiss* in populations below Link River Dam and some tributaries of Upper Klamath Lake. These molecular studies support the conclusion that before construction of the KHP, steelhead trout migrated to, and spawned in the Upper Klamath Basin.

While there are no historical records suggesting that Coho Salmon were present above Upper Klamath Lake, there is however, evidence that Coho Salmon spawned in tributaries to the Klamath River above Iron Gate Dam prior to dam construction (Hamilton et al. 2005). It has been reported that Coho Salmon spawned in Fall Creek, which now flows into Iron Gate Reservoir, and the confluence of Jenny Creek was a popular fishing location for Coho Salmon (Coots 1957; Coots 1962; CDWR 1964; Hamilton et al. 2005). It is also thought that Coho Salmon historical distribution extended into Spencer Creek, the upper-most tributary to the mainstem Klamath River. Spencer Creek is a medium-sized, low-gradient tributary that contains the type of side-channel beaver ponds juvenile Coho Salmon prefer as rearing habitat (Hamilton 2005). Based on the available habitat and current use by resident salmonids, Spencer Creek has a very high potential for use by Coho Salmon (Ramos 2020). Fish passage through the Klamath Hydroelectric Project would open up over 59 miles of Coho Salmon habitat above Iron Gate Dam, 31 miles being in Oregon (18 miles of mainstem Klamath River and 13 miles of tributary habitat within Spencer Creek), and likely more non-natal, rearing habitat in some of the smaller tributaries within the Klamath River Canyon (Figure 1-4).

Before the construction of Iron Gate Dam, Pacific Lamprey were documented to have entered Fall Creek, most likely to spawn (Coots 1957). Four landlocked species of lampreys occur in the Upper Klamath Basin that closely resemble Pacific Lamprey, which would have made historical taxonomic distinction between resident and anadromous lamprey difficult. Historically, Pacific Lamprey occurred throughout the mainstem Klamath River and there were no barriers to prevent them from migrating above the site of Iron Gate Dam prior to dam construction (Hamilton et al. 2005). Currently, Pacific Lamprey occur up to Iron Gate Dam. Anadromous Pacific Lamprey



USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen and the GIS User Community

Figure 1-4. Potential Coho Salmon habitat (highlighted with red) currently blocked by the Klamath Hydroelectric Project (Iron Gate Dam, Copco 1 and 2 Dams, and J.C. Boyle Dam). Fish passage through the Klamath Hydroelectric Project would open up over 31 miles of Coho Salmon habitat in Oregon (18 miles of mainstem Klamath River and 13 miles of tributary habitat within Spencer Creek).

occur in other river systems throughout the Pacific Northwest wherever salmon occur (Simpson and Wallace 1978; Wydoski and Whitney 2003), suggesting that prior to dam construction Pacific Lamprey were likely present throughout the Upper Klamath Basin including the tributaries of Upper Klamath Lake.

There is little historical evidence that a run of Sockeye Salmon (*Oncorhynchus nerka*) occurred in the Klamath River above Iron Gate Dam. Cobb (1930) reported twenty Sockeye Salmon were taken in the Klamath River in the autumn of 1915 at the Klamathon Racks site below the current location of Iron Gate Dam, these are thought to be a result of Kokanee Salmon plantings in Oregon in 1911 (John Hamilton, USFWS, Personal communication). Sockeye Salmon require lake-habitat for rearing and the only available lakes in the Upper Klamath Basin at the time were

Table 1-4. Anadromous fishes historically present in the Upper Klamath Basin prior to their extirpation construction of Copco 1 Dam in 1912 and their current conservation status in the Lower Klamath Basin.

Species	Federal Evolutionarily Significant Unit (ESU/DPS)	Federal Status (ESA)	State of Oregon Management Unit (SMU)	State of Oregon Status
Chinook Salmon (fall and spring-run), *Oncorhynchus tshawytscha*	Upper Klamath-Trinity River (UKTR)	None	Klamath	N/A, considered extirpated
Coho Salmon *Oncorhynchus kisutch*	Southern Oregon & Northern California Coast (SONCC)	Threatened	Klamath	N/A, considered extirpated
Steelhead Trout, *Oncorhynchus mykiss*	Klamath Mountains Province (KMP)	None	Klamath	Sensitive*, considered extirpated above Iron Gate Dam
Pacific Lamprey, *Entosphenus tridentatus*	None	Species of Concern	None	Sensitive

*Steelhead trout have been documented in the Oregon portion of the headwaters of Cottonwood Creek and Beaver Creek; two tributaries of the Klamath River located below Iron Gate Dam.

Upper Klamath Lake, Lower Klamath Lake, and Buck Lake at the head of Spencer Creek (currently drained). It has been presumed that any Sockeye Salmon south of the Columbia River are probably non-spawning strays (Moyle 2002). Kokanee Salmon (landlocked Sockeye Salmon) Kokanee) are currently observed in the springs on the west side of Upper Klamath Lake, believed to be fish that have drifted downstream from the non-native Fourmile Lake population that was introduced in the 1950’s or a naturalized population from releases of Sockeye Salmon smolts conducted by Oregon Department of Fish and Wildlife (ODFW) in the early 1900’s (Bill Tinniswood, ODFW, Personal communication).

Green Sturgeon are known to occur in the lower portion of the Klamath River and spawn in the Klamath River up to Ishi Pishi Falls (rkm 107; rm 66.4) and the Salmon River (tributary to the Klamath River at rkm 106; rm 65.8). Ishi Pishi Falls seems to be their upper distributional limit, presumably due to an inability to migrate upstream of the falls (Kroeber and Barrett 1960). Adult White Sturgeon (*Acipenser transmontanus*) that were introduced into Upper Klamath Lake in 1956 (ODFW 1997) still occur and are observed infrequently in Upper Klamath Lake, Lake Ewauna, and at Keno Dam (USGS, USBR, ODFW, Personal communication).

Eulachon (*Thaleichthys pacificus*), Coastal Cutthroat Trout (*Oncorhynchus clarkii clarkii*), Chum Salmon (*Oncorhyncus keta*), and Pink Salmon (*Oncorhynchus gorbuscha*) are all anadromous fish occasionally found in low numbers in the Klamath River. However, these species are known to be limited to the lower reaches and there are no accounts of them above the site of Iron Gate Dam. Eulachon were historically abundant up to rkm 40 (rm 24.8) and are now found in low levels in the Lower Klamath River (Larson and Belchik 1998). Coastal Cutthroat

Trout rarely migrate more than about 160 kilometers (100 miles) up coastal rivers (Behnke 1992). Chum and Pink Salmon are seen occasionally in the lower reaches of the Klamath River, but any historical populations have likely been extirpated and those seen now are thought to be strays from river basins to the north (Snyder 1931; Nehlsen et al. 1991; Moyle 2002).

1.1.3 Cultural Significance of Fisheries in the Upper Klamath Basin

Prior to dam construction on the Klamath River, the Klamath Basin Tribes subsisted on salmon as part of a diverse hunter-gatherer lifestyle (Hamilton et al 2016). The varying but regular supply of ocean-derived food provided an important cultural and nutritional foundation for Native Peoples throughout the basin. Subsequent to dam construction, the loss of salmon as a readily accessible and abundant food source further disrupted the remaining cultural and ethnographic fabric of the Tribes in the Upper Klamath Basin. The loss of salmon, and the associated network of cultural interactions, reinforced and exacerbated the historical trauma experienced by the Tribes following settlement by Europeans.

Since restoration of The Klamath Tribes' legal status as a federally recognized Indian Tribe in 1986, addressing sources of historical trauma has been paramount to repairing the Tribes' cultural identity. Given the importance of food collection from a nutritional and ceremonial perspective, the reintroduction of salmon to harvestable levels will further the Tribes' healing process and encourage a renewed sense of community. In particular, community scale inter-generational fishing activities using traditional methods are seen as highly effective methods of cultural renewal and healing.

Fishing for Chinook Salmon by The Klamath Tribes occurred throughout the Upper Klamath Basin (Stevenson and Butler 2015). Traditional fishing methods, including spearing, netting, and trapping took place at natural constrictions or obstructions, such as falls, natural or anthropogenic narrowed points in river channels, or shallow areas where fish could be readily captured. Anecdotal accounts by settlers and early newspaper reports indicate that Chinook Salmon were captured in the Sprague River from its mouth upstream to areas near the towns of Beatty and Bly. Fish were dried and smoked for direct consumption during winter months but were also traded to other tribes and to early settlers. Accounts by tribal members in the Upper Klamath Basin indicate that salmon "…provided the Indians with about one-third of their food supply each year" and that "1/6 of the subsistence of all the Indians residing on the Klamath River between 1890 and 1909 was provided by the salmon fish caught in the reservation streams…" (Hamilton et al. 2016).

1.1.4 Decline in the Fisheries of the Klamath Basin

Aquatic habitat degradation began in the Klamath Basin as early as 1850 with the influx of gold miners from the California gold rush. Hydraulic mining in the lower basin that involved eroding hillsides with pressurized water was common practice to extract gold from the sediments. Logging operations in the basin began with the gold rush, as timber was needed to support the rapidly growing population of California. In 1889 a wooden log-crib dam known as Klamathon Dam was constructed by a timber company for its mill at Klamathon, California (a short distance downstream of the current site of Iron Gate Dam, rkm 312; rm 193.9). When it was first constructed, Klamathon Dam lacked upstream fish passage and fish attempting to pass upstream in the fall of 1889 were illegally captured and sold commercially. Pressure from Oregon residents and politicians dismayed by the blockage of fish resulted in the immediate installation of a fish ladder at Klamathon Dam. The new ladder along with part of the dam was destroyed during high river flows in the winter of 1889-1890, allowing salmon to freely migrate up the river. The log-crib dam was repaired, and the ladder rebuilt in 1892. In the fall of 1902, a catastrophic fire destroyed the mill including the log-crib dam and the rebuilt ladder, including most of the town of Klamathon (Hamilton et al. 2016). After the destruction of Klamathon Dam, fish were again able to migrate to the Upper Klamath Basin without impediment until construction began on Copco 1 Dam in the fall of 1912.

Dwinnell Dam on the Shasta River (a tributary to the Klamath River that enters about 15 miles below Iron Gate Dam) was completed in 1928 and blocks anadromous fish access to 22% of the length of spawning tributaries in the Shasta River watershed (Wales 1951). Construction of the Trinity Dam on the Trinity River began in 1957 and was completed in 1962 (Figure 1-1; Table 1-3). Its purpose was to export water to the Central Valley of California, but it also blocked migratory access to historically important spawning and early rearing areas for some of the basin's anadromous fish runs.

A decline in commercial salmon catches was well underway by 1918 (Snyder 1931) and commercial catches and adult spawning escapements have continued to decline (Nehlsen et al. 1991; Moyle 2002). Historically, the fall-run Chinook Salmon in the Klamath River supported an in-river, commercial fishery which supplied multiple canneries near the mouth of the river until the early 1930's. In 1934, all commercial fishing on the Klamath River, and the use of gill nets on the lower river for tribal subsistence was banned by the State of California (Pierce 1998). Tribal commercial rights were not reaffirmed until the late 1970's (Pierce 1998). The fall-run Chinook Salmon continued to decline in rivers along the West Coast and the ocean commercial fishery was substantially limited due to declines in stock abundance and the allocation of fish to Tribes in the Klamath Basin with federally reserved fishing rights (Pierce 1998; Moyle 2002). Spring-run Chinook Salmon were already declining in the Klamath River due to habitat degradation and over-harvest before construction of the dams that eliminated them from the Upper Klamath Basin (Snyder 1931; Moyle 2002).

Degradation of ecological conditions and losses of functional habitat have been common contributors to declines in the abundance of many Klamath Basin fishes and led to federal endangered and threatened status under the ESA for Coho Salmon (threatened; 62 Fed. Reg. 24588, 6 May 1997), Lost River Sucker, Shortnose Sucker (both endangered; 53 Fed .Reg. 27130, 18 July 1988), Bull Trout (threatened; 63 Fed. Reg. 31647, 10 June 1998), as well as Eulachon (threatened; 75 Fed. Reg. 13012, 17 May 2010). There have also been petitions to list steelhead trout (61 Fed. Reg. 41541, 9 August 1996), Pacific Lamprey (69 Fed. Reg. 77158, 27 Dec 2004), and two petitions for spring-run Chinook Salmon (77 Fed. Reg. 1997, April 2, 2012; 83 Fed. Reg. 8410, 27 February 2018) in the basin under the ESA. The history of aquatic degradation and habitat loss in the basin has been reviewed by USDI (1991) and the NRC

Table 1-5. Declines in Klamath River Basin anadromous fishes (adapted from USDI and USDC 2013).

Species	Historical Level	Percent reduction from historical levels (estimates of individual runs)	Source
Pacific Lamprey	Unknown	98% (Represents reduction in tribal catch per effort)	Petersen Lewis (2009)
Steelhead Trout	400,000[1]	67% (130,000)	Leidy and Leidy (1984); Busby et al. (1994)
Coho Salmon	15,400 - 20,000	52% to 95% (760 - 9,550)	Moyle et al (1995); Ackerman et al. (2006)
Fall-run Chinook Salmon	500,000[2]	92% to 96% (20,000 - 40,000)[3]	Moyle (2002)
Spring-run Chinook Salmon	100,000[2]	98% (2,000)[2]	Moyle (2002)

[1] This estimate is from 1960. Anadromous fish numbers were already in decline in the early 1900s (Snyder 1931).
[2] Includes Klamath River and Trinity River Chinook.
[3] Excludes hatchery-influenced escapement.

(2004). Over the last 100-150 years, annual salmon and other anadromous fish runs have declined to levels far below historic abundances (Table 1-5) (USDI 2013).

1.2 Background and Justification for Reintroduction

1.2.1 Klamath River Basin Fishery Resources Restoration Act

In response to declining runs of salmon and steelhead in the Klamath Basin, the United States Congress passed the Klamath River Basin Fishery Resources Restoration Act (Klamath Act) in October 1986. The Klamath Act authorized $21 million to the Department of the Interior to implement a 20-year program to designate and restore a conservation area within the basin. The Klamath Act also established the Klamath Fishery Management Council to monitor the fish population and recommend annual fish harvest limits and established the Klamath River Basin Fisheries Task Force to advise the Secretary of Interior regarding implementation of the Restoration Program. The Task Force and Department of the Interior developed the *Long Range Plan for the Klamath River Basin Conservation Area Fishery Restoration Program* (Long Range Plan) to guide fishery and habitat restoration (USDI Klamath River Basin Fisheries Task Force 1991). The Long-Range Plan generally directs that fishery restoration is to be achieved through fish habitat protection and restoration from a total watershed perspective, not simply an in-stream perspective. The Long-Range Plan also advocates anadromous fish access to habitats above Iron Gate and Copco Dams. The Klamath Act was not renewed by Congress and expired in 2006.

1.2.2 ODFW 1966 Feasibility Study and the Current Klamath River Basin, Oregon Fish Management Plan

A study published in 1966 by ODFW (Fortune et al. 1966) considered the feasibility of reintroducing salmon and steelhead trout to the Upper Klamath Basin within their historic distribution. Based on that study, an inter-agency steering committee over-seeing the study did not recommend a program to re-establish those runs with the KHP dams in place. The committee's decision was based on problems related to downstream passage of juvenile fishes at impoundments, losses of upstream-migrating adults at fishways, difficulty of obtaining appropriate stocks, and a sense that the interactions of all factors would prevent establishment of self-sustaining runs capable of perpetuation at a "useful level" (Fortune 1966). However, ODFW Klamath River Basin, Oregon Fish Management Plan (1997) states: "ODFW will support such re-introductions if and when the biological and physical questions are addressed and show that such actions are feasible and prudent. Further, ODFW would support future studies addressing that feasibility and the habitat restoration that would be conducive to successful re-introductions (of anadromous salmon or steelhead trout to the Upper Klamath Basin). Still, the welfare of remaining native fish stocks in the upper Klamath River Basin ecosystem should be the paramount deciding factor in any future deliberations."

1.2.3 Federal Energy Regulatory Commission Relicensing Efforts and Response

The Federal Energy Regulatory Commission (FERC, formally Federal Power Commission) issued the original license for operation of the KHP in 1956. That license expired in 2006. As part of the relicensing proceeding, the U.S. Departments of the Interior and Commerce mandated, in accordance with the Federal Power Act, the installation of upstream and downstream volitional fish passage facilities at each dam, along with increased minimum flows in the J.C. Boyle Dam bypass reach, and restricted ramping rates in the J.C. Boyle peaking reach. PacifiCorp then challenged issues of fact related to these mandatory prescriptions in front of an administrative law judge who upheld the Department's facts used to determine the need for, and prescribe, the mandatory volitional fish passageways (Administrative Law Judge 2006). This means that if FERC issues a long-term license, it must include safe, timely, and effective fishways for migratory species at project hydroelectric dams. FERC staff have issued a final Environmental Impact Statement for relicensing the Project (FERC 2007). While FERC's preferred alternative did not include fishways mandated by the Departments of Interior and Commerce, case law shows these fishways will be required in a long-term license. The project has been operating under annual licenses since license expiration.

After the Administrative Law Judge's Findings, negotiations began in earnest between PacifiCorp, stakeholders, tribes, and federal and state agencies to find a long-term solution that could possibly include dam removal.

1.2.4 Klamath Hydroelectric Settlement Agreement (KHSA)

In November 2008, the States of California and Oregon, U.S. Department of Interior, U.S. Department of Commerce, Tribes, and PacifiCorp developed a framework for the potential removal of J.C. Boyle, Copco 1, Copco 2, and Iron Gate Dams. In February 2010, these organizations mentioned, and the National Marine Fisheries Service (NMFS) and 47 other parties, signed the Klamath Hydroelectric Settlement Agreement (KHSA). The KHSA provided for the removal of the four dams by using federal legislation to authorize dam removal action by the Secretary of the Interior. Removal of the four dams would occur as early as the beginning of

2020. Along with the KHSA, the Klamath Basin Restoration Agreement (KBRA) and Upper Klamath Basin Comprehensive Agreement (UKBCA) was signed by the above-mentioned parties to provide, among other benefits, funding for habitat restoration and reintroduction efforts, and providing a more stable basis for the continuation of agriculture in the Upper Klamath Basin following Federal approval. Congress did not enact legislation supporting the KBRA or UKBCA before January 2016, triggering the KHSAs dispute resolution procedure where the States, U.S. Department of the Interior, U.S. Department of Commerce, and PacifiCorp proposed amendments to the KHSA that would achieve dam removal through the FERC license transfer and surrender process. In April 2016 the Governors of the States, the U.S. Department of the Interior, NMFS, the Yurok Tribe, and the Karuk Tribe executed the Amended Klamath Hydroelectric Settlement Agreement (Agreement). The Agreement provides for the Klamath River Renewal Corporation (KRRC) to be the Dam Removal Entity (DRE), which is the entity responsible for the facilities removal. PacifiCorp and KRRC have now filed a joint application to transfer ownership of the four dams to KRRC along with an application to FERC to surrender and remove the four dams (FERC 2016; KRRC 2018).

On January 13, 2021, PacifiCorp (transferor) and the KRRC and the States of California and Oregon (transferees) jointly filed an application to FERC to transfer the license for the Lower Klamath Project from PacifiCorp to the Renewal Corporation and the States of California and Oregon as co-licensees for the purpose of surrendering, decommissioning, and removing the project dams, if approved separately by the Commission. In June of 2021, FERC approved the transfer of the license from PacifiCorp to the KRRC, and the States of Oregon and California. Subsequent approval of surrender and decommissioning plans of the four lower Klamath River dams could potentially mean removal beginning in January of 2023.

1.2.5 A Plan for the Reintroduction of Anadromous Fish in the Upper Klamath Basin – ODFW 2008

In 2008 ODFW produced *A Plan for the Reintroduction of Anadromous Fish in the Upper Klamath Basin* (Reintroduction Plan), which sought and obtained Oregon Fish and Wildlife Commission (OFWC) approval for amending the *1997 Klamath River Basin Fish Management Plan* (Management Plan) to include the re-establishment of anadromous fishes in the Oregon portion of the Klamath River Basin (ODFW 2008). The rationale for these efforts focused on the fact that the U.S. Departments of Commerce and Interior require volitional passage at the lower four mainstem KHP dams owned and operated on the Klamath River by PacifiCorp as part of the FERC relicensing process. Ongoing restoration activities to improve fish habitat and access to available habitat in the Upper Klamath Basin have occurred since the adoption of the 1997 Klamath River Basin Fish Management Plan. Additional scientific and historical information and significant social and political changes occurred in the basin, which prompted the consideration of active and passive reintroduction of anadromous fishes in the Upper Klamath Basin.

The purpose of the 2008 Reintroduction Plan was to modify ODFW’s existing Management Plan by presenting specific direction for managing spring and fall-run Chinook Salmon, Coho Salmon, summer steelhead trout, and Pacific Lamprey in the Oregon portion of the Klamath

River Basin. The 2008 Reintroduction Plan proposed to initiate reintroduction of anadromous fishes into the Upper Klamath Basin in a two-phased approach. In Phase 1, ODFW and the Klamath Tribes will prepare a *Reintroduction Implementation Plan* (this document, Implementation Plan) to guide the active reintroduction of Chinook Salmon into Upper Klamath Lake and tributaries and monitor natural repopulation of Chinook Salmon, Coho Salmon, steelhead trout, and Pacific Lamprey. A major assumption in Phase 1 is that acceptable upstream and downstream fish passage is provided throughout the Klamath River corridor, either through passage facilities at hydroelectric dams, which meet state and federal standards, or through dam removal. Phase 2 of the 2008 Reintroduction Plan will initiate following the re-establishment of viable and self-sustaining populations. Phase 2 will consist of a *Conservation Plan* developed under the Native Fish Conservation Policy and adopted by the OFWC, which will identify desired biological status for these populations, which could include escapement goals or other metrics, providing policy direction to guide management of established populations in the Oregon portion of the Klamath River Basin.

The 2008 Reintroduction Plan states that the Implementation Plan will:

- Serve as an administrative Appendix to the Amended ODFW Klamath River Basin Fish Management Plan.
- Identify facilities and near and long-term actions necessary to address key uncertainties
- Develop specific strategies for achieving the goals of reintroduction of Chinook Salmon into Upper Klamath Lake and tributaries.
- Develop monitoring and evaluation of reintroduction efforts, and other investigations as appropriate to narrow uncertainties.
- Identify facilities and strategies to monitor and evaluate natural repopulation of Chinook Salmon, steelhead trout, Coho Salmon, and Pacific Lamprey into the Oregon portion of Klamath River and its tributaries and upper Klamath Lake and its tributaries.
- Identify criteria and research protocols for determining when natural repopulation is not occurring or is too slow and when, how, and which species (salmon, steelhead trout, and/or Pacific Lamprey) ODFW and the Klamath Tribes will actively reintroduce into the Oregon portion of Klamath River and tributaries downstream of Upper Klamath Lake and/or tributaries of Upper Klamath Lake (depending on species).
- Identify and address key uncertainties necessary to complete an Anadromous Fish Conservation Plan, which will direct Phase 2 Management of anadromous fish returning to the Oregon portion of the Klamath River Basin, consistent with stipulations of the Department's Native Fish Conservation Policy (OAR 635-007-0503, ODFW 2002).
- Be adaptable in order to incorporate knowledge gained from monitoring and evaluation during reintroduction efforts.

1.3 Key Issues and Uncertainties

There are a variety of issues and uncertainties associated with reintroducing anadromous fishes into the Upper Klamath Basin. They are both technical and non-technical in nature and have been discussed in a variety of settings. Issues or uncertainties we view as key to the anadromous fish reintroduction efforts described by this Implementation Plan are highlighted here.

1.3.1 Rates and Extents of Natural Repopulation of Historically Occupied Habitats above Iron Gate Dam

Anadromous fishes were extirpated from the Upper Klamath Basin in 1912, more than a hundred years ago (Hamilton et al. 2016). There are some uncertainties regarding the future rate and extent of re-establishment of the upper basin by anadromous fishes expanding upstream from existing lower basin populations after fish passage is restored at Klamath River dam sites. These uncertainties stem from the weakened state of some of the anadromous fish populations below Iron Gate Dam, the natural variation in environments throughout the basin and Pacific Ocean, the altered condition of some upper basin habitats, and the unknown rate of straying into new habitat.

Most of the anadromous fishes of the Klamath basin are anticipated to begin repopulating the upper basin on their own after passage is restored. However, even though much of the habitat above Upper Klamath Lake is well suited for spring-run Chinook Salmon, the prognosis for volitional repopulation into those habitats without actively reintroducing them is questionable (Goodman et al. 2011). Watersheds within the Klamath Basin that currently have remaining wild populations of spring-run Chinook Salmon are considerable distances from suitable habitat in the Upper Klamath Basin, and those populations themselves are struggling to persist. Active and thoughtful intervention will be needed if this race is to be successfully reintroduced into the upper basin (Goodman et al. 2011).

1.3.2 Source Stocks for Active Reintroduction

Where source fish populations are unable to naturally repopulate historically occupied habitats following the removal of artificial barriers, active fish reintroduction is the only option available for re-establishing populations. The success of such interventions is likely to depend upon many factors, including the source stock(s) chosen, the methods used to introduce the fish to their new environment, and, if fish culture practices are used, the application of conservation hatchery principles.

Huntington and Dunsmoor (2006a) considered the availability of source stocks for spring-run Chinook Salmon reintroduction to the Upper Klamath Basin. They considered fish from the Salmon River (confluence with Klamath River at rkm 107; rm 66.5) population the best candidate from an ecological standpoint. However, they discounted that at-risk population as a major donor source due to its low abundance. Trinity River and Rogue River (out-of-basin stock) runs of spring-run Chinook Salmon were suggested instead as potential donor stocks, but they encouraged further discussion to determine the best option(s) for reintroduction to the upper basin (Huntington and Dunsmoor 2006b).

Further discussion of acceptable spring-run Chinook Salmon donor stock(s) took place on March 18th and 19th, 2019 in Yreka, CA among Klamath Basin fisheries management agencies/organizations (ODFW, CDFW, The Klamath Tribes, USFWS, NOAA/NMFS, Hoopa Valley Tribe, Karuk Tribe, and Yurok Tribe). The discussion was informed by professional fishery biologists from the above-mentioned agencies/organizations as well as research from state, federal, and academic fisheries geneticists involved in studies in the Klamath Basin and adjacent watersheds. Results of the discussion concluded that in-basin stocks are more acceptable than out-of-basin stocks (e.g., Rogue River Basin spring-run Chinook Salmon) based on the irreversible genetic risks associated with potential straying of introduced, out-of-basin stocks, and subsequent interbreeding with Klamath Basin populations. The risks to tribal cultural aspects of the Klamath Basin associated with introducing an out-of-basin stock were also mentioned and discussed. Based on information presented and the discussion that followed at this meeting, it was decided that any active reintroduction of spring-run Chinook Salmon should first consider the use of in-basin stocks as a source to repopulate the Oregon portion of the Upper Klamath Basin. The use of in-basin stocks for active reintroduction of spring-run Chinook Salmon is described in more detail in Section 4.6.

1.3.3 Use of Upper Klamath Lake and Keno Impoundment/Lake Ewauna

The influence that environmental conditions within UKL and Keno Impoundment/Lake Ewauna may have on the long-term success of anadromous fish reintroduction to the Upper Klamath Basin cannot be overstated. Both of these nutrient-rich waterbodies experience seasonally poor water quality that may constrain their use by anadromous fishes. Water quality conditions are suitable much of the year but typically become severely stressful (high temperature, low DO, high, pH, high ammonia) and at times unsuitable for salmonids from about late-June or early July through early-September in UKL and from late June or early July to as late as October or even November in Keno Impoundment/Lake Ewauna. Annual "boom-and-crash" cycles of the blue-green algae *Aphanizomenon flos aquae* in these waterbodies can seasonally raise pH, lower dissolved oxygen concentrations, and elevate ammonia to levels beyond those tolerated by many species of fish.

Food resources available in these nutrient-rich waterbodies allow for rapid fish growth during portions of the year, but when conditions become unsuitable as described above, salmonids can be forced to seek water quality refuge elsewhere. The adfluvial Redband Trout in Upper Klamath Lake, which have extremely fast growth rates and frequently exceed 76 cm (30 in) in length, are an example of how salmonids can successfully utilize the food resources in UKL when conditions are suitable (typically September through June) (Figure 1-5). Anadromous salmonid life histories that include growth in or passage through UKL and Keno Impoundment/Lake Ewauna during favorable periods have the potential to thrive. However, these same fish would need to vacate and avoid these waterbodies (other than within refuge areas) during the adverse water quality times.

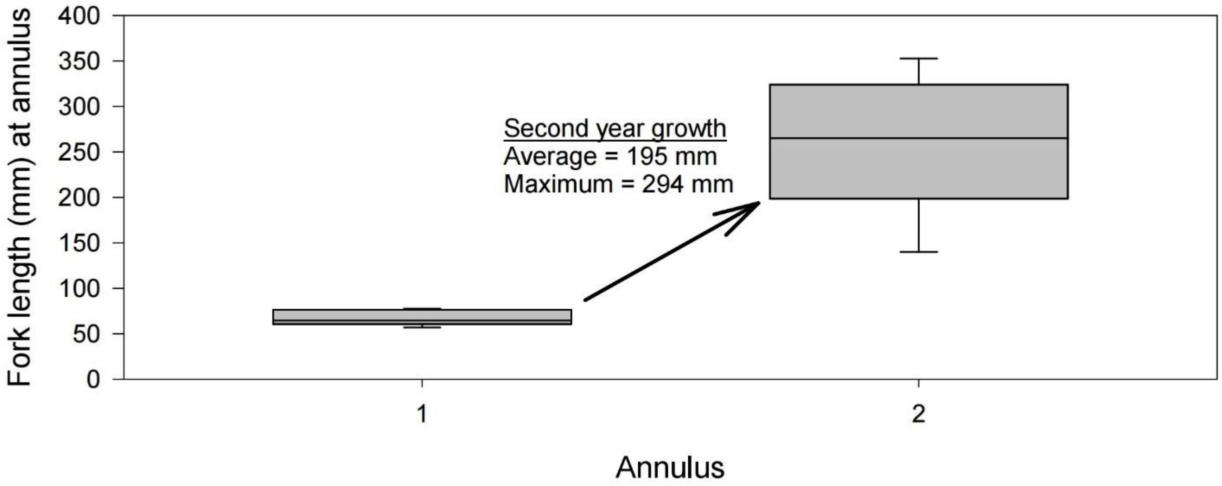


Figure 1-5. Growth of juvenile Redband Trout in Upper Klamath Lake as estimated through scale analysis of adults returning to spawn in Spring Creek, a cold spring-fed tributary to the lower Williamson River (source: Lisa Borgerson, ODFW, personal communication). Fish growth during their first year of life was in the tributary while most or all growth during their second year was in Upper Klamath Lake or its peripheral summer refugia.

Multiple live-box tests have exposed young salmonids to the water quality conditions in UKL. Conducted for a variety of purposes by researchers from Oregon State University, ODFW, and the U.S. Fish and Wildlife Service, the tests show in aggregate that conditions in the lake during summer can be harmful to salmonids that do not or cannot exercise behavioral options for avoiding unsuitable conditions (Figure 1-6). Test fish given no behavioral options for avoidance had a proportional daily survival of 1.0 in tests conducted up until mid or late-June, dropping to less than 0.90 in early July, to 0.0 in early August, rising to about 0.83 in early September, and back to 1.0 in autumn.

There are likely to be strong to severe selective pressures against life histories that would depend on use of UKL or Keno Impoundment/Lake Ewauna during periods of poor water quality. This situation is encouraging research and remedial actions directed toward water quality improvements (Doyle and Lynch 2005; Sullivan et al. 2012; NMFS and USFWS 2013; ESSA 2019; WAP in Prep.). It may also cause fish managers to develop near-term strategies for active anadromous fish passage intervention, should developing fish runs experience migratory blocks caused by unsuitable water quality.

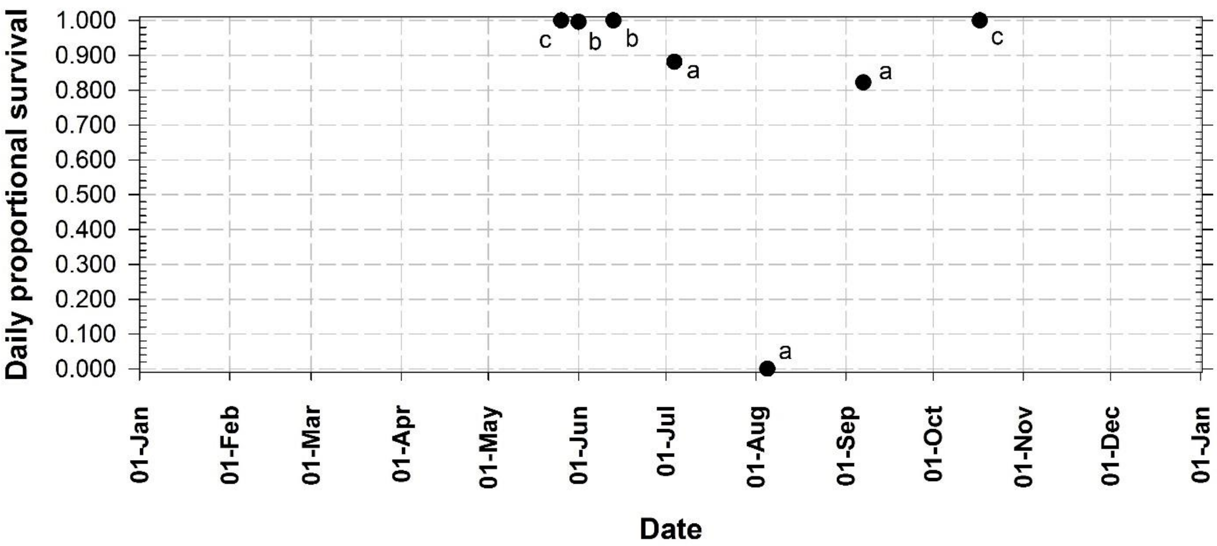


Figure 1-6. Seasonal variation in proportional daily survival of young hatchery-origin salmonids held for a minimum of 10 days in Upper Klamath Lake during multiple live-box challenges, 1966-2006. The challenges were of naïve hatchery fish given no behavioral options for avoiding harsh water quality conditions. Data sources: Bond et al. (1968, a), Hemmingsen et al. (1988, b), and Maule et al. (2009, c).

1.3.4 Fish Pathogens

Removing the dams on the Klamath River will not only change the dynamics of fishes in the basin, but the dynamics of the pathogens associated with the fishes is likely to change as well. Resident fishes above the dams have been isolated from specific pathogens associated with fishes below the dams for over 100 years. In the absence of selective pressure, upper basin fishes may have decreased resistance to below dam pathogens. Conversely, isolated resident fishes could transmit novel pathogens to anadromous fishes (Hurst et al. 2012). However, it was determined from the FERC Environmental Impact Statement (FERC 2007) and stated during the Secretarial Determination (USDI 2013) that the risks associated with the potential reintroduction of pathogens to Klamath River native fish above the dam sites would be low. Additionally, there are likely to be improvements to fish health in the Klamath River following dam removal caused by a return to a more natural flow regime downstream of the current site of J.C. Boyle Dam and improvements to water quality. These changes are predicted to alleviate many of the conditions that promote disease outbreaks associated with the parasite *Ceratonova shasta* (*C. shasta*) that occur below Iron Gate Dam (Hamilton et al. 2011).

Even though the risks associated with disease introduction following dam removal on the Klamath River have been deemed low, uncertainties associated with disease are important to consider in any reintroduction effort (Ewen et al. 2012; Muths and McCallum 2016). There is some degree of risk associated with both the active and volitional repopulation approaches as proposed. The risk associated with the active reintroduction approach also varies depending on the source stock and life stage utilized. Pathogen screened gametes or juveniles pose the lowest risk of pathogen introduction to the Upper Klamath Basin. Conversely, as there are currently no reliable non-lethal methods of detecting pathogens of concern (such as IHNV) in adult anadromous fishes, the use of adult fish poses the highest risk of pathogen introduction.

Active reintroduction is expected to proceed in a multi-year, multi-phased approach. Given the risk of pathogen introduction to resident fishes of the upper basin, this plan will be implemented using the lowest risk options. When anadromous adults begin to return to the Oregon portion of the Upper Klamath Basin, the balance between risks and benefits can be re-evaluated to determine if, when, and how adult fish will be moved.

Correspondingly, a rigorous pathogen-monitoring program will be needed to evaluate unintended consequences associated with the reintroduction of anadromous fishes into the Upper Klamath Basin. In addition, baseline studies will provide valuable information on multiple fish pathogens prior to dam removal and will allow for the assessment of pathogen dynamic changes post dam removal (Brenkman et al. 2008). Strategies for monitoring fish health are described in more detail in 3.4 of this document.

1.3.5 Hatchery vs. Wild Fish

Fish from wild salmonid populations are generally more genetically diverse and naturally fit, and likely to be more capable of repopulating new habitat than are those from hatchery-origin populations. As a general rule, the more life-stages and generations that have been subjected to the unnatural selective pressures associated with artificial culture, the less diverse and fit for a full life cycle in the natural environment a hatchery population of salmonids tends to become (NRC 1996). This typically makes wild populations, and particularly those in close proximity to newly available habitat, the best choice for repopulation. However, fishes sourced from wild populations may not be available to repopulate areas and even when available, their direct use is sometimes restricted to pathogen-screened individuals subject to some level of hatchery intervention. In these situations, the use of artificially spawned eggs from wild salmonid parents, or first-generation hatchery juveniles derived from wild parents, may be an option for repopulating habitat with a minimum of hatchery influence to new areas.

1.3.6 Fish Passage at Artificial Structures

Huntington et al. (2006) reviewed existing aquatic environmental conditions and concluded that success in re-establishing self-sustaining anadromous fish runs above Upper Klamath Lake will depend partly upon high levels of survival and low levels of unnatural delay as fish pass through the mainstem Klamath River extending from below Iron Gate Dam to above Link River Dam. We concur and consider removing the lower four KHP dams (J.C. Boyle, Copco 1 and 2, and Iron Gate) or providing timely and effective fish passage at these dams and the reservoirs behind them as essential to meeting the objectives of this reintroduction implementation plan. Similarly, effective fish passage will be required at Keno and Link River dams, which are not slated for removal, but whose fish facilities may require improvements depending on fish performance during passage. Juvenile and large adult adfluvial Redband Trout are known to pass both dams at present, and the facilities at Link River Dam have been designed to pass endangered suckers as both juveniles and as adults that can exceed 700 mm in body length. It appears that the facilities at these latter two dams may be sufficient to support reintroduction, particularly during its early stages. We do, however, recommend enhancements at Keno Dam that include improving the attraction flows at the fish ladder and improved downstream passage through the dam. Currently, impounded water exits Keno Dam via radial arm gates that draw water from several feet below the surface. Improvements that involve allowing water to spill over the gates are recommended for increased downstream passage and survival of fishes. We also recommend a facility at Keno Dam and/or Link River Dam to allow for the sampling of fishes passing upstream.

The level of success of the fish reintroduction effort can also be affected by fish passage at the locations of multiple unscreened irrigation diversions and several high-priority migration barriers upstream of UKL. ODFW staff and other organizations have been assessing the status of fish passage at these locations and evaluating their relative priority for remediation.

1.3.7 Potential Predation on Juvenile Anadromous Fishes

Pacific salmon and steelhead trout will be subject to predation of unknown magnitude within the upper basin. Multiple resident fishes, both native and non-native, are thought to prey upon young salmonids in tributaries that will be used for spawning and early rearing in the lakes and reservoirs, and in the Klamath River. However, the greatest potential for predation on salmon and steelhead trout in the Upper Klamath Basin will come from the seasonally robust populations of colonial, fish-eating waterbirds. Reintroduced anadromous fish may also become a part of the diet of terrestrial wildlife such as otters.

1.3.8 Potential Effects of Anadromous Fish Reintroduction on Resident Native Fishes

The native resident fishes of the Upper Klamath Basin have evolved with migratory anadromous fishes. It has only been recently, evolutionarily speaking, that anadromous fishes have been absent from the Upper Klamath Basin. Therefore, we hypothesize, in regard to potential competition, anadromous fishes will not negatively affect the assemblage of native residents. However, the state of native resident fishes in the Upper Klamath Basin is poorer than when anadromous fishes were present. Federally listed suckers and Bull Trout, and Redband Trout populations that ODFW (2005) identifies as being “vulnerable” and “at-risk”, will need to be taken into account as the reintroduction plan is implemented. At-risk species, such as suckers, Bull Trout, and Redband Trout are currently being monitored throughout the Upper Klamath Basin and it is imperative that monitoring of these populations continues into the future as anadromous fishes become re-established.

The reintroduction of anadromous fishes is likely to strengthen ongoing ecological restoration efforts in the Upper Klamath Basin, which should benefit native resident fishes. Specifically, one of the conservation recommendations in the Klamath Recovery Unit Implementation Plan for Bull Trout is to support actions to reintroduce anadromous fishes that were historically present as a way to increase prey base and productivity through increased marine derived nutrients (USFWS 2015). Fish passage through the mainstem Klamath River will benefit resident fishes in the Klamath River by allowing access to spawning tributaries and cold-water refuges that populations have been isolated from since the construction of dams. New funding sources, specifically for anadromous fishes, will become available for restoration projects, which will also benefit resident fishes.

1.3.9 Fisheries Conservation and Management

Efforts to re-establish and conserve self-sustaining runs of anadromous fishes in the upper basin, and particularly above UKL, will depend on collaborative fisheries management by fish agencies and Tribes on both sides of the Oregon-California border, and through coordinated efforts of the Pacific Fishery Management Council (PFMC). The harvest of fishes from new/developing runs will need to be managed with a strong emphasis on conservation that will allow for re-establishment. For example, increasing the conservation objective of Klamath River fall-run Chinook Salmon escapement for a few years following dam removal could potentially facilitate an increase in individuals straying into newly available habitat. Determining any future changes to the tribal, commercial, or recreation harvest of salmon/steelhead in the Lower Klamath Basin or the Klamath Management Zone in the Pacific Ocean is beyond the scope of this document alone. However, we do recommend the goals of this Implementation Plan be considered when decisions are made regarding the harvest of fishes of the Klamath Basin. Harvest of anadromous fishes within the Oregon waters of the Klamath Basin should be limited until populations become self-sustaining and an *Anadromous Fish Conservation Plan* is completed by ODFW (ODFW 2008). We recommend that ODFW and CDFW coordinate to ensure that harvest management for anadromous fishes is consistent between the two states in waters above the former site of Iron Gate Dam.

1.3.10 Scope, Rate, and Effectiveness of Environmental Restoration

There are uncertainties associated with the scope, rate, and effectiveness of environmental restoration activities in the Klamath Basin, including those within the upper basin. This is particularly the case given predictions of climate change, and the abandoning of the Klamath Basin Restoration Agreement (KBRA) and the Upper Klamath Basin Comprehensive Agreement (UKBCA).

The level of success of reintroducing anadromous fishes in the upper basin will depend on the performance of whatever organizing structure is ultimately adopted to guide efforts to improve key elements of the aquatic ecosystems. Key measures of that performance will include the ability to identify, prioritize, fund, and implement ecological improvements. Several past efforts, including the KBRA, UKBCA, Total Maximum Daily Load documents (ODEQ 2019), and Endangered Species Act recovery plans, have identified the need for a coordinated plan or strategy to prioritize and implement restoration actions in the Upper Klamath Basin. One such plan is the Upper Klamath Basin Watershed Action Plan (WAP in prep.). The goal of the WAP is to provide science-based guidance regarding types of restoration projects necessary to address specific impairments to riverine and riparian process and function, and development of monitoring regimes tied to quantifiable restoration activities in the Upper Klamath Basin. Additionally, the WAP outlines a process of adaptive management to refine condition assessments, recommended restoration actions, and monitoring approaches as new information becomes available (WAP in prep.). Another habitat restoration plan currently in preparation is the Klamath Basin Integrated Fisheries Restoration and Monitoring Plan (IFRMP). The vision of the IFRMP is to provide a unifying framework for planning the restoration and recovery of native fish species from the headwaters to the Pacific Ocean, while improving flows, water quality, habitat and ecosystem processes (ESSA 2019).

Multiple environmental issues will be central to future ecological restoration efforts in the basin. Some of these issues are highlighted below.

Flow management

Many of the ecological challenges facing fishes in the Klamath Basin relate to water usage and the effects of use on water quality. This principle has been central to multiple Biological Opinions relating to federal water management (NMFS and USFWS 2013; NMFS 2019 and USFWS 2019) and applies to water use not subject to federal control. Efforts to work with a variety of water users to achieve more normative flow conditions in the Upper Klamath Basin is critical to the ecological function of the river and associated health of both anadromous and resident fish populations.

Water quality

Anadromous fishes excluded from the upper basin for over a century are sensitive to water quality degradation, and their ability to repopulate historically occupied habitats above Iron Gate Dam will be affected by this sensitivity. While many streams in the upper basin have water quality that is suitable to excellent, seasonally adverse conditions like those described for UKL and Keno Impoundment will require varying levels of remediation.

Water quality assessments and integrated improvement plans are ultimately the responsibility of the Oregon Department of Environmental Quality within Oregon and of the North Coast Water Quality Control Board within the California portion of the Klamath Basin. The technical work of these agencies is conducted by internal staff assisted by dispersed networks of scientists, many of whom collaborate through the Klamath Basin Monitoring Program. Coordinated effort to address the basin’s high-priority water quality problems will depend on taking a systematic approach such as has been suggested in a first-stage synthesis document produced as part of the Klamath IFRMP (ESSA 2017).

Habitat conditions in tributary streams

Habitat conditions vary dramatically within the tributaries to the Klamath River and UKL that will become accessible to anadromous fish when KHP dams no longer block passage. Conditions found along these streams vary in terms of the vigor and composition of riparian vegetation, channel composition and stability, hydrologic and thermal regimes, instream structure, and inherent productivity. Many of the streams contain habitat that is in good condition and clearly suited to use by anadromous fishes, but others have been degraded to varying degrees and have diminished suitability or are unlikely to be repopulated without dramatic remedial measures (see Huntington et al. 2006). Improving the habitat conditions within upper basin streams to benefit anadromous and resident native fishes will be essential to a broadly successful reintroduction effort.

1.4 Climate and Ocean Change Considerations for the Reintroduction of Anadromous Fishes into the Upper Klamath River Basin

Climate and ocean change is expected to result in a wide variety of effects in the Pacific Northwest (Caldeira, K. & Wickett 2003; Barr et al. 2010; Dalton and Fleishman 2021) that could impact the quantity and quality of habitat available to native anadromous fishes. These changes could affect the future viability of salmon, steelhead, and Pacific Lamprey populations, especially in basins where they have already lost historic population structure, genetic diversity, and access to diverse thermal habitats due to human actions. Salmon, steelhead, and Pacific Lamprey have persisted for millions of years through frequent disturbances and climate extremes, which does include local extirpations and range shifts, but their current adaptive capacity to persist through extremes has been reduced in many cases. Protecting and restoring key freshwater habitats, including restoring access to habitats currently inaccessible to anadromous fishes due to anthropogenic barriers, is crucial for increasing population resilience and reducing risk to future viability from climate and ocean change (Crozier et al. 2019). Thus, reintroducing anadromous fishes to their former range in the Upper Klamath Basin is a critical climate change adaptation strategy (USDOI and USDOC 2013). Reintroduction efforts will be informed by climate change considerations, as directed by ODFW’s Climate and Ocean Change Policy (OAR 635-900-0001 through 635-900-0020). The following section presents climate and ocean change projections relevant to planning for the reintroduction of anadromous fishes into the Upper Klamath Basin and describes key features of the Upper Klamath River Basin that will affect habitat for anadromous fish in a changing climate. These projections and landscape features were considered when developing the reintroduction approaches described later in this plan.

Climate Change Projections for the Klamath River Basin

In general, climate and ocean model predictions for the Pacific Northwest including southern Oregon and northern California include the following (Caldeira and Wickett 2003; Grantham et al. 2004; USGCRP 2009; Salathe et al. 2010, Barr et al. 2010; FHWA 2010; OCCRI 2010, USBR 2011; Dalton and Fleishman 2021):

- Increased average air temperature
- Increased number of extreme heat days
- Changes to annual and seasonal precipitation, including diminished snowpack, more winter rain, and lower summer stream flows
- Increased heavy precipitation events
- Changes to annual and seasonal stream flow
- Ocean acidification and hypoxia

Specifically, in the Klamath River Basin climate change is resulting in significant declines on April 1 snow water equivalent since the 1950's at several snow measurement stations, particularly those at elevations lower than 6,000 feet (Van Kirk and Naman 2008). There is also strong evidence that winter precipitation in the Upper Klamath Basin has declined (Mayer and Naman 2011). Modeled water temperatures during the adult fall-run Chinook Salmon migration in the mainstem Klamath River indicate that future (now through 2061) water temperatures will be 1-3°C greater than historical (1961-2009) temperatures due to climate change (USDOI and USDOC 2013). Increasing air and water temperatures, changes in precipitation patterns, and the temporal and geographical variation associated in these changes has the potential to impact the physical, chemical, and biological processes associated with water quality in the Klamath River Basin, but the timing and magnitude of these consequences are not well understood (Lettenmaier et al. 2008; USBR 2011; USDOI and USDOC 2013). Some potential impacts to water quality from a changing climate include (from Barr et al. 2010):

- Decreased and fluctuating dissolved oxygen content from more rapid cycling of detritus.
- Increased nutrients, turbidity, and organic content from increased runoff and wildfires.
- Earlier, longer, and more intense algae blooms due to warmer water temperatures and increased nutrient availability.

Investigations into watershed-type specific impacts from climate change have found that watersheds where stream flow is influenced predominantly by the amount of precipitation that is stored as snowfall will be more negatively impacted (less stream flow) than watersheds that are dominated by groundwater inputs (Tague et al. 2008; Tague and Grant 2009). Though, while it is predicted that large, groundwater dominated streams will continue to flow year-round, the amount of flow will be affected by changes in precipitation patterns over the long-term (Tague et al. 2008). Streamflow in the Cascade Range in Oregon and Northern California is dominated by groundwater inputs, and in most instances the only source of flow in late summer.

The hydrologic characteristics of the Lower Klamath River and its tributaries (with the exclusion of the Shasta River) are dominated by seasonal melt of snowpack and precipitation (NRC 2004). In contrast, the hydrologic characteristics of the Upper Klamath Basin are substantially dominated by groundwater sources, due in most part to its permeable volcanic bedrock (NRC 2004; Gannet et al. 2007; Gannet et al. 2012). Groundwater dominated streams can act as a buffer from the immediate impacts of climate change (Thompson 2007; Tague et al. 2008). Groundwater inputs are also generally cooler in the summer and warmer in the winter than surface water and are less likely to be altered in response to climate change (Tague et al. 2007).

The vast majority of streams in the Upper Klamath Basin are perennial throughout the year because groundwater contributes to the baseflow (late-summer flow), but in some streams (specifically in the Lower Williamson River and Wood River Basins) groundwater is the dominant source of flow throughout the year (Gannet et al. 2007). These groundwater dominant watersheds, such as the Wood River and Williamson River systems are characterized by cool summer temperatures (daily mean temperature <16°C), and relatively constant flows (both ~ 490 and 350 cfs, respectively) which currently provide large amounts of habitat for resident salmonids when water temperatures in Upper Klamath Lake become too warm (July-August) (Hahlbeck et al. in review). Numerous other groundwater-sourced tributaries and springs provide water inputs into Upper Klamath Lake and the Klamath River that total about 1,895 cfs (Table 1-6). One of the largest sources (>200 cfs) of groundwater in the upper basin is located one river mile below J.C. Boyle Dam and approximately 30 river miles above Iron Gate Dam along the margins of the Klamath River (Gannett et al. 2007). This particular cold-water region of the Klamath River will be available for anadromous fishes immediately after fish passage is restored, providing a valuable resource for anadromous fish migrating through the Klamath River (USDOI and USDOC 2013).

The expert overview report for the Department of Interior and Department of Commerce secretarial determination on whether or not removing the lower four Klamath Hydroelectric dams would be beneficial for people and the ecosystem confirmed that dam removal in conjunction with habitat restoration would improve ecosystem resilience to climate change by offsetting some of the associated impacts (USDOI and USDOC 2013). The report concluded that dam removal, which would return approximately 160 miles of the river from J.C. Boyle Reservoir in Oregon to the Salmon River in California to a more natural thermal regime, would immediately decrease late summer/early fall water temperatures in the mainstem Klamath River by approximately 2 - 10°C (3.6 - 18° F). Modeling efforts that included dam removal along with the effects of climate change 50 years into the future also resulted in a decrease in water temperatures of 4°C downstream of the Iron Gate Dam site (Perry et al. 2011). Returning the Klamath River to a more natural flow and temperature regime and allowing anadromous fishes in the Klamath Basin access to historical, thermally diverse habitat that includes the largest groundwater inputs in the basin will improve conditions for Chinook Salmon, Coho Salmon, steelhead trout, and Pacific Lamprey in the basin and allow them a better chance to adapt to and tolerate a changing climate (Goodman et al. 2011; Dunne et al. 2011; and Hamilton et al. 2011; Crozier et al. 2019).

Incorporating Climate and Ocean Change considerations into reintroduction planning

The development of this Plan was informed by previous and on-going research and monitoring conducted by State, Federal, Tribal, and non-governmental partners. Research to date suggests that dam removal and subsequent reintroduction of anadromous fishes into the Oregon portion of the Klamath Basin is the best strategy to provide resiliency for these stocks in the Klamath River Basin in a changing climate (see USDOI and USDOC 2013).

Given the climate and ocean changes outlined above and the uncertainties around timing and spatial impacts, this plan incorporates several elements that are intended to aid implementers in tracking changes in key habitat features, assessing the likely impact of those changes on the success of reintroduction, and informing which management strategies are most likely to result in success. The following is a high-level summary of how the plan incorporates climate and ocean change considerations.

Table 1-6. Total estimated amount of stream and spring flow solely contributed by groundwater inputs in the Upper Klamath Basin (upstream of Iron Gate Dam) by river system.

River System	Section	Groundwater Flow (cfs)
Lower Williamson River and tributaries	Mouth of Williamson River up to Kirks Reef	350
Wood River and tributaries	Crooked Creek confluence to headwaters	490
Sevenmile Creek and tributaries	Crane Creek confluence to headwaters	90
Sprague River	South Fork Sprague to Sprague River	202
Upper Klamath Lake	Springs in Upper Klamath Lake including Malone, Crystal, Sucker and Barkley Springs	350
Klamath River	Keno Dam to J.C. Boyle Powerhouse	285
Klamath River and Fall Creek	J.C. Boyle Powerhouse to Iron Gate Dam	128
Total		1,895

Source: Buchanan et al. 2011; Gannet et al. 2007; from USDOI and USDOC 2013

Science/Monitoring

- ODFW and State, Federal, Tribal, and non-governmental partners will continue monitoring water temperature, flows, and dissolved oxygen, and pH through the repopulation phase of the reintroduction to track spatial and temporal changes in key habitat features.

- ODFW will take the lead in coordinating with partners to develop new monitoring efforts specifically targeted for anadromous fishes through migratory corridors, spawning, and rearing habitat to determine if and how climate change is impacting repopulating anadromous fishes. Monitoring will focus on mark-recapture studies to determine movement and survival as well as visual surveys of fishes in conjunction with habitat data (water temperature, flows, and dissolved oxygen, and pH) to determine any correlated effects of habitat to movement behavior and survival.

Species and Habitat Management Strategies

- ODFW understands that climate change models predict warmer air temperatures, changes to annual and seasonal precipitation, including diminished snowpack, more winter rain, and lower summer stream flows, all leading to annual and seasonal stream flow. Because of this, active reintroduction of Chinook Salmon into tributaries above Upper Klamath Lake will be focused on streams that are dominated by groundwater inputs that are more buffered to climate change impacts than precipitation sourced streams.

- ODFW understands that changing ocean conditions, including warming, acidification, and hypoxia, are impacting food webs associated with anadromous fishes and could lead to more frequent periods of low abundance. As such, monitoring will take into account that during some years adult returns may be less abundant than they would be under non-climate and ocean change scenarios. Monitoring anadromous fishes should be adaptive with the understanding that populations may fluctuate depending on ocean conditions.

- Currently and into the future, ODFW will prioritize the protection and restoration of habitat in the Upper Klamath Basin that is, or could be, more resilient to the effects of climate change (groundwater sourced and high elevation streams). However, ODFW will also prioritize protecting and restoring habitat that is located downstream, within migratory corridors, to climate change resilient habitat to ensure anadromous fishes can access this high functioning habitat. This will result in the protection of a diverse assemblage of aquatic habitat, which will enhance the adaptive capacity of anadromous fishes in the Klamath River Basin, thus increasing the likelihood of their persistence through frequent disturbances and periods of droughts associated with climate and ocean change.

- Once populations are re-established, a Conservation Plan will be developed to guide future management of anadromous fish populations. The Conservation Plan will be informed by the research and monitoring that occurs during the reintroduction phase as well as available science on future changes in climate and ocean.

2. APPROACHES TO THE REINTRODUCTION OF ANADROMOUS FISHES INTO THE OREGON PORTION OF THE UPPER KLAMATH BASIN

2.1 Goal

The goal of this plan is to re-establish viable, self-sustaining, naturally producing populations of anadromous fishes in the Oregon portion of the Upper Klamath Basin. Re-established populations will help sustain harvests that significantly contribute to the welfare of fishery-dependent Klamath Basin communities, while also restoring an integral component to the ecosystem that has been absent for over a century.

The approaches proposed in this plan are guided by the following documents:

- A Plan for the Reintroduction of Anadromous Fish in the Upper Klamath Basin (ODFW 2008).
- Oregon Administrative Rules (OAR) Klamath Basin Anadromous Fish Reintroduction Plan (OAR 635-500-3890 to 635-500-3910).
- Reintroduction of Anadromous Fish into the Upper Klamath Basin: An evaluation and Conceptual Plan (Huntington et al. 2006).

Details related to strategies for monitoring volitional repopulation and strategies for active reintroduction efforts are addressed in Section 3 and 4, respectively, in this document.

2.2 Geographic Extent for Reintroduction of Anadromous Fishes

The geographical extent of this reintroduction implementation plan includes all streams and waterbodies in the Oregon portion of the Upper Klamath Basin with the exception of the Lost River system (Figure 2-1). This plan does not propose to purposefully introduce anadromous fishes into the Lost River sub-basin. There is no evidence that the Lost River sub-basin historically provided habitat for anadromous fishes. The natural hydrology of the Lost River sub-basin and its connectivity through Lower Klamath Lake to the Klamath River has been described as irregular (water exiting Lower Klamath Lake to the Klamath River in the spring and entering the lake from the river in the fall), due to the topography of the area (Weddell 2000). Currently, connectivity between Lower Klamath Lake and the Klamath River is regulated solely through irrigation channels (NRC 2004). The reintroduction approaches, strategies, and tactics to be applied vary among geographic areas; therefore, it is important to define the boundaries of these areas. The Klamath River and its tributaries are defined as any waterbody or stream downstream of Link River Dam (rkm 414.4, rm 257.5) and includes Keno Dam at rkm 380.5 (rm 236.4). Upper Klamath Lake and its tributaries are defined as any waterbody or stream above Link River Dam. Williamson River Falls (rkm 32, rm 19.8) is a natural barrier to upstream migration of fishes on the Williamson River (major tributary to Upper Klamath Lake) and is the upstream limit to anadromous fishes in the Williamson River (Figure 2-1).

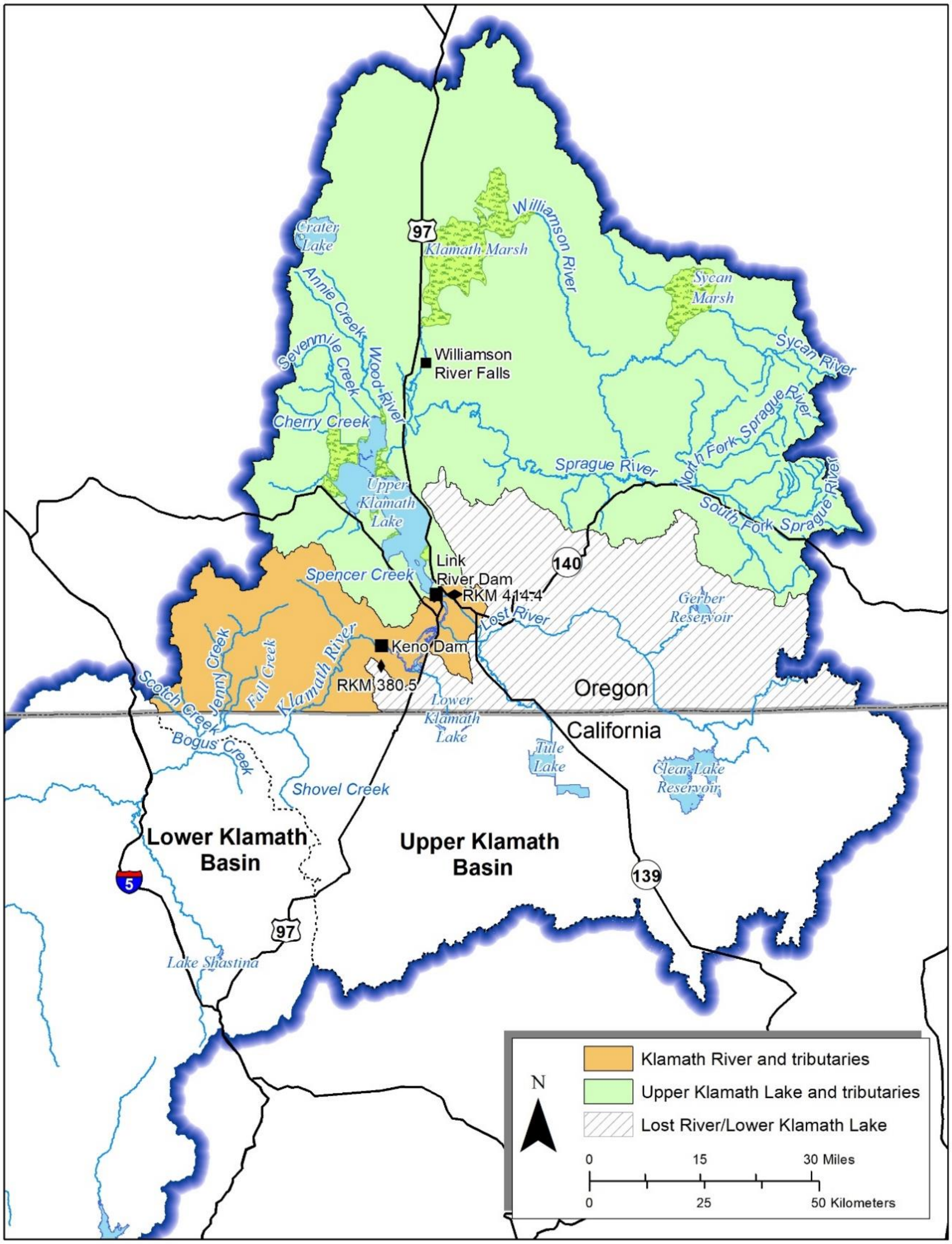


Figure 2-1. The geographic boundaries that define the Klamath River and its tributaries and Upper Klamath Lake and its tributaries for the purpose of reintroduction of anadromous fishes in the Oregon portion of the Upper Klamath Basin. Lost River and Lower Klamath Lake watersheds are also represented but are not included in reintroduction efforts.

2.3 The Concept of Natural vs. Active Repopulation

There are three types of approaches to consider when planning reintroductions (Anderson et al. 2014). These approaches are: (1) natural repopulation via volitional migration (letting fish stray into new habitat on their own); (2) active repopulation via transplants of adults (of hatchery or natural origin); and (3) active repopulation via releases of fertilized gametes and/or juveniles. Natural repopulation is generally considered the approach with the lowest risk of failure or unintended consequences because it minimizes the interruption or alteration of natural biological processes (reviewed in Pess et al. 2009 and Anderson et al. 2014).

Active reintroduction by means of transplanting adults, juveniles, or fertilized gametes has the benefit of immediately placing fish in the reintroduction area but has increased ecological risks relative to natural repopulation. Hatchery releases may reduce the genetic fitness of wild fish (e.g., Araki et al. 2008) or induce density-dependent ecological processes affecting naturally spawning fish (e.g., Kostow 2009).

Early reintroduction efforts in the Upper Klamath Basin will be shaped by an intent to avoid active transplants of hatchery and wild adults and the potential risks of pathogen outbreaks that might be associated with such transplants. The decision framework proposed for the reintroduction of anadromous fish into the Upper Klamath Basin is based on the work of Anderson et al. (2014), which highlights key decisions affecting reintroduction efforts and emphasizes the use of low-risk source populations and strategies (Figure 2-2). The decision framework for reintroductions into the upper basin is based on whether or not there is a reasonable likelihood of natural repopulation from nearby spawning areas or populations (source populations). If a source population exists and there is reason to believe individuals will migrate to newly accessible habitats, natural repopulation through volitional migration will be the approach taken. If a source population does not exist, or there is reason to believe that volitional migration of individuals to new habitat(s) will not occur in a reasonable timeframe, active reintroduction(s) will be implemented. Criteria for determining whether nearby source populations exist are based on species and stock abundance immediately below Iron Gate Dam, habitat conditions within differing portions of the Upper Klamath Basin, and the life history characteristics of each species and stock.

2.4 Decision Making

The two approaches this plan is proposing to pursue as part of an adaptive strategy to reintroduce anadromous fishes to the Upper Klamath Basin are: 1) natural repopulation via volitional migration of adults, and 2) active reintroduction using juveniles. The volitional repopulation approach involves a “wait-study-see” strategy that gives naturally migrating adults an opportunity to migrate into new habitat unassisted. The success and rate of this approach may be affected by several factors that include accessibility, proximity to a donor stock, productivity and condition of donor stock, habitat suitability, straying rate, interactions with existing fish populations, and intraspecific competition for food and space (Pess 2009; Pess et al. 2012, 2014). Active reintroduction using juveniles involves the capture of adults of existing populations, the extraction and fertilization of gametes, and the use of in-basin facilities for rearing. Rearing facilities will include ODFW’s Klamath Hatchery facility (located on Crooked Creek in the Wood River Watershed), acclimation facilities (if deemed necessary), and any other appropriate facilities.

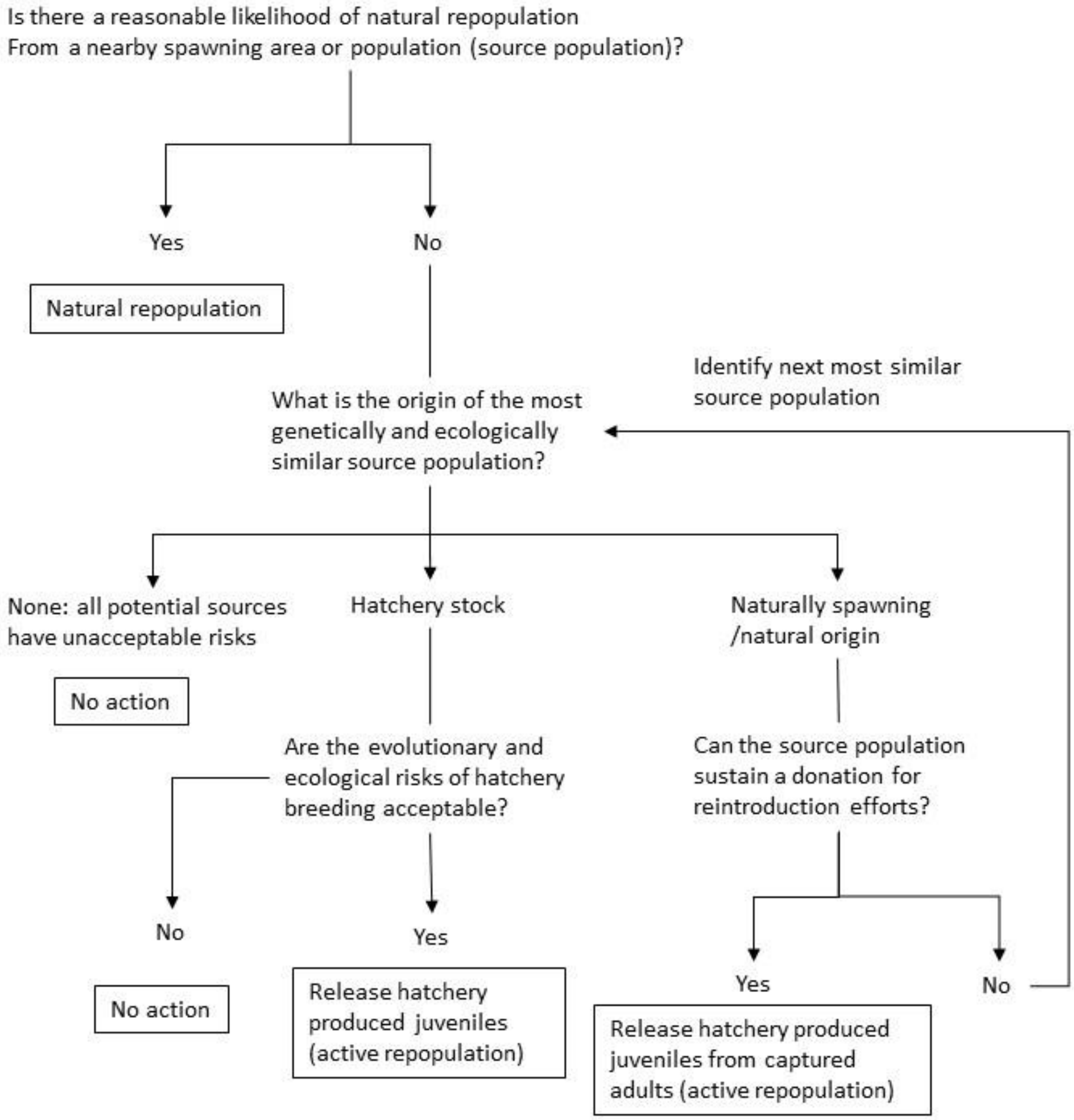


Figure 2-2. Decision framework for selecting a low-risk reintroduction approach and source population. This framework does not encompass every possibility but is intended to highlight the key decisions affecting reintroduction risks. Boxes indicate decision endpoints. Adapted and modified from figure 4 of Anderson et al. (2014).

The actions taken to achieve the desired goal of viable, natural-producing populations of anadromous fishes are dependent upon the particular species, its ecotype/race, time, ecological risk, and logistical constraints. The actions are based on the assumptions and rationale as described below (2.5). Active reintroduction strategy will proceed in two phases. The first of these phases (Phase 1 – Reintroduction Studies) will involve investigations to determine the best approaches for active reintroduction, while Phase 2 (Repopulation) will implement the approaches learned in Phase 1 with the goal of repopulating habitat in the Upper Klamath Basin. Initially, we hypothesize that fall-run Chinook Salmon, Coho Salmon, steelhead trout, and Pacific Lamprey will migrate upstream of their own accord when fish passage is restored. The timing and extent of this volitional migration following passage restoration is uncertain. After three generations (fall-run Chinook Salmon = 12 years, Coho Salmon = 9 years, steelhead trout = 15 years, Pacific Lamprey = 15 years) an assessment will be conducted to determine if, where, and when active reintroduction is needed to help establish populations of these species.

Due to the expected lack of an adequate source population of spring-run Chinook Salmon ready to volitionally repopulate the upper basin, this ecotype/race of Chinook Salmon will be actively reintroduced into tributaries of Upper Klamath Lake following the availability of fish passage to the Upper Klamath Basin. Active reintroduction of spring-run Chinook Salmon will begin with a study phase (Phase 1), which will involve investigations to determine the best approaches for Phase 2 (repopulation) of active reintroduction. Strategies for the active reintroduction of spring-run Chinook Salmon are described in detail in Section 4 of this document.

The decisions and associated actions proposed in this reintroduction implementation plan are based on assumptions and rationale of current and near future ecological conditions and processes in the Klamath Basin. Monitoring and evaluation of anadromous fishes in the Oregon portion of the Upper Klamath Basin will determine the accuracy of assumptions and rationale, which are listed in the following subsection.

2.5 Assumptions and Rationale

- Upstream and downstream fish passage is provided throughout the Klamath River corridor, consistent with state and federal standards at PacifiCorp’s hydroelectric dams, or through dam removal.
- Volitional upstream and downstream fish passage through Keno Dam and Link River Dam via fish ladders and spillways is timely and effective.
- Migration through Keno Impoundment, Lake Ewauna, and Upper Klamath Lake will occur when water quality is suitable for salmonids.
- If/when water quality in Keno Impoundment and Lake Ewauna are not suitable for salmonids, a trap and haul program from Keno Dam to Upper Klamath Lake and/or tributaries may be necessary.

- Currently, suitable habitat located in tributaries above Upper Klamath Lake could be considered isolated from the mainstem Klamath River during certain times of the year, due to within and among year variability of water quality in Upper Klamath Lake, Lake Ewauna, and Keno Impoundment. These conditions will affect the life histories of reintroduced anadromous fish.
- Enough suitable habitat currently exists in the Upper Klamath Basin to support and sustain populations of anadromous fish.
- Tributaries of Upper Klamath Lake contain most of the climate resistant cold-water refuges within the entire basin and have the potential to support robust populations of salmon and steelhead trout.
- Upper Klamath Lake currently supports a robust population of adfluvial Redband Trout.
- Upper Klamath Lake currently supports a population of introduced Kokanee Salmon that are known to reside in Pelican Bay.
- Previous studies have shown that Chinook Salmon smolts had high survival and high growth rates when raised in net pens in Upper Klamath Lake (Maule et al. 2009).
- Fall-run Chinook Salmon are present in the mainstem Klamath River immediately downstream of Iron Gate Dam and will volitionally repopulate upstream reaches once fish passage is restored at existing Klamath Hydroelectric Project dam sites.
- Spring-run Chinook Salmon are only present in the Lower Klamath River (Trinity River and Salmon River sub-basins). The long distance from their current distribution to Iron Gate Dam will likely preclude natural repopulation of the Oregon portion of Klamath River, Klamath River tributaries, and tributaries above Upper Klamath Lake.
- Steelhead trout are present in the mainstem Klamath River immediately downstream of Iron Gate Dam and will volitionally repopulate upstream reaches once fish passage is restored at existing Klamath Hydroelectric Project dam sites.
- Resident Redband Trout/Rainbow Trout (*O. mykiss*) in the Upper Klamath Basin have the capacity to produce offspring that exhibit anadromous life histories and will contribute to the repopulation of steelhead trout once fish passage is restored at existing Klamath Hydroelectric Project dam sites.
- Coho Salmon are present (albeit, at low abundance) in the Klamath River immediately downstream of Iron Gate Dam and will volitionally repopulate upstream reaches once fish passage is restored at existing Klamath Hydroelectric Project dam sites. Due to low abundance, re-establishment of upstream reaches may be slower than other species.
- Pacific Lamprey are present in the Klamath River immediately downstream of Iron Gate Dam and will volitionally repopulate upstream habitat once fish passage is restored at existing Klamath Hydroelectric Project dam sites. Significant potential lamprey habitat exists in the Oregon portion of Klamath River, Upper Klamath Lake and tributaries, which should aid repopulation of upstream reaches once fish passage is restored.

- Spring-run Chinook Salmon gametes will be available from hatchery, naturally spawning, and/or wild donor stocks within the Klamath Basin for use in active reintroduction into tributaries of Upper Klamath Lake.
- Klamath Basin stocks of pathogen-screened juvenile spring-run Chinook Salmon are available for active reintroduction as hatchery reared juveniles into the Upper Klamath Basin. Adult fish present the highest risk of pathogen introduction and as of yet, there are no reliably accurate non-lethal methods for screening adults for pathogens of concern.
- Resistance to *C. shasta* will be a primary consideration for any stock of Chinook Salmon used in active reintroduction.
- The absence in the Upper Klamath Basin of multiple fish species that are known to compete with, prey upon, or otherwise impair the performance of salmonids elsewhere in the Pacific Northwest should contribute to successful re-establishment of anadromous fishes (Redside Shiner, Mountain Whitefish, Northern Pikeminnow, Smallmouth Bass, Walleye, Coastal and Westslope Cutthroat Trout, Striped Bass, White Catfish, Channel Catfish).

2.6 Reintroduction Approaches to be Implemented

Each species (and ecotype/race of Chinook Salmon) has a distinct reintroduction approach determined by the reasonable likelihood of natural repopulation from a nearby source population. Approaches also vary among geographic locations within the upper basin. When the initial approach to be taken is volitional repopulation, three fish generations (12 years for fall-run Chinook Salmon, 9 years for Coho Salmon, 15 years for steelhead trout) will be allowed a chance before active measures are considered. This timeframe should be long enough to allow for at least one, relatively large run of salmon during this initial phase. Pacific Lamprey do not necessarily return to their natal stream to reproduce; therefore, the duration of their repopulation phase will be based on their unique life cycle as well as examples from other reintroduction efforts. Because of this, fifteen years seems like a reasonable timeframe to allow Pacific Lamprey to naturally repopulate habitat in the Upper Klamath Basin.

Monitoring will occur immediately following the availability of fish passage to evaluate volitional migration and repopulation. An assessment will be made based on evaluation of the monitoring effort and a decision will be made to determine if active intervention is warranted. Investigations into potential anthropogenic and/or biological impediments will be conducted before efforts shift to active reintroduction. Descriptions and the reasoning for the proposed species-specific reintroduction approaches are described in the following sections and summarized in Table 2-1.

Table 2-1. Summary of reintroduction implementation approaches for anadromous fishes in the Oregon portion of the Upper Klamath Basin.

Location	Reintroduction Implementation Approaches									
	Natural repopulation					Active repopulation				
	Steelhead Trout	Pacific Lamprey	Coho Salmon	Fall-run Chinook Salmon	Spring-run Chinook Salmon	Steelhead Trout	Pacific Lamprey	Coho Salmon	Fall-run Chinook Salmon	Spring-run Chinook Salmon
Oregon portion of Klamath River and tributaries (below Link River Dam, rkm 414.4)	yes	yes	yes	yes	yes	Assessment will be made after **15** years of monitoring and evaluation to determine if active reintroduction is warranted	Assessment will be made after **15** years of monitoring and evaluation to determine if active reintroduction is warranted	Assessment will be made after **9** years of monitoring and evaluation to determine if active reintroduction is warranted	Assessment will be made after **12** years of monitoring and evaluation to determine if active reintroduction is warranted	no
Upper Klamath Lake and tributaries (above Link River Dam, rkm 414.4)	yes	yes	yes	yes	yes	Assessment will be made after **15** years of monitoring and evaluation to determine if active reintroduction is warranted	Assessment will be made after **15** years of monitoring and evaluation to determine if active reintroduction is warranted	no	Assessment will be made after **12** years of monitoring and evaluation to determine if active reintroduction is warranted	yes

2.6.1 Species-Specific Reintroduction Approaches

Steelhead Trout (*Oncorhynchus mykiss*)

Genetic studies have demonstrated that some of the resident *Oncorhynchus mykiss* (Redband Trout) populations in the Upper Klamath Basin are in the same lineage as their coastal counterparts below Iron Gate Dam (Currens et al. 2009; Pearse et al. 2011). Genetic similarities exist in populations below Keno Dam (rkm 380.5; rm 236.4) and in some tributaries of Upper Klamath Lake (for example, Cherry Creek, Rock Creek, and Rock Creek tributary of the Sprague River) (Pearse et al. 2011). A more robust genetic assessment of *O. mykiss* throughout the Klamath Basin is currently being conducted with the objective of refining the understanding the genetic relationship among populations throughout the basin.

The life history strategies of *O. mykiss* are both variable and flexible and include anadromous (spend some time in the ocean, but spawn in freshwater, called steelhead trout) and non-anadromous (freshwater residents, fluvial and adfluvial) migrators. Studies have shown that variation in life histories is due to a combination of gene expression, condition status, environmental influences, and likely many other factors (Kendall et al. 2015). Currently, *O. mykiss* populations below the dams express at least 38 life histories that exhibit differences in the durations of freshwater and ocean rearing, age at maturation, and incidence of repeat spawning (Hodge et al. 2016). Adults do not always produce offspring that exhibit the same life history as themselves (steelhead trout can produce non-anadromous progeny and resident *O. mykiss* can produce anadromous progeny) (Hodge et al. 2016; Kendall et al. 2015). Resident populations of *O. mykiss* located above barriers, both natural and man-made, are known to produce juveniles that exhibit smoltification behaviors (skin reflectance, Na^+, K^+-ATPase activity, and migration timing), and exhibit downstream migrations past barriers to upstream migration (Holecek et al. 2012; Wilzbach et al. 2012). Juvenile *O. mykiss* are known to express characteristics of smolts (individuals that exhibit smoltification behaviors) in a resident, adfluvial Redband Trout population that was once anadromous but that has been isolated above an impassable dam for over 50 years (Holecek et al. 2012). Thrower and Joyce (2004) found that the capacity for expressing anadromy can be maintained for extended periods in artificially isolated resident *O. mykiss*. The results of these and other studies (see Kendall et al. 2015) imply that resident populations of *O. mykiss* can contribute significantly to the maintenance of anadromous populations, and therefore gene flow between sympatric resident and anadromous forms is common (Olsen et al. 2006; McPhee et al. 2007). Recent investigations on the Elwha River in Washington demonstrate that steelhead trout descendants from below and above impassable dams repopulated the river following dam removal, and that dam construction did not reduce the genetic diversity associated with anadromous life histories (Fraik et al. 2021).

Based on the literature and studies described above, it is clear that the relationship between resident and anadromous forms of *O. mykiss* in the Klamath Basin is complex, and uncertainty exists regarding the effects reintroduced steelhead trout will have on the resident population of Redband Trout. We hypothesize that populations of steelhead trout in the Kamath River below Iron Gate Dam will repopulate habitat in the Upper Klamath Basin. In addition, resident Redband Trout/Rainbow Trout in the Upper Klamath Basin, having the potential to produce anadromous smolts, may also contribute to the expression of the anadromous life history when upstream and downstream fish passage is reestablished at the Klamath River Dam sites. Based on these hypotheses, this reintroduction plan proposes implementing a conservative approach to reintroducing steelhead trout to the Upper Klamath Basin, based entirely on volitional repopulation. Initially, no steelhead trout will be transported and released into the Oregon portion of the Klamath River, Upper Klamath Lake or its tributaries. This strategy follows the direction of ODFW's *Steelhead Trout in the Oregon Portion of the Klamath River, Upper Klamath Lake and Tributaries Policy* (OAR 635-500-3900). Steelhead trout in the Oregon portion of the Klamath River, Upper Klamath Lake or its tributaries are to be managed for natural production consistent with ODFW's *Native Fish Conservation Policy* (OAR 635-007-0503). Further research is needed to investigate the extent to which, resident Redband Trout progeny exhibit smoltification and migration behaviors in the Upper Klamath Basin as a means of determining if they might contribute to the repopulation process.

Following the availability of fish passage into the Oregon portion of the Upper Klamath Basin, volitional repopulation of steelhead trout will be monitored and evaluated for fifteen years. After this period, an assessment will be made to determine if, when, and where active reintroduction of steelhead trout will occur. This criterion allows three generations of fish the opportunity to repopulate and is based on research that investigated the life history diversity of steelhead trout in the Klamath River, which found that smolt age ranged from 1-3 years and time at sea for maiden spawners was from two months to four years (Hodge et al. 2016).

Pacific Lamprey (*Entosphenus tridentatus*)

Pacific Lamprey are indigenous to the Klamath River Basin and are currently presumed to be found within the current range of anadromous salmonids (Moyle 2002). Adults are found throughout the basin and are seasonally captured in a downstream juvenile salmonid trap in Bogus Creek, which enters the Klamath River approximately 2,000 feet downstream of Iron Gate Dam (Morgan Knechtle, CDFW, Personal Communication). Reports and studies not related to their distribution have found Pacific Lamprey in the Shasta and Scott Rivers, as wells as in Clear and Dixon Creeks (tributaries to the Klamath River) (Goodman et al 2008; Close et al. 2010). The historical distribution of the Pacific Lamprey within the Oregon portion of the Klamath River, Upper Klamath Lake and tributaries is not clear. Throughout the historic and current range of Pacific Lamprey, distribution is closely tied to Chinook Salmon spawning and rearing habitat (Simpson and Wallace 1978; Wydoski and Whitney 2003). Historically, Chinook Salmon were present upstream of Iron Gate Dam and in the tributaries of Upper Klamath Lake (Hamilton et al. 2005); so, it is assumed Pacific Lamprey may have been present as well.

Research suggests Pacific Lamprey do not have a strong fidelity to natal streams (Goodman et al. 2008; Hatch and Whitaker 2009; Spice et al. 2012). Adult Pacific Lamprey are attracted to pheromones produced by larvae during their upstream spawning migrations (Robinson et al. 2009; Yun et al. 2011). A growing body of evidence indicates that Pacific Lamprey have rapidly migrated into various rivers that were formerly blocked by dams, rockslides, or volcanic eruptions (Maitland et al. 2015; Clemens et al. 2017; Moser and Paradis 2017; Jolley et al. 2018). Lampreys can also be attracted to pheromones of other lamprey species (Fine et al. 2004; Moser et al. 2015). There is a potential for pheromones from the five resident lampreys in the upper basin (see Table 3-5 in Section 3 for lamprey species list) to facilitate the repopulation of Pacific Lamprey through cross-species pheromonal attraction.

Based on the aforementioned evidence, we hypothesize that Pacific Lamprey will repopulate the Upper Klamath Basin volitionally when fish passage is restored. Based on this hypothesis, this reintroduction plan proposes implementing a conservative approach to reintroducing Pacific Lamprey to the Upper Klamath Basin, which relies upon volitional repopulation. Initially, no Pacific Lamprey shall be transported and released into the Oregon portion of the Klamath River, Upper Klamath Lake or its tributaries. This strategy follows the direction of ODFW’s *Pacific Lamprey in the Oregon Portion of the Klamath River, Upper Klamath Lake and Tributaries Policy* (OAR 635-500-3910). Pacific Lamprey in the Oregon portion of the Klamath River, Upper Klamath Lake or its tributaries are to be managed for natural production consistent with ODFW’s *Native Fish Conservation Policy* (OAR 635-007-0503).

Following the availability of fish passage into the Oregon portion of the Upper Klamath Basin, volitional repopulation of Pacific Lamprey will be monitored and evaluated for fifteen years. After this period, an assessment will be made to determine if, when, and where active reintroduction of Pacific Lamprey will occur.

Coho Salmon (*Oncorhynchus kisutch*)

Due to many factors contributing to their low abundance, the U.S. Fish and Wildlife Service (USFWS) was petitioned to list Coho Salmon in the Klamath River Basin under the Endangered Species Act in 1993, with the National Marine Fisheries Service (NMFS) completing the status review of Southern Oregon Northern California Coast (SONCC) Evolutionarily Significant Unit (ESU) Coho Salmon in 1995. Following subsequent delays and further reviews, SONCC Coho Salmon were listed as threatened in 1997 (NMFS 1997). The total estimated Coho Salmon returns to the Upper Klamath River (Iron Gate Dam down to Seiad Creek at rkm 213; rm 132.3) and its tributaries from 2001 to 2004 were from 600 to 4,000 fish (Ackerman et al. 2006). The 53-year average of Coho Salmon returning to Iron Gate Hatchery is 1,033 individuals; the median return run from 2000 to 2014 was 723 individuals (Chesney and Knechtle 2015).

There are no documents or evidence that suggests Coho Salmon once occupied any habitat upstream of the outlet of Upper Klamath Lake (Klamath River rkm 414.4; rm 257.5). However, documented evidence suggests that Coho Salmon spawned in Klamath River tributaries above Iron Gate Dam (Hamilton et al. 2005). It is thought that the upper extent of Coho Salmon distribution with the Upper Klamath Basin was at least to and including Spencer Creek (rkm 371; rm 230.5) because they are primarily tributary spawners and suitable Coho Salmon habitat exists in tributaries up to and including Spencer Creek (Hamilton et al. 2005; Williams et al. 2006; USDI and CDFW 2012; NMFS 2014). Fish passage through the Klamath Hydroelectric Project would open up over 59 miles of Coho Salmon habitat above Iron Gate Dam, 31 miles being in Oregon (18 miles of mainstem Klamath River and 13 miles of tributary habitat within Spencer Creek), and likely more non-natal, rearing habitat in some of the smaller tributaries within the Klamath River Canyon (Figure 1-4). This estimate of available habitat was calculated using the National Hydrography Dataset (found at: https://www.usgs.gov/core-science-systems/ngp/national-hydrography) and measured using ESRI's ArcMap 10.6. The estimate of available stream habitat is likely an underestimate due to the numerous side channels of Spencer Creek.

Spencer Creek contains a large quantity of habitat suitable for Coho Salmon. Using a Habitat Limiting Factors model to estimate juvenile capacity, Ramos (2020) estimated that Spencer Creek could support 66,300 juvenile Coho Salmon throughout the summer months, the highest among all Klamath River tributaries above Iron Gate Dam. Among all Klamath River tributaries, Spencer Creek also contains the most suitable spawning habitat for Coho Salmon, with an estimated ability to sustain less than 18,000 Coho Salmon redds (Ramos 2020).

This reintroduction plan proposes implementing a conservative approach to reintroducing Coho Salmon into Oregon tributaries that relies upon volitional repopulation. Initially, no Coho Salmon will be actively transported and released into the Oregon portion of the Klamath River, Upper Klamath Lake or its tributaries. This approach follows the direction of ODFW's *Coho Salmon in the Oregon Portion of the Klamath River and Tributaries Policy* (OAR 635-500-3905).

Short-term management strategies will focus on providing safe and effective fish passage. An important part of the short-term management framework will be to work with basin partners in improving habitat in Spencer Creek. Due to the current low abundance of Coho Salmon in the Klamath Basin, the restoration of reconnected upstream tributary and mainstem habitats will be important as a means of helping to secure populations within its existing range. Long-term management will focus on addressing factors limiting the survival of juvenile Coho Salmon in Spencer Creek and the Klamath River.

Following the availability of fish passage into the Oregon portion of the Upper Klamath Basin, volitional repopulation of Coho Salmon will be monitored and evaluated for nine years. After this period, an assessment will be made to determine if, when, and where active reintroduction of Coho Salmon will occur. This criterion, which allows three generations the opportunity to repopulate, is based on data that Coho Salmon generally have a 3-year life cycle (with about half spent in freshwater and half spent in the ocean) (Moyle 2002; Quinn 2018).

Chinook Salmon (*Oncorhynchus tshawytscha*)

Spring, fall, and perhaps winter-run Chinook Salmon ecotypes/races were present in the Klamath River above Iron Gate Dam and Upper Klamath Lake and its tributaries before the construction of the dams on the Klamath River (Nehlsen et al. 1991; Hamilton et al. 2005; Hamilton et al. 2016). Currently, naturally produced spring-run Chinook Salmon populations in the Lower Klamath Basin are at very low abundance and are found only in a few tributaries (South Fork Trinity River, North Fork Trinity River, New River, and Salmon River) (Kinziger et al. 2013; Dave Hillemeier, Yurok Tribe, Personal Communication). South Fork Trinity River escapements of spring-run Chinook Salmon (adults and jacks) averaged 155 fish (range of 0 to 348) from 1999 to 2009 (CDFW, unpublished data). The 1990-2015 average annual escapement of natural spawning spring-run Chinook Salmon into the Salmon River sub-basin was 674 individuals and 8,431 individuals in the Trinity River sub-basin (CDFW 2018). The average estimated total run size of spring-run Chinook Salmon in the Trinity River sub-basin above Junction City weir (rkm 136.5; rm 84.8) from 1991 to 2016 was 14,874, with hatchery produced individuals contributing 59% on average (up to 81.6%) to the total run size (Kier et al. 2017). Recent (2015-2017) annual Salmon River snorkel surveys have shown a dramatic decline in escapement of this population, with annual counts less than 300 individuals (SRRC 2017).

Fall-run Chinook Salmon in the Lower Klamath Basin are more abundant than their spring-run counterparts, with fish reaching Iron Gate Dam each year. Estimates from 1978 to 2016 of the total in-river adult fall-run Chinook within the entire Klamath River Basin averaged 108,809 (median = 83,736) individuals (CDFW 2017). The average return of adult fall-run Chinook Salmon to Iron Gate Hatchery is 16,791 (37-year average; median ~ 14,000) individuals (Chesney and Knechtle 2015). Estimated spawner escapement in the 21.2 km (13.1 miles) reach below Iron Gate Dam (Iron Gate Dam to confluence of Shasta River) averaged 7,304 (median 4,894) individuals from 2001 to 2015, with an average of 1,781 (median 1,238) of those being of hatchery origin (Gough and Som 2017). The estimated proportion of natural origin fall-run

Chinook Salmon returns to Iron gate Hatchery from 2002 to 2017 range from 0.007 in 2008 to 0.289 in 2002 with an average of 0.167 (Morgan Knechtle, CDFW, Personal communication).

Spring-run Chinook Salmon were believed to be the dominant race in the Upper Klamath Basin before European settlement, although fall-run Chinook Salmon were the remaining dominant race at the time of development of the KHP in the early 1900's (Snyder 1931). A regional status review of Chinook Salmon populations that was completed in 1998 identified two ESUs with populations in the Klamath Basin (Myers et al. 1998). The Southern Oregon and California Coastal ESU comprises spawners in coastal watersheds from Cape Blanco, Oregon (south of the Elk River) to the southern extent of the current range, which includes the Klamath River up to the confluence of the Trinity River. The Upper Klamath and Trinity Rivers ESU includes all Klamath Basin populations upstream from the confluence of the Klamath and Trinity Rivers and includes both spring and fall-run races (Myers et al. 1998). Oregon Department of Fish and Wildlife manages native fishes at a level where populations from a common geographic area with similar genetic and life history characteristics are grouped and called *Species Management Units* (SMUs). Thus, as with all anadromous fishes that historically occupied the Oregon portion of the Upper Klamath Basin, the Upper Klamath Spring-run Chinook Salmon SMU is designated as *extinct* (ODFW 2005).

Past genetic research investigating divergence in run timing behaviors (spring-run vs. fall-run) suggested that parallel evolution of these life-history traits has occurred many times in Chinook Salmon and that the direction of evolution has generally been from the more generalized fall-run type to the more specialized spring-run type. This is also supported by data that suggests that the relatedness of fall-run and spring-run Chinook Salmon within a geographical region are more similar to each other than to individuals of the same ecotype/race in adjacent geographical areas (Waples et al 2004; Kinziger et al. 2013). However, recent genetic research has allowed for new insights into the origin of migration behavior in Chinook Salmon (Prince et al. 2017). The authors of this research propose a single, highly conserved allele (GREB1L) responsible for premature (spring-run) migration in Chinook Salmon, suggesting that mutational events creating new premature migration alleles are exceptionally rare and existing populations are necessary for the spread and maintenance of these alleles (Prince et al. 2017). Further research again found a strong association between migration phenotype and this single locus, while also determining that both fall-run and spring-run Chinook Salmon historically existed in the Williamson-Sprague River system using archeological samples found at tribal fishing sites (Thompson et al. 2019).

Other research has demonstrated that at a genome-level, multiple major effect genes on a single chromosome beyond the single GREB1L gene play a role in the variation of migration phenotypes in Chinook Salmon (Narum et al. 2018). In the Klamath River Basin, the genotypes associated with this region are in near equilibrium where homozygous individuals for the spring-run ecotype are still present (Trinity River Basin and Salmon River Basin) (Carlos Garza, NMFS, Personal Communication; Unpublished Data). Chinook Salmon that enter the Klamath River estuary in the spring (spring-run) express a homozygous genotype at the region of strong association for spring run timing, while individuals that enter in the late-summer through fall (fall-run) express a homozygous genotype at the region of strong association for fall run timing, and individuals that are heterozygous express an intermediate timing of entry into the estuary (summer-run) (Carlos Garza, NMFS, Personal Communication; Unpublished Data). Future genetic research on Chinook Salmon will likely reveal other, new factors to consider in regard to reintroduction decisions. The best available science will be used to make informed decisions about reintroduction efforts.

Due to current population status and distributions that vary among fall-run and spring-run Chinook Salmon in the watershed below Iron Gate Dam, approaches to reintroducing fall-run and spring-run Chinook Salmon to the Upper Klamath Basin will be distinct.

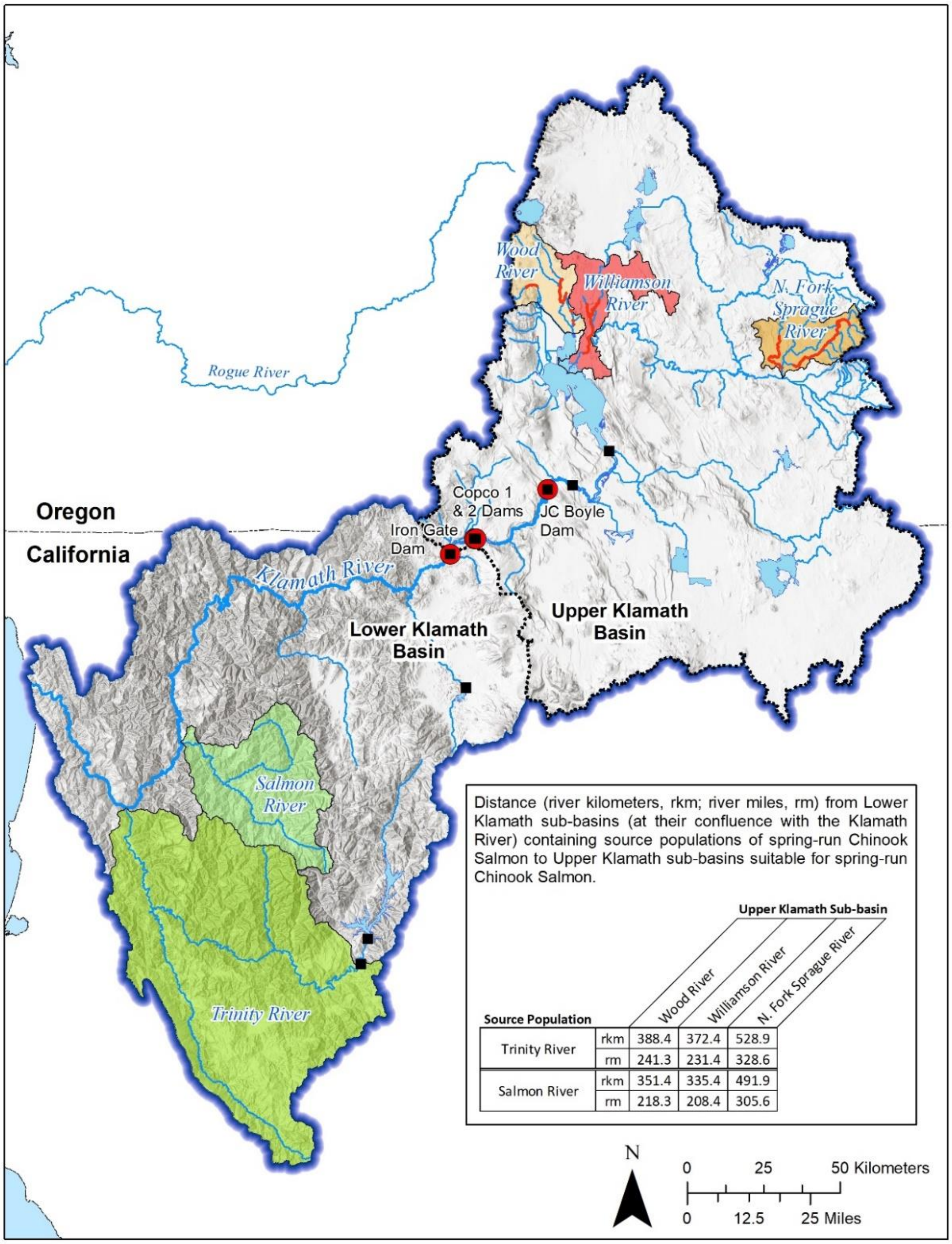
Fall-run Chinook Salmon

Due to the presence and relatively high abundance of fall-run Chinook Salmon immediately below Iron Gate Dam, this reintroduction plan proposes implementing a conservative approach to reintroducing fall-run Chinook Salmon, which relies upon volitional repopulation. We hypothesize that individual fall-run Chinook Salmon will stray into the Upper Klamath Basin from relatively abundant downstream sources once passage is available. The reintroduction approach for fall-run Chinook Salmon will be focused on efforts to monitor Upper Klamath Basin habitat to estimate fall-run Chinook salmon escapement immediately following the restoration of fish passage.

Following the availability of fish passage into the Oregon portion of the Upper Klamath Basin, volitional repopulation of fall-run Chinook Salmon will be monitored and evaluated for twelve years. After this period, an assessment will be made to determine if, when, and where active reintroduction of fall-run Chinook Salmon will occur. These criteria, allow three generations the opportunity to repopulate, and are based on age-specific escapement estimates of fall-run Chinook Salmon. The results of these estimates depict the age of the majority of returning individuals to the Klamath River to be age three or four (KRTT 2017). However, recent surveys (2013-2015) conducted in the reach between the confluence of the Shasta River and Iron Gate Dam (21.7 km; 13.5 miles) found the majority of individuals to be age four (Gough and Som 2017).

Spring-run Chinook Salmon

Volitional repopulation of spring-run Chinook Salmon into the Upper Klamath Basin would almost certainly be limited to individuals straying from the Salmon River sub-basin (confluence with Klamath River at rkm 107; rm 66.5) and/or Trinity River sub-basin (confluence with Klamath River at rkm 70; rm 43.5). The distance individuals would need to stray into newly available habitat from these source populations is substantial. Spring-run Chinook Salmon habitat (summer holding and spawning) in the Upper Klamath Basin is not located immediately above the dams as it is for the other anadromous fishes. Instead, individuals from the Trinity River sub-basin would have to stray 372.4 rkm to 528.9 rkm (231.4 miles to 328.6 miles; includes at least 28 kilometers/17.4 miles of lake habitat) depending on the receiving upper sub-basin, and individuals from the Salmon River sub-basin would have to stray 335.4 rkm to 491.9 rkm (208.4 miles to 305.6 miles) (Figure 2-3).



Distance (river kilometers, rkm; river miles, rm) from Lower Klamath sub-basins (at their confluence with the Klamath River) containing source populations of spring-run Chinook Salmon to Upper Klamath sub-basins suitable for spring-run Chinook Salmon.

Source Population		Upper Klamath Sub-basin		
		Wood River	Williamson River	N. Fork Sprague River
Trinity River	rkm	388.4	372.4	528.9
	rm	241.3	231.4	328.6
Salmon River	rkm	351.4	335.4	491.9
	rm	218.3	208.4	305.6

Figure 2-3. Selected hydrography and sub-basins of the Klamath River Basin associated with the current distribution of spring-run Chinook Salmon (Salmon River and Trinity River) below the four Klamath hydroelectric dams planned for removal (highlighted in red), and sub-basins in the Upper Klamath Basin (UKB) that have suitable spring-run Chinook habitat (summer holding, and spawning habitat). Streams in the UKB with spring-run Chinook Salmon spawning habitat within suitable sub-basins are highlighted in red. Distances (river kilometer and river mile) between sub-basins that contain potential source populations (below the dams) and sub-basins that have the potential for repopulation (above the dams) are shown.

The extensive distance separating the natal streams of these source populations (200 river miles to over 300 miles, depending on location) from estimated spring-run Chinook Salmon habitat in tributaries to Upper Klamath Lake is a limiting factor for volitional repopulation. Additionally, the source populations of these potential strays are already low (particularly in the Salmon River sub-basin), therefore it seems unlikely that spring-run Chinook

Salmon will re-establish in the foreseeable future without any assistance. This was also the conclusion of the *Klamath River Expert Panel for the Scientific Assessment of Two Dam Removal Alternatives on Chinook Salmon* (Goodman et al. 2011). Therefore, active reintroduction of spring-run Chinook Salmon to the Upper Klamath Basin is likely to be the most successful approach to establishing a new, self-sustaining population(s).

The active reintroduction effort for spring-run Chinook Salmon will have two phases. The Reintroduction Studies Phase (Phase 1) will be initiated in tributaries of Upper Klamath Lake. The intention of Phase 1 is to use an adaptive management strategy where hypotheses will be developed, active reintroduction strategies will be implemented to test hypotheses, and results of strategies will be assessed through monitoring efforts. Studies will involve the release of tagged juveniles to monitor their migration behavior and survival post release. Active reintroduction strategies will be re-evaluated and updated, if necessary, thus, creating an active adaptive management cycle aimed at providing information on the most appropriate reintroduction strategy (McCarthy et al. 2012). Phase 2 (Repopulation Phase) will build on the results of Phase 1 to use the most effective methods, extent, and intensity of transplantation required to repopulate habitat above Upper Klamath Lake. Reintroduction studies may begin prior to the availability of fish passage through the KHP.

This approach follows the direction of ODFW’s *Chinook Salmon in the Oregon Portion of the Klamath River and Tributaries Policies* (OAR 635-500-3890 and OAR 635-500-3895). Chinook Salmon in the Oregon portion of the Upper Klamath Basin will be managed for natural production consistent with ODFW’s *Native Fish Conservation Policy* (OAR 635-007-0503). Hatchery production and supplementation efforts associated with reintroduction of spring-run Chinook Salmon into the Upper Klamath Basin will be developed consistent with ODFW’s *Fish Hatchery Management Policy and Guidelines* (OAR 635-007-0542).

3. A STRATEGY FOR MONITORING AND EVALUATING REPOPULATION OF ANADROMOUS FISHES INTO THE OREGON PORTION OF THE UPPER KLAMATH BASIN

3.1 Introduction

3.1.1 Purpose of Monitoring and Evaluation Section

The purpose of this section is to provide guidelines, recommendations, and strategies for monitoring and evaluating the repopulation, redistribution, reproduction, abundance, and life histories of anadromous fishes in the Upper Klamath Basin following the availability of fish passage through the Klamath River following the removal of Iron Gate, Copco 1 & 2, and J.C. Boyle Dams. These guidelines and recommendations are intended for monitoring volitional repopulation of fall-run Chinook Salmon, Coho Salmon, steelhead trout, and Pacific Lamprey. Monitoring the outmigration of released juvenile spring-run Chinook Salmon as part of the active reintroduction approach for spring-run Chinook Salmon is described separately in the subsequent section (*A strategy for actively reintroducing spring-run Chinook Salmon into the Upper Klamath Basin*). However, monitoring returning adult spring-run Chinook Salmon that are a product of active reintroduction efforts and their naturally produced offspring should follow the guidelines and recommendations of this section (Figure 3-1).

The objectives of this section are to: 1) identify constraints to monitoring and the key questions monitoring should address, 2) identify monitoring facilities and activities required to address the questions, and 3) provide recommended monitoring and evaluation parameters, as well as the tools to measure them, to determine if populations are becoming self-sustaining. Unique monitoring activities are described for steelhead trout and Pacific Lamprey, which have resident conspecifics (*O. mykiss*), or closely related resident species (*Entosphenus* sp.) residing above the dams.

3.1.2 Setting Description and Monitoring Constraints

The Upper Klamath Basin is defined as the Klamath River Watershed above Iron Gate Dam (current upper extent of anadromy in the Klamath Basin) at Klamath River kilometer (rkm) 312 (rm 194) and encompasses 20,859 km^2 (8,053 square miles) (13,343 km^2; 5,151 square miles when excluding the Lost River sub-basin). From the site of Iron Gate Dam to Keno Dam (rkm 380.5; rm 236.4) there is approximately 68.5 rkm (42.5 miles) of mainstem Klamath River habitat (includes potential habitat under KHP reservoirs). This reach of the Klamath River cuts through the Cascade Range creating the Klamath River Canyon. Historically, Chinook Salmon were known to spawn in suitable habitat in this reach of the mainstem Klamath River and its multiple tributaries (Hamilton et al. 2016). Spencer Creek, a tributary to the Klamath River in Oregon (9.5 rkm; 5.9 rm below Keno Dam), is estimated to contain 23.6 km (14.6 miles) of habitat suitable for anadromous fishes (Huntington et al. 2006).

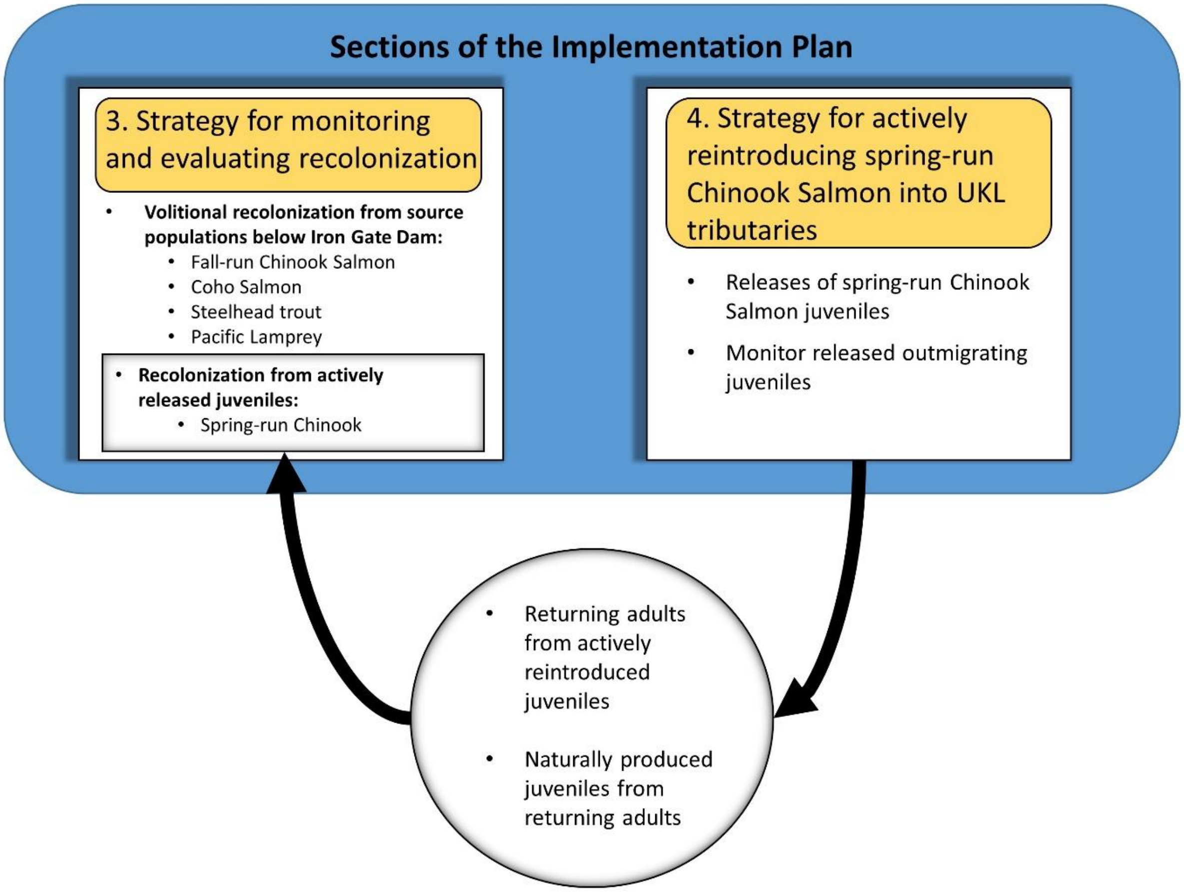


Figure 3-1. Flow diagram depicting returning spring-run Chinook Salmon that are a product of active reintroduction efforts (described in the Strategy for actively reintroducing spring-run Chinook Salmon into Upper Klamath Lake tributaries) and their naturally produced juveniles will be monitored following the guidelines and recommendations provided in the Strategy for monitoring and evaluating repopulation (this section). The guidelines and recommendations for monitoring released juvenile spring-run Chinook Salmon are provided in the Strategy for actively reintroducing spring-run Chinook Salmon into Upper Klamath Lake tributaries section.

Keno Impoundment and Lake Ewauna are waterbodies along the Klamath River above Keno Dam that currently experience periods of seasonal water quality conditions unsuitable for salmonids. Between Upper Klamath Lake and Lake Ewauna, the Link River flows from Link River Dam downstream for two rkm (1.2 rm) (Figure 3-2).

Although not as severe as Keno Impoundment/Lake Ewauna, Upper Klamath Lake is a hypereutrophic lake that also experiences seasonal water quality conditions that can be seasonally unsuitable for salmonids. However, multiple locations (e.g., Pelican Bay, Wood River Delta, and Williamson River Delta) on the periphery of Upper Klamath Lake serve as seasonal water quality refuges for salmonids and other fishes (Banish et al. 2009; Tinniswood et al. 2010).

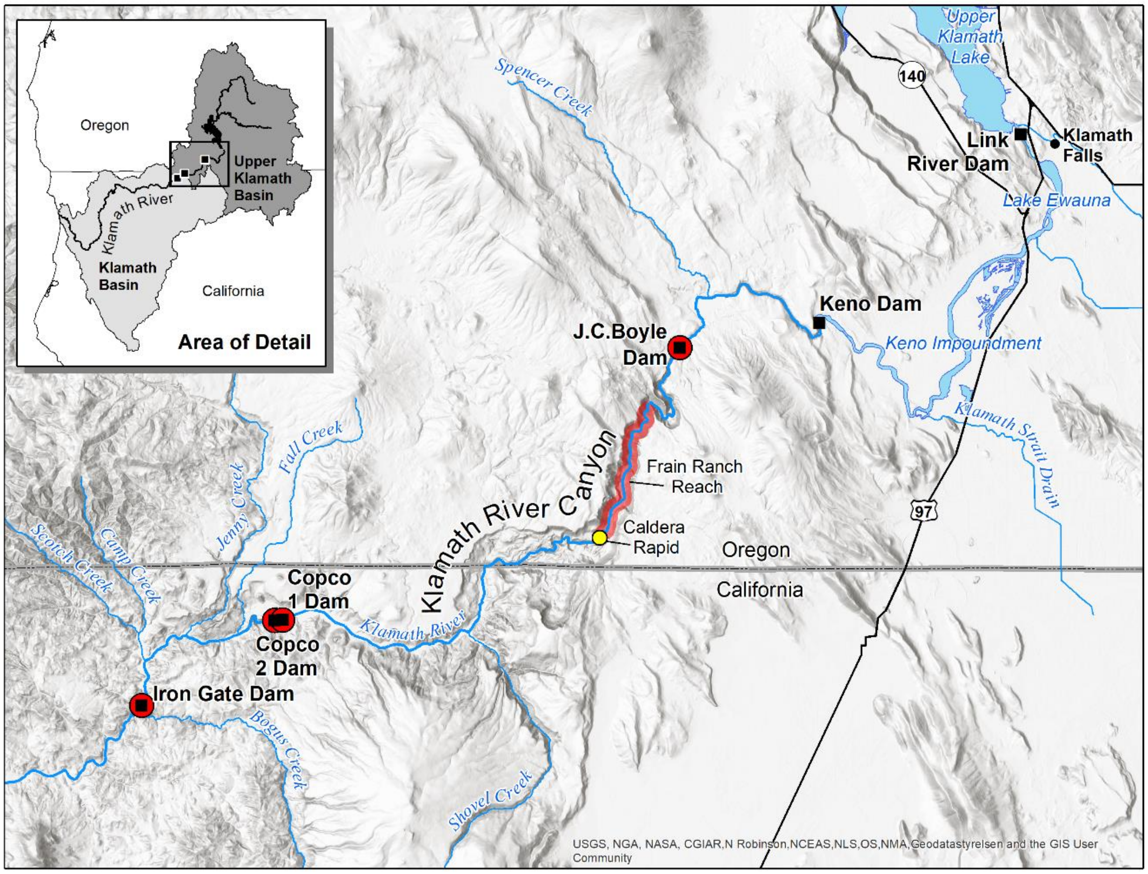


Figure 3-2. The Klamath River and tributaries upstream of Iron Gate Dam (current upstream extent of anadromy). Between Iron Gate Dam and J.C. Boyle Dam the Klamath River cuts through the Cascade Range creating the Klamath River Canyon. The Frain Ranch Reach, above Caldera Rapid is a relatively low-gradient reach that contains spawning habitat suitable for salmon. Dams highlighted in red will be removed in 2023.

Two main tributaries, the Williamson and Wood Rivers enter Upper Klamath Lake 28 km (17.4 miles) and 43 km (26.7 miles), respectively, from the outlet of the lake. The Wood River sub-basin is a groundwater-dominated system with an estimated total of 77 km (47.8 miles) of existing anadromous fish habitat. The Williamson River sub-basin (not including the Sprague River) is a groundwater-dominated system with an estimated 40.8 km (25.4 miles) of available habitat. The Sprague River sub-basin is a large tributary to the Williamson River that is fed by both groundwater and snow-melt sources, and has an estimated 425.9 km (264.7 miles) of available habitat suitable for use by anadromous fishes (Figure 3-3; Table 3-1).

The size, habitat complexity, land ownership, physical properties (particularly access to streams, visibility in water column, and high flows) pose substantial challenges, if not constraints, in respect to monitoring the re-establishment of anadromous fish populations. Visibility, or lack thereof, will be a major constraint on the effective use of standard visual surveys (e.g., spawner

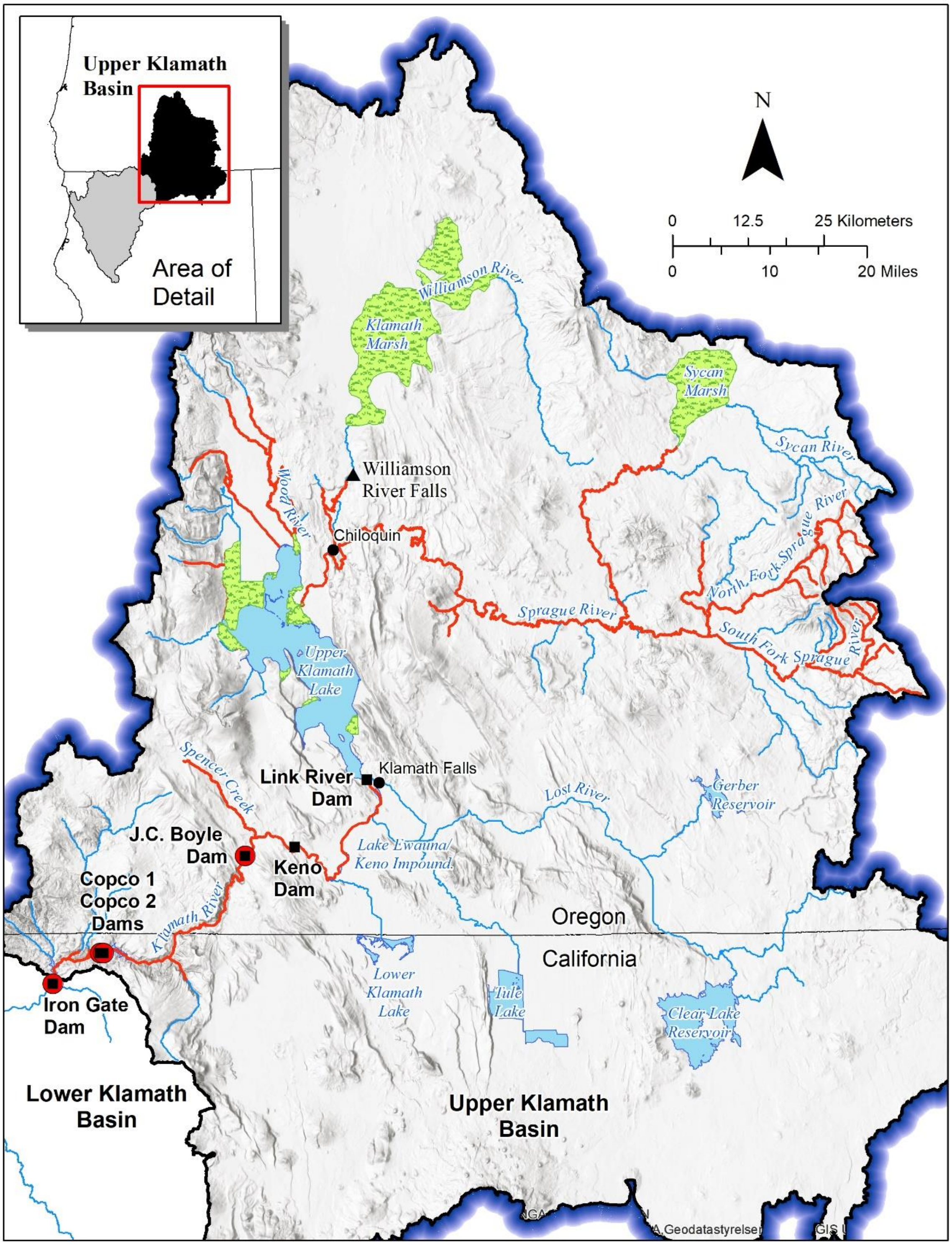


Figure 3-3. Estimated existing habitat (in red) that has the potential for current usage by anadromous fishes in the Upper Klamath Basin following the removal of Iron Gate, Copco 1, Copco 2, and J.C. Boyle Dams (highlighted with red circles). Adapted from Huntington et al. (2006).

Table 3-1. Estimates of the quantity of existing habitat suitable for current usage by anadromous fishes above Iron Gate Dam (Upper Klamath Basin; UKB). Adapted from Huntington et al. (2006) and modified using the National Hydrography Dataset (NHD). Mainstem streams are designated in bold lettering, and their tributaries are designated by italicized lettering. Stream habitat in the Klamath River above the present site of Iron Gate Dam was estimated absent the four hydroelectric dams. Rehabilitating streams in the Upper Klamath Basin to allow for passage and/or improving habitat has the potential to increase available suitable habitat by as much 100 km (see Huntington et al 2006 for specific streams).

Sub-basin	Stream	Estimates of potential existing habitat in km (miles)
Upper Klamath River	**Klamath River (without dams)**	102.1 (63.5)
	Spencer Creek	20.8 (12.9)
	Shovel Creek (California)	5.3(3.3)
	Fall Creek (California)	1.4 (0.9)
	Jenny Creek (California)	1.8 (1.1)
	Others (Oregon and California)	21.1 (13.1)
	TOTAL	**152.5 (94.8)**
Wood River and Westside tributaries to UKL	**Wood River**	35.1 (21.8)
	Sun Creek	8.0 (5.0)
	Annie Creek	15.0 (9.3)
	Fort Creek	5.8 (3.6)
	Crooked Creek	12.2 (7.6)
	Agency Creek	0.9 (0.6)
	Sevenmile Creek	33.3 (20.7)
	Short Creek	2.2 (1.4)
	Recreation/Crystal Creek	19.3 (12.0)
	TOTAL	**131.8 (81.9)**
Williamson River (excluding Sprague River system)	**Williamson River**	34.9 (21.7)
	Larkin Creek	1.1 (0.7)
	Sunnybrook Creek	0.9 (0.6)
	Spring Creek	3.9 (2.4)
	TOTAL	**40.8 (25.4)**
Sprague River	**Sprague River**	140.2 (87.1)
	N. Fork Sprague River	58.7 (36.5)
	Dead Cow Creek	6.9 (4.3)
	School Creek	6.1 (3.8)
	Cold Creek	3.3 (2.1)
	Gearhart Creek	4.8 (3.0)
	Boulder Creek	4.8 (3.0)
	Sheepy Creek	1.8 (1.1)
	Fivemile Creek	22.4 (13.9)
	S. Fork Sprague River	54.7 (34.0)
	Corral Creek	2.5 (1.6)
	Camp Creek	2.9 (1.8)
	Buckboard Creek	6.6 (4.1)
	Whitworth Creek	17.4 (10.8)
	Brownsworth Creek	20.8 (12.9)
	Sycan River (below marsh)	60.7 (37.7)
	Trout Creek	11.3 (7.0)
	TOTAL	**425.9 (264.7)**
All streams in UKB		**751.0 (466.7)**

surveys, redd surveys, snorkel surveys) in the mainstem Klamath River from Iron Gate Dam to Keno Dam (Figure 3-4). The high turbidity present in the river year-round is due to inputs from the shallow, turbid Upper Klamath Lake. Therefore, visual survey techniques alone will not be wholly effective for detecting salmon, steelhead, and lamprey in this reach. Another constraint in this reach will be safely navigating the river. The Klamath River cuts through the Cascade Range in this reach and creates a high-gradient, swift current with many large boulders and the associated rapids that are rated higher than the class IV range (Quinn and Quinn 1983; Figure 3-5).

Due to the topography of the Klamath River Canyon (from Keno Dam to the Stateline), no major roads parallel this reach. There are some minimally maintained gravel and dirt roads paralleling portions of the river canyon from below J.C. Boyle Dam downstream to Iron Gate Dam, however river access from these roads is limited due to the steepness of the canyon. Because of these and other topographic factors along with the remoteness of this reach, monitoring may prove to be challenging and the use of passive sampling tools, such as sonar at a fixed location or environmental DNA (eDNA) at multiple locations may be useful.

A major consideration to monitoring anadromous fishes in tributaries above Upper Klamath Lake involves access to streams. Over 60% of the potential anadromous fish habitat is located on private lands, with over 82% of mainstem habitat on the Wood, Williamson, and Sprague Rivers being in private ownership. An active landowner outreach effort towards gaining cooperation and access to key monitoring locations will be important, while otherwise working to identify key sites for locating Passive Integrated Transponder (PIT) tag arrays, telemetry arrays, and juvenile screw traps that provide the opportunity to collect necessary data when private ownership does not avail itself. Multiple species and life histories will have access to habitat above the dams, and because of this, the estimated potential life-stage periodicity for anadromous fishes in the Upper Klamath Basin will likely consist of multiple adult migrations throughout the year. This variation in adult migration timing among species and life histories coupled with the diversity of habitat in the upper basin will likely result in juvenile rearing and/or migration every month of the year (Table 3-2). Because of this, multiple tools will be needed to collect appropriate data.

Figure 3-4. Klamath River above the Caldera Rapid at rkm 350 (rm 217.5). Photo depicts the turbid characteristics of the Upper Klamath River between Keno Dam and Iron Gate Dam.

Figure 3-5. The Klamath River at rkm 348 (rm 216). Between Iron Gate Dam and Keno Dam the Klamath River cuts through the Cascade Range creating the Klamath River Canyon. High gradients and large boulders create numerous Class IV and higher rated rapids in this reach. The topography of this reach makes access to the river difficult.

Table 3-2. Estimated potential life-stage periodicity chart for anadromous fishes in the Upper Klamath Basin*.

Life stage/activity/species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Upstream adult migration/holding												
Steelhead trout	■	■	■	■	■	■	■	■	■	■	■	■
spring-run Chinook Salmon			■	■	■	■	■	■	■	■		
fall-run Chinook Salmon									■	■	■	◧
Coho Salmon									◨	■	■	■
Pacific Lamprey	■	■	■	■	■	■	■	■	■	■	■	■
Adult spawning												
Steelhead trout[1]		■	■	■	■	◧						
spring-run Chinook Salmon									■	■		
fall-run Chinook Salmon									◨	■	■	◧
Coho Salmon										◨	■	■
Pacific Lamprey					■	■	■					
Egg incubation through fry emergence												
steelhead trout		■	■	■	■	■						
spring-run Chinook Salmon	■	■	■	■	■				■	■	■	■
fall-run Chinook Salmon	■	■	■	■					◨	■	■	■
Coho Salmon	■	■	■	■	◧					◨	■	■
Pacific Lamprey					■	■	■	■				
Juvenile rearing and emigration[2]												
steelhead trout	■	■	■	■	■	■	■	■	■	■	■	■
spring-run Chinook Salmon	■	■	■	■	■	■	■	■	■	■	■	■
fall-run Chinook Salmon	■	■	■	■	■	■	■	■	■	■	■	■
Coho Salmon	■	■	■	■	■	■	■	■	■	■	■	■
Pacific Lamprey	■	■	■	■	■	■	■	■	■	■	■	■

* This chart is estimated based on available sources that document the life-stage periodicities of nearby anadromous fish populations, and therefore is subject to change. Sources: Shaw et al. (1997); USFWS (1997); Close et al. (2002); Close et al. (2010); ODFW (2018).

[1] No data in mainstem Klamath River, data comes from tributaries.

[2] Includes yearlings.

3.2 Monitoring Strategy

3.2.1 Phased Strategy for Monitoring Based on Fundamental Questions

Due to uncertainties regarding natural repopulation of anadromous fishes into the Upper Klamath Basin, this monitoring strategy is based on fundamental questions and associated hypotheses. Questions will be prioritized based on the immediacy and/or management action. For example, immediately following the availability of passage, monitoring will focus on determining if anadromous fishes are migrating into habitat immediately above the dams. As fish populations become more widely established, monitoring should be more specific and focused on management objectives, such as determining the productivity and emigration timing of juveniles from each sub-basin.

This plan recognizes that re-establishment by anadromous fishes into suitable habitat may not be immediate, and therefore monitoring questions and the associated tools will be implemented in phases. To this end, the strategy for monitoring will be guided by questions that are specific for each phase of the process (Table 3-3). Phases of monitoring efforts are based on the idealized growth of a reintroduced population (population growth) where initially, the reintroduced population undergoes an establishment phase, followed by a growth phase, and ultimately leading to regulation phase (IUCN 2013; Seddon and Armstrong 2016; Figure 3-6).

This plan provides first and foremost for a volitional repopulation approach for fall-run Chinook Salmon, Coho Salmon, steelhead trout, and Pacific Lamprey. Therefore, the curve depicting the idealized growth of a reintroduced population (Seddon and Armstrong 2016) is modified to include an initial repopulation phase, where individuals from existing source populations stray into reopened habitats above the former dams, which is then followed by an establishment phase (Figure 3-6).

3.2.2 Initiation, Focus, and Priority of Monitoring Efforts

Immediately following the availability of passage above the former dams, monitoring activities will commence in the watershed from the Iron Gate Dam site to Keno Dam. Detection of migrating adults at Keno Dam and/or Link River Dam Fish Ladder will trigger the initiation of monitoring activities in Upper Klamath Lake and its tributaries. Ideally, a proportion, if not all, adults encountered at Keno Dam and/or Link River Dam fish ladders will be sampled and tagged with telemetry and/or PIT tags. Tagging adults and subsequently detecting them in tributaries above Upper Klamath Lake will allow for more precise monitoring efforts targeted within specific tributaries. Sampling adult fish and tagging them at Keno Dam and/or Link River Dam will be an integral component to the monitoring strategy due to large amount of habitat above Keno Dam (575.5 km; 357.5 miles of stream habitat; 293.0 km^2; 113 sq. miles of lake habitat). The spatiotemporal strategy for initiating monitoring activities, associated objectives, and potential tools are depicted in Figure 3-7.

Table 3-3. The strategy for monitoring anadromous fishes in the Upper Klamath Basin following the availability of passage above Iron Gate Dam, Copco 1 and 2 Dams, and J.C. Boyle Dam will be based on fundamental questions that will be addressed in phases as individuals begin to stray above the former barriers.

PHASE	MONITORING QUESTIONS
INITIAL REPOPULATION	Are adult anadromous fishes migrating upstream past the former dam sites, and if so, what is their abundance and species composition?
	If anadromous fishes are migrating past the former dam sites, where are they spawning (distribution)?
	Are adult anadromous fishes migrating above Keno Dam and Link River Dam?
	Are adult anadromous fishes migrating into tributaries above Upper Klamath Lake?
	Are juvenile anadromous fishes successfully emigrating out of the Upper Klamath Basin?
	Are anadromous life histories being expressed by *O. mykiss* (steelhead trout) above the former dam sites?
ESTABLISHMENT	What is the abundance and species composition of adult anadromous fishes within each sub-basin of the Upper Klamath Basin (UKB)?
	What is the productivity, emigration timing, and health of juvenile fishes from each Upper Klamath Basin sub-basin?
	What are the temporal characteristics of adults migrating up to the UKB?
	What is the source population of anadromous fishes?
POPULATION GROWTH	What life histories are expressed by anadromous fishes?
	What is the genetic diversity and characterization of anadromous fishes? How does genetic diversity of Pacific Lamprey and steelhead trout compare to the resident populations?
	What is the spatial distribution of anadromous fishes in the Upper Klamath Basin?

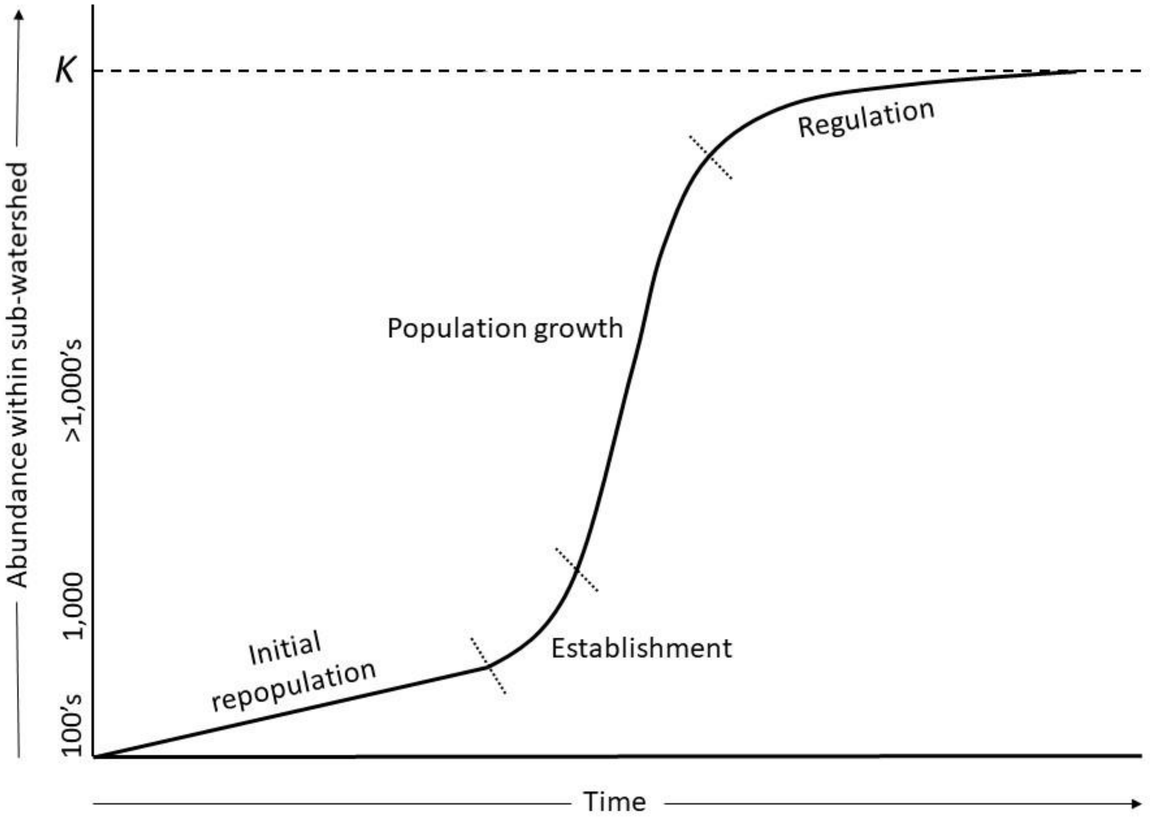
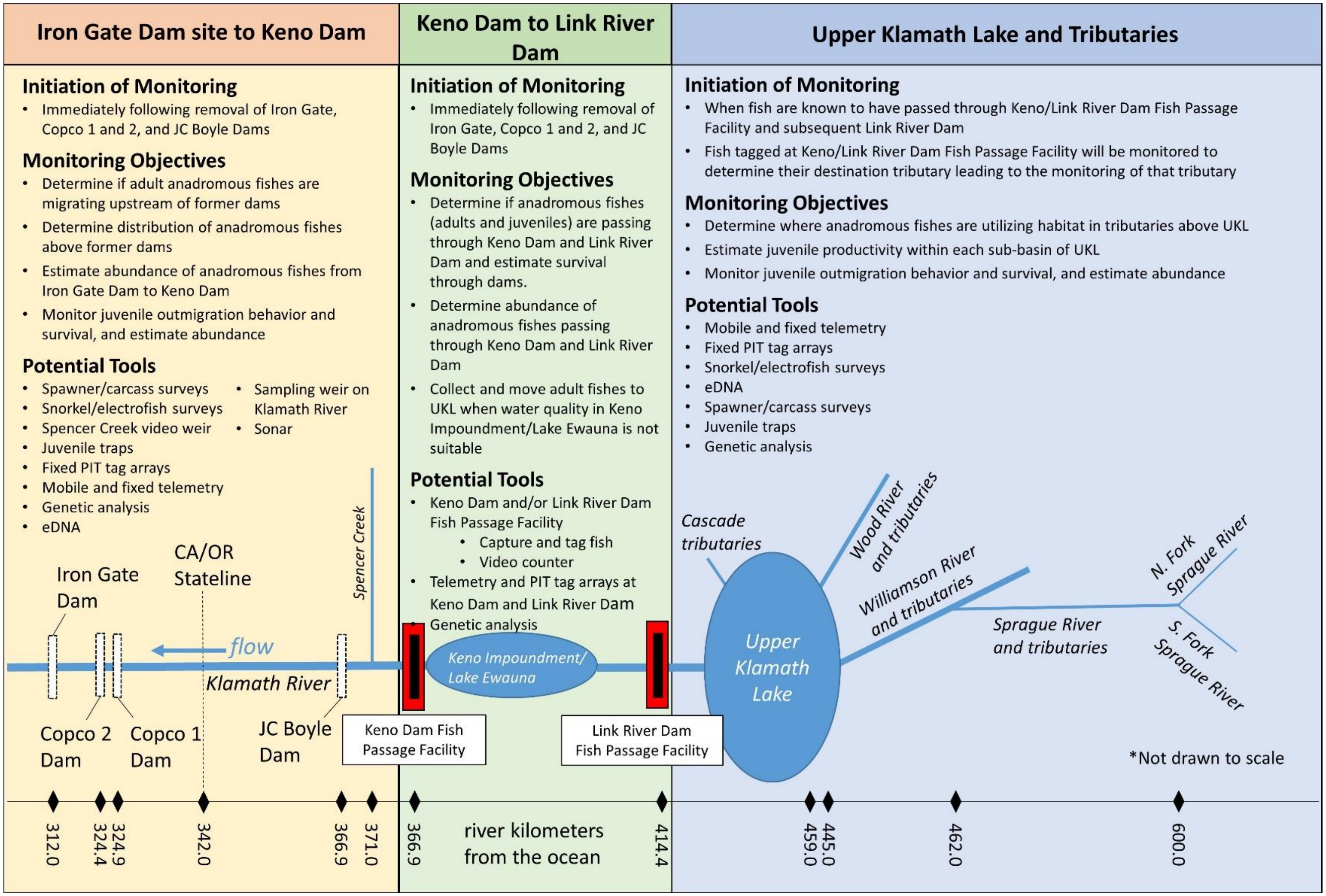


Figure 3-6. Population growth curve and associated phases depicting the idealized population growth rate of new population(s) of fishes above the dams (Iron Gate, Copco 1 & 2, J.C. Boyle Dams) to be removed on the Klamath River, Oregon and California. Initially individuals begin repopulating newly available habitat above the dams by straying from source populations below the dams (Initial repopulation phase). Populations begin to become established as more individuals stray from source populations (Establishment phase). If a population establishes, it begins to grow, facilitated by there being more breeders and little constraint from resource availability (Population growth phase). As the population approaches K, the carrying capacity of the habitat, it transitions into the Regulation phase, and approaches the goal of viable, self-sustaining populations. Adapted from Seddon and Armstrong (2016).

3.2.2.1 Iron Gate Dam to Keno Dam

Following the availability of fish passage through the KHP to the Upper Klamath Basin (as early as fall of 2023; KRRC 2019), monitoring efforts will be focused in the watershed extending from the former dam sites up to Keno Dam. This consists of an estimated 104 km (65 miles) of free-flowing anadromous fish habitat (of which 59 km or 37 miles is in Oregon). Due to the location (immediately upstream of the dams) and the amount of available habitat, we hypothesize that this area will be repopulated by fall-run Chinook Salmon, Coho Salmon, steelhead trout, and Pacific Lamprey before any other area within the Upper Klamath Basin.



Iron Gate Dam site to Keno Dam

Initiation of Monitoring

- Immediately following removal of Iron Gate, Copco 1 and 2, and JC Boyle Dams

Monitoring Objectives

- Determine if adult anadromous fishes are migrating upstream of former dams
- Determine distribution of anadromous fishes above former dams
- Estimate abundance of anadromous fishes from Iron Gate Dam to Keno Dam
- Monitor juvenile outmigration behavior and survival, and estimate abundance

Potential Tools

- Spawner/carcass surveys
- Snorkel/electrofish surveys
- Spencer Creek video weir
- Juvenile traps
- Fixed PIT tag arrays
- Mobile and fixed telemetry
- Genetic analysis
- eDNA
- Sampling weir on Klamath River
- Sonar

Keno Dam to Link River Dam

Initiation of Monitoring

- Immediately following removal of Iron Gate, Copco 1 and 2, and JC Boyle Dams

Monitoring Objectives

- Determine if anadromous fishes (adults and juveniles) are passing through Keno Dam and Link River Dam and estimate survival through dams.
- Determine abundance of anadromous fishes passing through Keno Dam and Link River Dam
- Collect and move adult fishes to UKL when water quality in Keno Impoundment/Lake Ewauna is not suitable

Potential Tools

- Keno Dam and/or Link River Dam Fish Passage Facility
    - Capture and tag fish
    - Video counter
- Telemetry and PIT tag arrays at Keno Dam and Link River Dam
- Genetic analysis

Upper Klamath Lake and Tributaries

Initiation of Monitoring

- When fish are known to have passed through Keno/Link River Dam Fish Passage Facility and subsequent Link River Dam
- Fish tagged at Keno/Link River Dam Fish Passage Facility will be monitored to determine their destination tributary leading to the monitoring of that tributary

Monitoring Objectives

- Determine where anadromous fishes are utilizing habitat in tributaries above UKL
- Estimate juvenile productivity within each sub-basin of UKL
- Monitor juvenile outmigration behavior and survival, and estimate abundance

Potential Tools

- Mobile and fixed telemetry
- Fixed PIT tag arrays
- Snorkel/electrofish surveys
- eDNA
- Spawner/carcass surveys
- Juvenile traps
- Genetic analysis

Figure 3-7. Spatiotemporal strategy for initiating monitoring activities in three sections of the Upper Klamath Basin. Monitoring objectives and potential tools to be used to monitor the repopulation of anadromous fishes following the removal of Iron Gate, Copco1, Copco 2, and J.C. Boyle Dams. River kilometers from the ocean of key locations are given on the bottom of figure. Figure is not drawn to scale.

The focus of this document is the Oregon portion of the Klamath River Basin. However, because the Iron Gate to Keno Dam section is bisected by the Oregon/California Stateline (rkm 342.0; 212.5 rm), coordination between the two states in regard to monitoring will be imperative. One goal of the monitoring strategy in the Iron Gate Dam to Keno Dam section will be to replicate and compliment the monitoring program that currently occurs below Iron Gate Dam (see Knechtle and Chesney 2016; Gough and Som 2015).

Immediately following dam removal, monitoring efforts will focus on answering the first three questions of the Initial Repopulation phase in Table 3-3. Additionally, monitoring will be complementary to the *Klamath River Cooperative Spawner Survey* (annual survey of fall-run Chinook Salmon in the California portion of the Klamath Basin below Iron Gate Dam, described in more detail below in 3.2.4), with the goal of contributing to the estimate of age-specific escapement of fall-run Chinook Salmon in the Klamath Basin. The strategy and the tools used to monitor repopulation will require a high level of adaptability. Initially, the monitoring facilities (description of facilities/activities are given in 3.3.1) will involve lifecycle monitoring on Spencer Creek, which will include a video weir, downstream juvenile trap, and PIT tag arrays. If deemed scientifically valuable, a sonar system could be utilized on the Klamath River at a suitable location(s) above the former Iron Gate Dam site to aid in the detection of salmon and subsequent estimation of escapement.

A sampling weir on the mainstem Klamath River for the purpose of aiding escapement estimates and sampling adult fish (for the purpose of tagging and collecting biological data) could be a useful tool. The location and purpose of such a weir would have to be agreed upon among by those fish management agencies in both Oregon and California. The ability to sample adult salmon (specifically fall-run Chinook Salmon) as they migrate above the former Iron Gate Dam site and subsequent Copco Dams would allow for the tagging (telemetry and/or PIT tags) of individuals and subsequent detection. This type of monitoring has the potential to allow for the detection of fishes into habitats in the Upper Klamath Basin, estimate abundance of spawners in the Klamath River Canyon, identify where fish are spawning (allowing for more targeted monitoring through on-the-ground spawning/carcass surveys), determine if fish are migrating past Keno and Link River Dams, and if and where they are migrating to tributaries of Upper Klamath Lake. If it is agreed that a weir on the mainstem Klamath River is appropriate, all necessary precautionary measures should be taken to ensure that the weir does not inadvertently impede natural migration into the Upper Klamath Basin.

Recommended precautionary measures for utilizing a weir include

- Any weir should not impede, in any way, the volitional migration of fish to the Upper Klamath Basin, except for the purpose of capturing and subsequent sampling of fish for the purpose of tagging and release.
- All fish species at all lifestages should be able to volitionally pass upstream and downstream of any weir when the intent, at the time, is to not capture fish.
- Any weir that is used should be defined as temporary and easily removed if/when needed.

- Fish captured at any weir should be released as near as feasible to the upstream side of the structure, but also, so as to prevent fall back to the weir or downstream of the weir.
- Location of weir should be in an area that is easily accessible.
- Frequent monitoring below any weir should be conducted to assess any impediment to migration the weir is causing.
- The weir will be removed or modified should it become a site for focused predation.

Monitoring activities should include spawner and carcass surveys on mainstem Klamath River and tributaries, as well as snorkel and electrofishing surveys in tributaries of the Klamath River. River characteristics and access points will allow surveyors to use inflatable rafts to monitor The Keno Reach (class III; 11 km; 6.8 miles) and the Frain Ranch Reach (class II; 9.5 km; 6 miles; put in at Spring Island Boat Ramp and take out above Caldera Rapid) of the mainstem Klamath River (Figure 3-8). Access to other locations along the Klamath River will be restricted to walk in only, or by attempts to navigate class IV+ rapids in the Hells Corner Gorge of the Klamath River below Caldera Rapid (a class IV+ rapid). The monitoring and evaluation program will likely be limited to the amount of funds available. In the case that funds are limited, the priority for monitoring objectives of anadromous fishes from Iron Gate Dam to Keno Dam are summarized in Table 3-4. Potential monitoring facilities and activities in this section are described in Table 3-5 and are spatially depicted in Figure 3-8.

Table 3-4. Priority of monitoring objectives and the targeted species associated with the objectives from Iron Gate Dam site to Keno Dam.

Priority	Monitoring Objective	Species
1	Determine presence and species composition in Klamath River and tributaries	Chinook Salmon Coho Salmon Steelhead Trout Pacific Lamprey
2	Estimate escapement (abundance) of adults in Klamath River and tributaries	Chinook Salmon Coho Salmon
3	Spatial distribution of spawners and juveniles in Klamath River and tributaries	Chinook Salmon Coho Salmon Steelhead Trout Pacific Lamprey
4	Juvenile production and survival in Klamath River and tributaries	Chinook Salmon Coho Salmon
5	Fish health	Chinook Salmon Coho Salmon Steelhead trout Pacific Lamprey

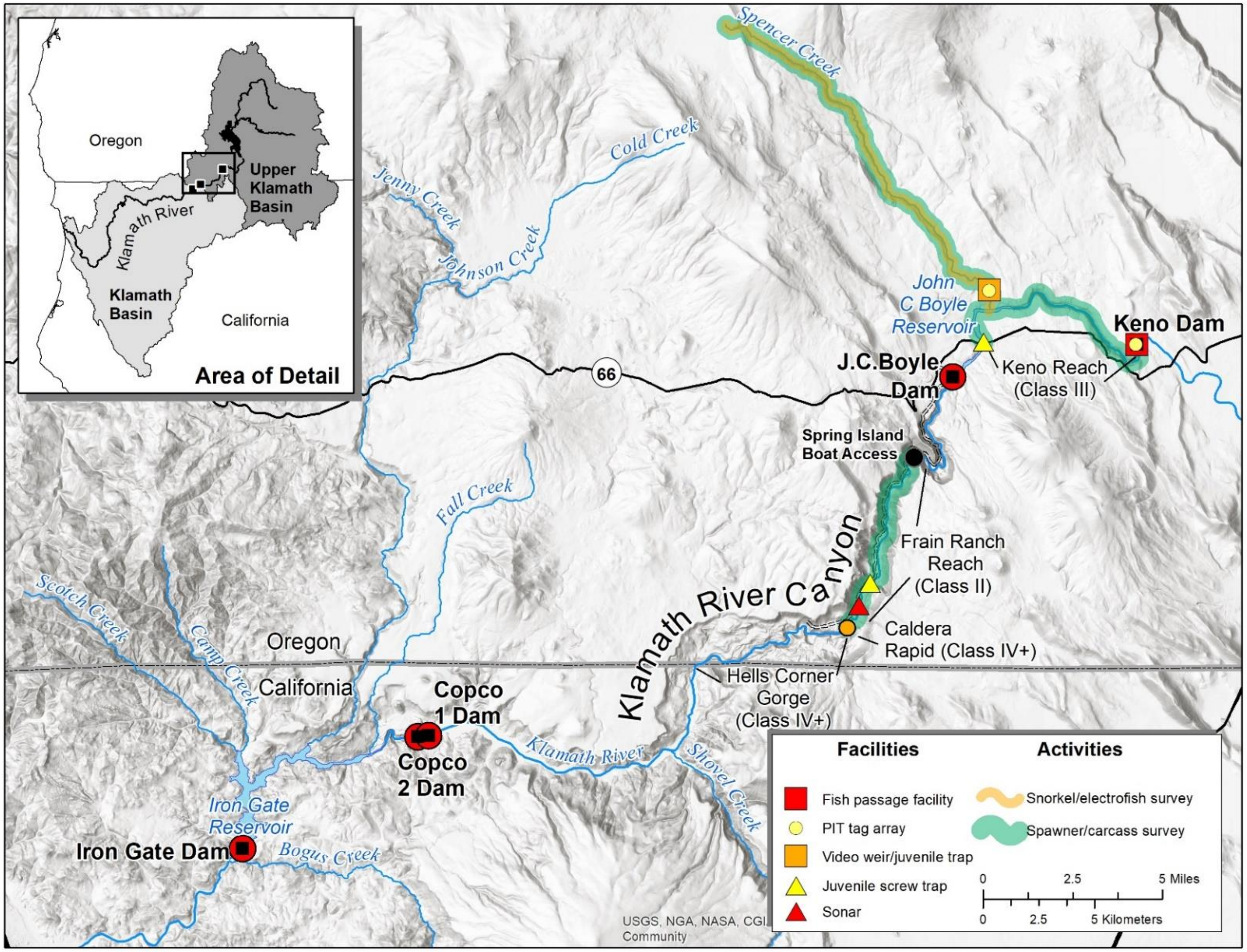


Figure 3-8. Spatial depiction of potential monitoring facilities and activities to monitor repopulation of fall-run Chinook Salmon, Coho Salmon, steelhead trout, and Pacific Lamprey in the Oregon portion of the Iron Gate Dam (site) to Keno Dam section of the Upper Klamath Basin.

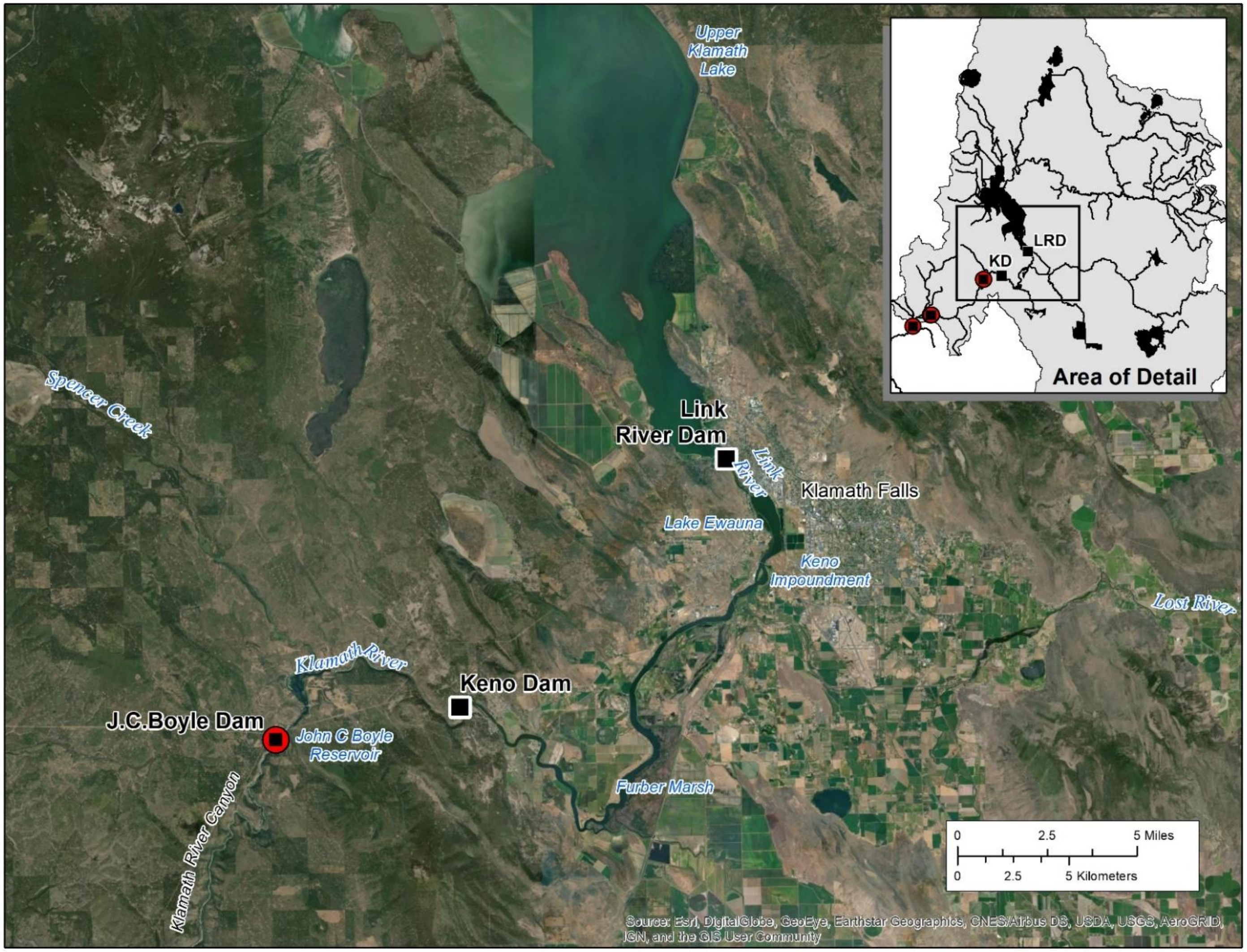
Table 3-5. Description of potential monitoring facilities and activities that could be used to monitor anadromous fishes in the Oregon portion of the Upper Klamath Basin between Iron Gate Dam and Keno Dam following the removal of the Klamath Hydroelectric Project dams (Iron Gate Dam, Copco 1 and 2 Dams, and J.C. Boyle Dam).

Monitoring Facilities	Approximate Location	Objective
Video weir	Lower end of Spencer Creek	Determine presence of adult anadromous fishes in Spencer Creek.
Keno Dam Fish Passage Facility	Keno Dam	Determine Presence and abundance of anadromous fish at and above Keno Dam.
PIT tag array	Keno Dam Fish Passage Facility	Detect PIT tagged juveniles and adults at Keno Dam.
	Lower end of Spencer Creek	Detect PIT tagged juveniles and adults at lower end of Spencer Creek.
Juvenile downstream trap	Lower end of Spencer Creek	Capture/quantify outmigrating juveniles.
Screw trap	Klamath River downstream of Spencer Creek confluence and/or lower end of Frain Ranch Reach	Capture/quantify outmigrating juveniles.
Sampling weir	Above the former Copco Reservoir but downstream of the Shovel Creek confluence	Determine presence of adult salmon above Iron Gate Dam site. Sample fish to tag and subsequently detect. Aid in estimating escapement above Iron Gate Dam site.
Sonar system	Above Iron Gate Dam and below Frain Ranch Reach	Determine presence of adult salmon above Iron Gate Dam site and/or other dam sites. Estimate abundance of adult salmon above dam sites.
Monitoring Activities	**Approximate Location**	**Objective**
Snorkel/electrofishing survey	Spencer Creek (100% census or randomized samples)	Determine presence, estimate abundance, and capture juvenile anadromous fishes.
Spawner/carcass survey (wadeable tributaries)	Spencer Creek (100% census or randomized samples) Other tributaries	Determine presence, estimate abundance, and capture juvenile anadromous fishes. Determine presence, estimate escapement of anadromous fishes. Contribute to *Klamath River Cooperative Spawner Survey*. Collect fish health samples from carcasses to establish baseline pathogen prevalence or causes of pre-spawning mortality. Collect tissues samples for genetic analysis.
Spawner/carcass survey (Mainstem Klamath River)	**Klamath River - Keno Reach** (floatable) **Klamath River - Frain Ranch Reach** (floatable) **Klamath River** - depending on accessibility	Determine presence, estimate escapement of anadromous fishes. Contribute to *Klamath River Cooperative Spawner Survey*. Collect fish health samples from carcasses to establish baseline pathogen prevalence or causes of pre-spawning mortality. Collect tissues samples for genetic analysis.
Environmental DNA (eDNA)	Klamath River and tributaries	Determine presence and distribution

3.2.2.2 Upstream of Keno Dam (Keno Dam to Link River Dam, Upper Klamath Lake and its tributaries)

The majority of available stream habitat in the Upper Klamath Basin is located above Keno Dam (Figure 3-3 and Table 3-1). The main tributaries (Williamson and Wood Rivers) and other smaller tributaries that drain watersheds containing suitable habitat all enter Upper Klamath Lake at unique locations (Figure 3-3). This hydrography, combined with the large size of Upper Klamath Lake (surface area ~133 km^2), leads to difficulties in recommending a strategy for monitoring in this section of the Upper Klamath Basin. Therefore, monitoring this section will require a high level of adaptability that will be informed by opportunities to tag captured adult fish migrating upstream through Keno Dam and or/Link River Dam with telemetry and/or PIT tags.

Monitoring above Keno Dam will be initiated once adult fish are known to have migrated upstream of Keno Dam or Link River Dam (Figure 3-7 and Figure 3-9). Ideally, adult fish will be captured and sampled at a recommended Keno Dam and/or Link River Dam Fish Passage Facility. Captured fish should be tagged with telemetry and/or PIT tags to monitor movements from Keno Dam to Link River Dam and subsequent tributaries of Upper Klamath Lake. We do not anticipate that all fish migrating through Keno Dam or Link River Dam will be sampled and tagged. Therefore, we recommend a fish counting station(s) at Keno Dam and/or Link River Dam to help inform the presence and abundance of anadromous fishes in this section. Any indication of anadromous fishes above Keno Dam from other sources (anglers, landowners, other fish monitoring/research efforts, etc.) will be investigated to determine presence. Monitoring efforts will then be initiated in the stream where fish are known to occur. Monitoring where adult fishes are known to occur in tributaries of UKL will follow a similar strategy as that of the Iron Gate Dam to Keno Dam section. The monitoring and evaluation program will likely be limited to the amount of funds available. In the case that funds are limited, the priority for monitoring objectives above Keno Dam is summarized in Table 3-6. Potential locations of monitoring facilities above Keno Dam are depicted on Figure 3-10.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 3-9. Locations of Keno Dam and Link River Dam downstream of Upper Klamath Lake. The ability to sample and tag (radio and/or PIT) adults at one or both of these locations as they migrate upstream will help focus monitoring efforts on tributaries above Upper Klamath Lake.

Table 3-6. Priority of monitoring objectives and the targeted species associated with the objectives upstream of Keno Dam (Keno Dam to Link River Dam, Upper Klamath Lake and its tributaries).

Priority	Monitoring Objective	Species
1	Determine presence at Keno Dam and Link River Dam and use of fish passage facilities	Chinook Salmon Coho Salmon Steelhead Trout Pacific Lamprey
2	Estimate escapement (abundance) of adults migrating above Keno Dam and Link River Dam	Chinook Salmon Coho Salmon Steelhead Trout Pacific Lamprey
3	Monitor survival of adults migrating from Keno Dam to Link River Dam	Chinook Salmon Steelhead Trout Pacific Lamprey
4	Spatial distribution in sub-basins of Upper Klamath Lake	Chinook Salmon Steelhead Trout Pacific Lamprey
5	Juvenile abundance and survival migrating downstream through Link River Dam and Keno Dam	Chinook Salmon
6	Abundance of fish within each sub-basin of Upper Klamath Lake	Chinook Salmon
7	Fish health	Chinook Salmon Steelhead Trout Pacific Lamprey

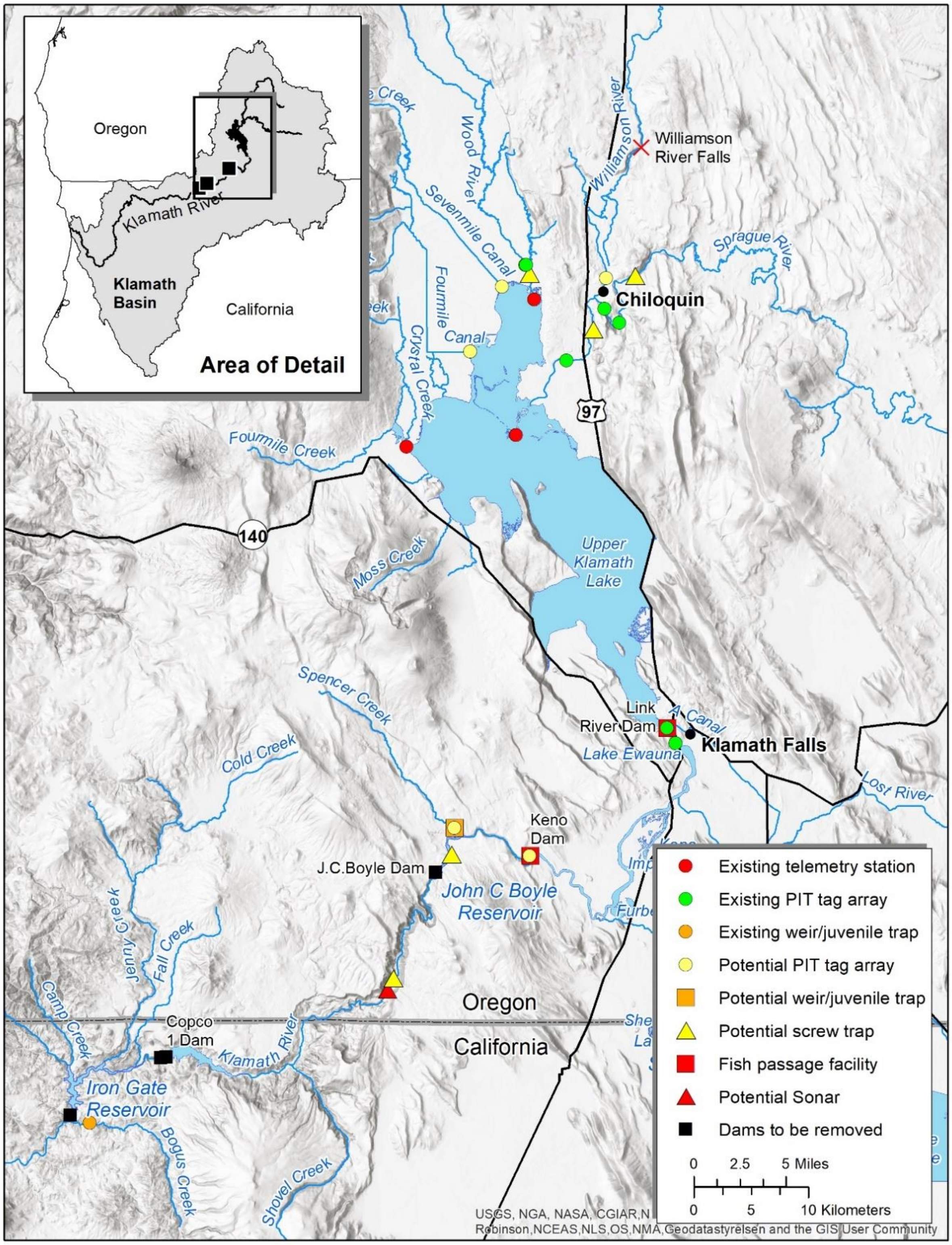


Figure 3-10. Existing locations and approximate recommended locations of facilities for monitoring anadromous fishes above Iron Gate Dam and the Oregon portion of the Klamath Basin.

3.2.3 Monitoring and Evaluation Parameters

Due to the many uncertainties surrounding the timing and abundance of fishes migrating upstream of the former dams, this monitoring and evaluation strategy will require versatility to be successful. This will include using multiple tools to obtain data to meet a desired objective. Monitoring and evaluation objectives involve measuring the following parameters associated with viable salmonid populations (McElhany et al. 2000), as well as additional parameters associated with reintroducing populations: presence/absence, distribution, abundance, productivity, life history diversity, genetic diversity, and fish health. The Monitoring and Evaluation Parameters are described below, and the potential tools used to measure the parameters are summarized in Table 3-7.

- **Presence/Absence:** whether or not fishes are present in a defined area, and the timing of that presence.
- **Distribution (spatial structure):** Where individuals or populations are located on the landscape. A population's spatial structure depends fundamentally on habitat quality, spatial configuration, and dynamics, as well as the dispersal characteristics of individuals in the population.
- **Abundance:** The number of spawners in a population. Large populations exhibit a greater degree of resilience than smaller ones. Spawning escapement can also be estimated as a parameter for abundance. Where appropriate and feasible, the number of juveniles produced.
- **Productivity:** Measurements of recruitment to a particular life stage divided by the number of parental spawners.
- **Life History Diversity:** The number of life histories expressed by adults, such as spring-run and fall-run races, as well as the number of different life histories expressed by juveniles (Example: Type 1, sub-yearlings that migrate out of the Upper Klamath Basin in the spring or summer; Type 2, sub-yearlings that migrate out of UKB in the fall or early winter; Type 3, sub-yearlings that migrate out of UKB late winter or spring; Type L, juveniles that rear in the lake before migrating out of UKB). The number of life histories expressed by *O. mykiss* (Hodge et al. 2016). The expression of stream and ocean-maturing Pacific Lamprey (Clemens et al. 2013; Parker 2018).
- **Genetic Diversity:** Measurements of genetic diversity include commonly applied methods to acquire F-statistics, measures of allelic richness, population genetic structure, and genetic diversity within populations.
- **Fish Health:** Establish baseline pathogen prevalence in returning spawned fish as well as any pre-spawn mortality. Evaluate fish health status and pathogen prevalence in juvenile out-migrants. Compare fish health status of different juvenile life histories. Determine if bottlenecks in migration (i.e. Keno or Link River Dams/fishways or Keno Impoundment/Lake Ewauna) are associated with higher pathogen prevalence or intensity.

Table 3-7. Summary table depicting which monitoring tools (facilities and activities) are intended for measuring specific evaluation parameters for assessing the re-establishment of anadromous fishes into the Upper Klamath Basin following the availability of passage through former Iron Gate, Copco 1 & 2, and J.C. Boyle Dams.

	Evaluation Parameters						
Monitoring Tools	Presence/absence	Distribution	Abundance	Productivity	Life-history diversity	Genetic diversity	Fish health samples
Monitoring Facilities							
Spencer Creek weir	X		X		X	X	X
Keno Fish Passage Facility	X		X		X	X	X
Link River Dam fish ladder	X		X		X	X	X
Fixed telemetry stations	X	X	X		X		
Fixed PIT tag antenna arrays	X	X	X		X		
Juvenile traps			X	X	X	X	X
Sonar	X		X				
Monitoring Activities							
Carcass surveys	X	X	X		X	X	X
Visual surveys for redds and spawners	X	X	X		X		
Snorkel surveys	X	X	X	X	X		
Aerial surveys	X	X	X				
Mobile telemetry surveys	X	X			X		
Electrofishing	X	X	X	X	X	X	X
eDNA	X	X					X

3.2.4 Klamath River Cooperative Spawner Survey

Since 1986, a cooperative group of state and federal agencies, tribes, non-profit organizations, watershed councils, and volunteers have conducted fall-run Chinook Salmon spawning ground surveys throughout out the Klamath River (below Iron Gate Dam) and its tributaries (CDFW 2017). The main purpose of this cooperative spawning survey is to estimate age-specific escapement of fall-run Chinook Salmon in the Klamath Basin. The data collected from these surveys is presented annually to the Klamath River Technical Team (KRTT) and are incorporated into the *Klamath River Fall Chinook Age-Specific Escapement, River Harvest, and Run Size Estimate*. This information is used by the Pacific Fishery Management Council (PFMC) for allocating fisheries for the following season. Methodologies for surveys include: Redd counts, foot and boat-based carcass counts, snorkeling, and adult counting facilities. Survey methods vary among reaches depending on the locations and characteristics of the reach being surveyed (CDFW 2017).

The fall-run Chinook Salmon spawning surveys obtain biological data from carcasses, that are essential to the determination of the age, hatchery composition and sex composition of each year's run (CDFW 2017). These data include:

- Collection of scales for aging
- Fork length (for pre-season grilse/adult determination)
- Collection of coded-wire tags (CWT) from adipose fin-clipped carcasses
- Inspection of marks and clips
- Sex
- Spawning success (of female carcasses)
- Collection of tissue samples for genetic analysis and otolith samples for micro-chemical analysis

The Stateline of Oregon and California bisects the Klamath Basin at Klamath River kilometer 342 (rm 212.5). Three of the four dams (Iron Gate Dam and Copco 1 &2 Dams) planned for removal are located in California. Copco 1 Dam has blocked passage of anadromous fish into Oregon since 1912 (construction of dam was completed in 1918; passage was blocked before completion, see Hamilton et al. 2016). Once passage is restored, close coordination between California Department of Fish and Wildlife, Oregon Department of Fish and Wildlife, Tribes, and Federal Fish Management agencies will be needed to successfully monitor fishes migrating between the two states. Monitoring programs will need to be complementary to maximize efficiency and to ensure corroboration amongst collected data. Specifically, methodologies for monitoring fall-run Chinook Salmon in the Upper Klamath Basin should be consistent with the monitoring program below Iron Gate Dam to ensure accurate and compatible age-specific escapement estimates above Iron Gate Dam are presented to the KRTT and incorporated into the annual *Klamath River Fall Chinook Age-Specific Escapement, River Harvest, and Run Size Estimate*.

3.3 Monitoring Tools

We define "monitoring tools" as the means of collecting data. The strategy for monitoring will consist of two different types of tools: Monitoring facilities and monitoring activities. Monitoring facilities are tools that are site-specific and involve stationary equipment used and maintained to collect data at particular sites. Monitoring activities are tools that involve on-the-ground surveys and/or sample collection(s) conducted by personnel and can occur throughout the watershed. The tools we recommend for monitoring are described in the following sections and are spatially depicted in Figure 3-10.

3.3.1 Monitoring Facilities

Klamath River (mainstem) Sampling Weir

A sampling weir on the mainstem Klamath River could provide the ability to sample and enumerate adult salmon (specifically fall-run Chinook Salmon) as they migrate above the former Iron Gate Dam. Sampling would allow for the tagging (telemetry and/or PIT tags) of individuals and subsequent detection of fishes in habitats further upstream, estimate abundance of spawners in the Klamath River Canyon, and identify where fish are spawning (allowing for more targeted monitoring through on-the-ground spawning/carcass surveys). If it is agreed that a weir on the mainstem Klamath River is appropriate, all necessary precautionary measures will be taken to ensure that a weir is not impeding natural migration into the Upper Klamath Basin.

Spencer Creek lifecycle monitoring station

Spencer Creek is a major tributary to the Klamath River in Oregon (rkm 371; rm 230.5 above JC Boyle Dam and below Keno Dam) with the possibility of supporting anadromous fishes. Currently it is the only spawning tributary for the robust population of Redband Trout in the Klamath River between Keno Dam and J.C. Boyle Dam. Historically, large numbers of Chinook Salmon migrated up Spencer Creek to Spawn (BLM 1995). Spencer Creek is also believed to be the historical upstream limit to Coho Salmon in the Klamath Basin (Hamilton et al. 2005). Spencer Creek represents the first major tributary in Oregon that anadromous fishes will have the opportunity to repopulate following the availability of fish passage. We recommend the use of a video weir with the capability of capture on Spencer Creek. This tool will allow for immediate detection of adult Chinook Salmon, Coho Salmon, steelhead trout, and Pacific Lamprey in Spencer Creek. As anadromous fish numbers build, the video weir can also be used to estimate adult abundance estimates, species composition, run time diversity, and help estimate productivity as a part of a lifecycle monitoring facility. The video weir will be primarily used in the fall through winter months (ideally, spring months as well, flow dependent, to monitor *O. mykiss*) to monitor adult migration and paired with a downstream juvenile trap in the spring during outmigration to estimate juvenile production, survival, and timing (Figure 3-11).

California Department of Fish and Wildlife (CDFW) currently operates video weirs on three tributaries to the upper Klamath River below Iron Gate Dam (Scott River, rkm 234.5; Shasta River, rkm 290.0; Bogus Creek, rkm 311.0 to help estimate escapement of adult Chinook Salmon, Coho Salmon, and steelhead trout. Juvenile downstream traps (screw traps and fyke traps, depending on size of stream) are used to help estimate production. CDFW plans on a similar monitoring strategy on Klamath River tributaries (i.e., Jenny Creek, rkm 318.0; Shovel Creek, rkm 337.5) upstream of the hydroelectric dams following the availability of fish passage (CDFW 2021). Due to similar hydrology, ODFW will use CDFW's Bogus Creek video weir with optional capture capabilities, as well as the juvenile fyke-style downstream trap as a model for a weir on Spencer Creek. Coordination among the agencies will be imperative to ensure that monitoring strategies within the Upper Klamath River are compatible.

Figure 3-11. Spencer Creek at rkm 1 (rm 0.6) (confluence with Klamath River at rkm 371; rm 230.5). Photo depicts the recommended location for a video weir to monitor adult anadromous fishes migrating up Spencer Creek. This location is also recommended for a juvenile downstream trap to monitor juvenile production and outmigration behavior. This location has been used in the past for a downstream trap for monitoring resident *O. mykiss* (Starcevich et al. 2006).

Fish Passage facility at Keno Dam or Link River Dam

Keno Dam is located at rkm 380.5 (rm 236.4; 6 river miles upstream of Spencer Creek). The dam is owned by PacifiCorp and operated to manage water elevations in Keno Impoundment for agricultural purposes. By means of the KHSA, upon notification by the DRE, ownership of Keno Dam will be transferred to U.S. Bureau of Reclamation (USBR). Keno Dam was built in 1966 and contains a fish ladder for the purpose of upstream passage for salmonids. The ability of the Keno Dam structure to provide safe downstream fish passage is not known. ODFW is not aware of any studies to date by PacifiCorp or USBR pertaining to downstream or upstream fish passage at the dam, other than a very limited attempt by PacifiCorp to collect information on Total Dissolved Gas levels related to potential gas supersaturation downstream of the spillway. The majority of Keno Impoundment outflow is released through the bottom of radial arm gates (Figure 3-12). Passage by downstream migrants through spillways can be a source of direct or delayed mortality (e.g., injuries that cause greater susceptibility to predation). Downstream fish injury and mortality can result from high pressure changes and shear zones and fish impact with solid objects or substrate in the apron basin. Also, upstream migrating fish exiting the upstream fish ladder may potentially fall back through the spillway if the ladder exit is improperly located, with corresponding downstream injury through the radial arm gates and over the apron structure.

Improvements to the existing fish ladder could potentially increase its usage through a more effective placement of attraction flows to attract fish to the entrance of the ladder as opposed to the dam itself (Figure 3-12). The ability of lamprey to migrate upstream and downstream of Keno Dam is poorly understood and should be investigated.

Figure 3-12. Keno Dam (left) located at rkm 380.5 (rm 236.4) with radial arm gates that draw water from below the surface. Keno Dam fish ladder (right) with attraction flow occurring to the side of the ladder entrance.

Link River Dam, built in 1927, is located at rkm 414.4. (rm 257.5; 21 river miles upstream of Keno Dam). The dam is operated pursuant to a contract between PacifiCorp and USBR (the owners of the dam) to provide regulation of Upper Klamath Lake levels for irrigation, divert water into PacifiCorp’s Eastside and Westside powerhouses, and maintain at least a minimum flow in the Link River and subsequent downstream minimum flows out of Iron Gate Dam. USBR replaced an inadequate fish ladder in 2005 to allow efficient passage of endangered suckers, Redband Trout, and lampreys migrating from Lake Ewauna to Upper Klamath Lake (Figure 3-13). The Link River Dam fish ladder has four PIT tag detection arrays (maintained and operated by USGS; Biomark, full duplex) constructed within them to determine usage by tagged fish.

Figure 3-13. Link River Dam located at rkm 414.4 (rm 257.5) constructed in 1927 at the outlet of Upper Klamath Lake (background), and the associated fish ladder (foreground) constructed in 2005, specifically for the use by suckers, salmonids, and lampreys.

The vast amount of habitat above Keno and Link River Dams (see 3.1.2; Figure 3-3; Table 3-1) will make initial monitoring efforts in this area difficult. The ability to detect adults as they migrate into main tributaries (such as the Wood, Williamson, and Sprague Rivers) will allow for targeted monitoring efforts, which will be more efficient and more accurate than randomly sampling a subset from hundreds of miles of rivers and streams. One way to achieve this, would be the capture of adult fish before they reach Upper Klamath Lake. Captured fish could then be sampled for biological and demographic data and implanted with a PIT tag and telemetry tags (or other appropriate device). Current fish monitoring facilities (PIT detection arrays, telemetry stations) located throughout the upper basin tributaries as well as some additional facilities could then detect tagged fish as they migrate upstream (see Figure 3-8). Link River Dam Fish Ladder and Keno Dam Fish Ladder are two locations along the migratory route to the tributaries of Upper Klamath Lake where fish will be artificially constrained allowing for the capture and sampling of adult fishes. We recommend a fish passage monitoring facility for the purpose of sampling and enumerating fishes be constructed on either Keno Dam or Link River Dam. The ability to sample fishes would allow managers/researchers the opportunity to obtain valuable biological and demographic data (length, weight, sex, and timing), deploy appropriate tags for mark-recapture studies, health assessments, genetic samples, estimating escapement to Upper Klamath Lake tributaries, and many unforeseen purposes.

When sampling fishes is not needed, the use of a video counting station should be used to estimate abundance of fish passing Keno Dam and/or Link River Dam. We also recommend the use of remote PIT (full duplex) tag detection systems for both upstream and downstream migration at Keno and Link River Dams to help answer uncertainties regarding survival and timing of migration though these facilities.

Priorities for Keno Dam and Link River Fish Passage Facilities

1. Upstream and downstream volitional passage through Keno Dam and Link River Dam for all life stages of all fish species throughout the entire year.
2. Fish detection systems for upstream and downstream movement through Keno Dam and Link River Dam (i.e., PIT tag antenna, video/counting system, telemetry).
3. Ability to sample adult fishes migrating upstream via a sampling station for the opportunity to obtain valuable biological and demographic data, deploy appropriate tags for mark-recapture studies, health assessments, genetic samples, estimating escapement, and many unforeseen purposes.

Fixed Telemetry Stations

Biologists from Oregon State University and ODFW currently maintain and operate three fixed telemetry stations to monitor and research seasonal movements of adfluvial Redband Trout. The three stations are strategically located at the mouths of Pelican Bay, Wood River, and Williamson River. These locations are the entrances to the major upper basin spawning reaches for the Upper Klamath Lake adfluvial Redband Trout populations and their summer thermal refuge habitats. The Wood and Williamson Rivers are the primary tributaries to Upper Klamath Lake and their watersheds contain the majority of suitable habitat for anadromous fishes in the Upper Klamath Basin. Any anadromous fishes that are telemetry tagged as part of the monitoring effort will have the potential to be detected at these locations.

Stationary Passive Integrated Transponder (PIT) Tag Antenna Arrays

U.S. Geological Survey (USGS) currently maintains and operates seven stationary PIT tag antenna (Biomark, full duplex) arrays strategically located in tributaries of Upper Klamath Lake (Wood River, Crooked River, Williamson River, and Sprague River), Link River Dam fish ladder, and the Link River 1.5 rkm (~1 mile) below the fish ladder. These PIT tag arrays are intended to monitor tagged endangered suckers, but also provide detection of PIT tagged Redband Trout. While these existing PIT tag arrays can be utilized for monitoring anadromous fishes, we recommend additional stationary PIT tag arrays at a number of locations to provide additional information on the movements of various life stages of anadromous fish populations.

An additional PIT tag array located on the Williamson River above the confluence of the Sprague River would allow for detections of individuals migrating in the Williamson River and its tributaries (Spring Creek, ~300 cfs) above the Sprague River confluence. PIT tag arrays located on Fourmile Canal and Sevenmile Creek would allow for detection of fishes in these tributaries located on the northwest side of Upper Klamath Lake. Additional PIT tag arrays on the Upper Sprague River would allow for detections above the current arrays in the lower river. A PIT tag array at the outlet of Keno Dam would increase detection probability of emigrating juveniles out of the tributaries above Upper Klamath Lake as well as allow for survival and migration investigations of juveniles migrating From Link River Dam, through Lake Ewauna/Keno Impoundment to Keno Dam. A PIT tag array near the mouth of Spencer Creek (tributary to Klamath River below Keno Dam) would allow for detections of tagged fish moving in and out of this tributary.

Juvenile Traps

The purpose of rotary screw traps and other juvenile downstream fyke traps is to capture downstream migrating juvenile salmonids and other fishes. Operation of juvenile downstream traps will allow for the estimation of juvenile abundance, outmigration timing, assessment of egg-to-smolt survival, smolt-to-adult survival, assessment of genetic diversity, and genetic parentage assignment, as well as many other metrics. Initially, following the availability of fish passage, juvenile traps will be strategically placed in Upper Klamath Basin tributaries downstream of areas where it is known that spawning has occurred, or the presence of adults is known. The type of juvenile trap (rotary screw trap or fyke trap) will be determined by the size and location of tributary. Recommended locations for juvenile traps include: Klamath River between Spencer Creek confluence and the Oregon-California border, Spencer Creek, Williamson River, Sprague River, and Wood River. Traps should be located in the lower most reach of streams/tributaries to capture as many juveniles as possible migrating out of each system. The capture of juveniles will also allow for fish health assessments.

Sonar

Sonar is a hydroacoustic tool typically used to detect presence and estimate abundance of migrating fishes in streams when other traditional methods are not feasible, such as in large, turbid streams (Maxwell and Glove 2004; Maxwell 2007; Denton et al. 2016). Certain conditions need to be met in order for Sonar to be effective at addressing monitoring questions as described by Maxwell (2007). First, fish need to be actively migrating and not traveling back and forth across the sonar beam. Second, fish must travel within the detection range. Third, the river bottom profile must be mostly linear with laminar current flow. Lastly, the species of interest is the only species present, or a technique is used to determine species designation and/or composition.

Enumeration of adult Chinook Salmon and steelhead trout in the Elwha River, Washington is quantified by the use of DIDSON (Dual-Frequency Identification Sonar) and the newer version, ARIS (Adaptive Resolution Imaging Sonar) (Denton et al 2016). This tool has been successfully utilized before and after dams were removed on the Elwha River to assess relatively small and protracted runs of Chinook Salmon and steelhead trout in a large turbid River (Denton et al. 2016).

Sonar could be used as a potential tool to help determine the presence of adult salmon migrating above the former dam sites. The mainstem Klamath River is a large, turbid river that has many difficult to access reaches from Iron Gate Dam to Keno Dam, making sonar a potential tool for monitoring this portion of the basin to determine if fish are migrating upstream of the dams. The location for sonar equipment should meet the conditions mentioned above as well as other conditions that will help meet the objectives of determining if/when adult salmon are migrating above the dams and into the Upper Klamath Basin.

The Frain Ranch Reach located above Caldera Rapid (rkm 350; rm 217.5) is a relatively low-gradient, riffle-glide reach that was historically used as spawning habitat by fall-run Chinook Salmon (Hamilton et al. 2005). The downstream end of this reach may be a suitable location (both for access and for stream characteristics) for a sonar station to detect fish migrating above Iron Gate Dam and estimate abundance into suitable spawning habitat on the Klamath River from Caldera Rapid to Keno Dam (Figure 3-14).

Figure 3-14. Stream habitat along the Frain Ranch Reach of the Klamath River above Caldera Rapid (rkm 350; rm 217.5; see Figure 3-8). Upstream of Caldera Rapid could be a potential location for a hydroacoustic station to detect adult salmon migrating above the former dams.

3.3.2 Monitoring Activities

Klamath River Carcass Surveys

Valuable information can be obtained from salmon carcasses including: age, length measurements, sex composition, spawning success, and prevalence of some pathogens. Coded-Wire Tags (CWT) from hatchery fish could also be collected during carcass surveys to determine the source of hatchery origin spawners. Tissue samples and scales can be collected for genetic analysis, and carcass surveys can also be used as a tool to estimate spawning escapement. The U.S. Fish and Wildlife Service (USFWS) has been conducting carcass surveys on the mainstem Klamath River below Iron Gate Dam (rkm 312; rm 193.9) to the confluence of the Shasta River (rkm 288.5; rm 179) during the fall-run Chinook Salmon spawning season since 2000 to estimate annual escapement, characterize the age and sex composition, and spawning success of the run. USFWS uses a postmortem mark-recapture methodology and an area-under-the-curve estimator to estimate escapement to the Klamath River from Iron Gate Dam to the confluence of Shasta River (Gough and Som 2017). Carcass surveys should be conducted on logistically feasible, floatable reaches of the mainstem Klamath River below Keno Dam in reaches where Chinook Salmon were historically known to spawn and/or reaches that are suitable for spawning. Carcass surveys in this section of river should begin in the spawning season following the availability of passage through the Klamath River and should follow the methodologies of Gough and Som (2017). Carcass surveys should also be conducted anywhere in the Upper Klamath Basin where it is known that Chinook Salmon or Coho Salmon are present.

Foot-based Visual Surveys

Visual surveys for redds, spawning fish, and carcasses can be an effective method for counting spawning salmon in smaller tributaries. We recommend visual surveys be conducted in Spencer Creek during the spawning season following the availability of fish passage. Visual surveys should be conducted in tributaries above Upper Klamath Lake when it known that adults are present. Mobile telemetry tracking for individuals with tags should occur regularly when there is a possibility of occurrence in the upper basin.

Snorkel Surveys

Snorkel surveys are widely used in streams to monitor fish populations. Snorkel surveys are typically used to determine presence/absence, distribution, species assemblages, population characteristics, habitat use, and to estimate both relative and total abundance. Snorkel surveys will be conducted in Spencer Creek immediately following the availability of fish passage above the former dams to determine the presence of anadromous fishes. Snorkel surveys should occur in tributaries above Upper Klamath Lake when it is known that fishes are present above Link River Dam.

Aerial Surveys

Aerial surveys, by fixed-winged, helicopter, or unmanned aerial vehicles (UAV) should be considered as a monitoring approach for adult fish in the upper basin. Fixed-wing aircraft could be used for radio telemetry monitoring and visual surveys for spawning adults, redds, and carcasses where applicable. The use of UAVs (drones) could be a valuable option for surveying for spawning adults, redds, and carcasses in certain situations where surveys would need to occur in proximity to the surface elevation, but access is difficult due to geography. Spring-fed tributaries of Upper Klamath Lake (Wood River, Williamson River, and their tributaries) present a unique opportunity due to the clarity of the water, making the usage of UAVs for both adult spawning fish and redd observations applicable when ground surveys are difficult, as well as situations where the use of UAV’s would be more efficient and accurate. Radio telemetry surveys from aerial flights could also occur and be incorporated into the above-mentioned aerial surveys.

Electrofishing

Backpack electrofishing is one of the most widely used tools for sampling fishes in in streams that are conducive to wading, and is typically used to estimate abundance, species richness, and size structure of fishes (Temple and Pearsons 2007). Electrofishing is also an efficient tool for capturing fish to collect tissue samples for genetic analysis or conducting mark-recapture studies. In streams that can be waded, we recommend the use of electrofishing as a tool to collect data of juvenile anadromous fishes in wadeable streams of the Upper Klamath Basin. When it is known or suspected that adult fish have spawned in a stream, electrofishing for juveniles will confirm presence, distribution, and will allow for other pertinent analysis such as abundance and size structure. The objective of the survey will determine the sampling design, whether it be a targeted survey, random design, stratified random design, or any number of objective appropriate design.

Environmental DNA (eDNA)

Environmental DNA (eDNA) analysis is a method that can be used to detect the presence of aquatic species based on the collection, extraction, and amplification of DNA from the environment (Ficetola et al. 2008; Goldberg et al. 2011). Under certain circumstances, eDNA methods are more advantageous and cost effective than conventional methods (Evans et al. 2017). eDNA is becoming a useful tool to determine the distribution of sparsely populated salmonids in large watersheds (Laramie et al 2015), as well as in parts of watersheds that are difficult to access or where traditional detection methods are difficult or not feasible (Duda et al. 2020). eDNA can also be used to detect the presence and relative abundance of certain fish pathogens (Hallett et al.2006).

We recommend the use of eDNA as a tool to detect the presence and distribution of anadromous fishes in the Upper Klamath Basin following the availability of passage. The tool is not intended to replace other traditional monitoring methods, but could be a valuable, complementary tool to determine where anadromous fishes are located in this large system when initial abundance may be small and not easily detected by other methods. The knowledge of distribution will allow for more targeted monitoring efforts in reaches where species are detected. eDNA monitoring should begin during the first spawning season immediately upstream of the dams following the availability of passage. When it is known that fish are above Link River Dam eDNA monitoring should be conducted in tributaries of Upper Klamath Lake. As a fish health sampling tool, eDNA or targeted pathogen quantitative water sampling (Hallett et al. 2012) can identify the presence and relative abundance of a suite of fish pathogens that would be more labor intensive to sample and culture by traditional laboratory methods. Pathogen detection in water samples can then be correlated to fish health status of fish that are residing in or that migrated through the area.

Genetic Monitoring

We recommend non-lethal tissue samples be collected from fishes that are captured at monitoring facilities or during monitoring activities as well as tissue samples from carcasses for genetic analysis. Genetic analysis will allow for testing of population structure, testing for potentially adaptive differences among populations, monitoring of genetic diversity within populations, parentage analysis, and estimating reproductive success of adults. Genetic analysis of tissue samples from lampreys (Hess et al. 2014; Hess et al. 2015) and *O. mykiss* (Pearse et al. 2014) could help distinguish between anadromous and resident forms (see table 3-5 for resident lamprey species). Recent genetic research has identified a single gene associated with premature and mature migration life histories of Chinook Salmon (spring-run vs fall-run) and steelhead trout (summer-run vs winter-run) (Prince et al. 2017). Genetic markers identified by Prince et al. (2017) should be incorporated into genetic monitoring efforts to determine life histories of Chinook Salmon and steelhead trout (Thompson et al. 2019).

3.4 Fish Health Monitoring

Removing the dams on the Klamath River to allow for the passage of anadromous fishes will not only change the dynamics of fishes in the basin, but the dynamics of the pathogens also associated with the fishes is likely to change as well. Resident fishes above the dams have been isolated from some pathogens associated with fishes below the dams for over 100 years. In the absence of selective pressure, upper basin fishes may have decreased resistance to below dam pathogens. Conversely, isolated resident fishes could transmit novel pathogens to anadromous fishes (Hurst et al. 2012). Therefore, a rigorous pathogen monitoring program will be needed to evaluate any unintended consequences associated with the reintroduction of anadromous fishes into the Upper Klamath Basin. In addition, baseline studies will provide valuable information on multiple fish pathogens prior to dam removal and will allow for the assessment of pathogen dynamic changes post dam removal (Brenkman et al. 2008).

Specific pathogens that are of concern include viruses, bacteria, and parasites. Infectious Hematopoietic Necrosis Virus (IHNV) is a virus known to cause the disease infectious hematopoietic necrosis in salmonids and has not been detected in the Oregon portion of the Upper Klamath Basin. California has not had any detections of the virus in their surveys of returning adults to Lower Klamath Basin hatcheries for over 20 years (Joe Maret, Personal communication, CDFW). In other river basins in Oregon, the pattern of IHNV prevalence in returning adult fish is sporadic and unpredictable from year to year (ODFW Fish Health records). Additionally, there are no reliable non-lethal methods of detecting the virus and if introduction were to occur, the expected impact to resident Redband Trout and other native fishes would be high.

Myxobolus cerebralis, the cause of salmonid whirling disease, has a similar history in the Klamath River Basin in California; having been detected in the past but no continued detections in long-term monitoring efforts. *O. mykiss* are highly susceptible to whirling disease, so if this parasite were to become established in the Upper Klamath Basin it could have significant negative effects on the resident Redband Trout populations. Therefore, active reintroduction of adult fish with unknown pathogen prevalence from the lower basin to the upper basin is considered high risk to the health of resident fishes. There is no way to screen for these pathogens in adult fish before they migrate to the upper basin. However, as described earlier, the spatiotemporal pattern of volitional migration and natural selection for fish that survive the long-distance migration, are predicted to dilute and disperse pathogens, decreasing the overlap between host, pathogen and environment.

The bacterium *Flavobacterium columnare* causes the disease Columnaris that affects a broad range of fish species. This bacterium can cause severe lesions on the skin and/or gills, or cause systemic infection, all of which can lead to fish mortality. In the Upper Klamath Basin, Columnaris has been associated with mortality in suckers, Redband trout, and other fish species. This bacterium is highly contagious and can cause fatal infections at temperatures as low as 15°C. Considering the temperature profile for Upper Klamath Lake over the summer, salmonids in the lake could already be experiencing thermal stress. In the presence of a bacterial pathogen that thrives in these conditions (warm temperatures, stressed fish), the risk of Columnaris to reintroduced fishes is quite high. A relatively common and widespread pathogen, it is present in the lower basin rivers and streams as well. In 2002 co-infections with Columnaris and the external parasite *Ichthyophthirius multifiliis* were associated with extensive pre-spawn mortality in returning fall-run Chinook Salmon (Guillen 2003). Depending on river conditions, this bacterium continues to have the potential to be cause of pre-spawn mortality for returning adult fishes.

Renibacterium salmoninarum is another bacterial pathogen present in the Klamath Basin affecting salmonids and can cause Bacterial Kidney Disease (BKD), characterized by lesions and necrosis in the kidney. *R. salmoninarum* has been detected in trout in wild fish surveys throughout the upper basin (ODFW fish health records), but these fish have largely been asymptomatic carriers. Chinook Salmon and Coho Salmon are the most susceptible species to BKD, so these species will likely not affect prevalence and severity of BKD in resident species. However, the infected resident fish have the potential to infect the newly reintroduced salmon. The severity of BKD will depend on a variety of factors, but close proximity of infected and naïve hosts in shared habitat is one of the highest risk factors.

Some other parasites found in the Upper Klamath Basin have a similar relationship with temperature as Columnaris. *Ichthyobodo*, *Ichthyophthirius multifiliis*, and *Trichodina sp* have been detected in ODFW wild fish surveys in a variety of fish species. The copepod *Lernea* sp. (known as Anchor worm) is a parasite affecting trout and suckers in the Upper Klamath Basin. These four parasites utilize a broad host range and, like *F. columnare*, are passed from fish to fish through the water. In areas where fish are crowded together, such as in small thermal refugia, these pathogens would have close proximity to stressed hosts, increasing their susceptibility to infection. In the Lower Klamath Basin, combined infections with *Ichthyophthirius* sp. and Columnaris was associated with extensive returning adult mortality in 2002 (Guillen 2003).

Ceratonova shasta (*C. shasta*), another endemic parasite in the Klamath Basin, causes a parasite-induced enteronecrosis, a disease characterized by severe inflammation, hemorrhage, and necrosis of the intestine (Bartholomew et al. 1989). This disease is associated with significant juvenile salmon mortality in the Lower Klamath Basin (True et al. 2017). Unlike the bacteria, viruses and parasites previously described, *C. shasta* cannot be transmitted from one fish to another and requires both a salmonid and freshwater polychaete host. The salmonid host releases the myxospore stage of the parasite that infects the polychaete host (*Manayunkia speciosa*) followed by the development and release of the actinospore, which is the lifestage that infects the fish (Bartholomew et al. 1997). *C. shasta* has three known genotypes that are host-specific, meaning the ability of the parasite to establish and reproduce is influenced by the species of salmonid (Hurst 2010). Two distinct genotypes of *C. shasta* (type 0, II) are known to occur in the Upper Klamath Basin and are host specific to native (type 0) and non-native (type II) *O. mykiss* (Hurst et al. 2012). Known locations of *C. shasta* in the Upper Klamath Basin include: Klamath River from Iron Gate Dam up to and including Link River (Stocking et al. 2006), Upper Klamath Lake near Modoc Point (Stocking et al. 2006), Sprague River, and Williamson River (Hurst et al. 2012). The highest densities of the parasite occur in the Williamson River from the confluence with the Sprague River to Upper Klamath Lake (Hurst et al. 2012).

Parvicapsula minibicornis is another myxozoan parasite endemic to the Klamath Basin. Like *C. shasta*, there is no direct fish-to-fish transmission of this microscopic parasite, and it relies on *M. speciosa* to complete its lifecycle. *P. minibicornis* and *C. shasta* are often present as co-infections in fish but disease severity is variable and influenced by dose and temperature. Although *P. minibicornis* has been detected in the upper basin, fish health monitoring so far has only detected clinical disease associated with the parasite in the lower basin (True et al. 2010).

When Chinook Salmon begin to repopulate the Upper Klamath Basin, they will more than likely bring *C. shasta* type I (Chinook specific genotype) from the lower basin as well as additional *P. minibicornis* myxospores. Once introduced, type I will likely establish in habitat populated by *M. speciosa*, where type 0 and II currently exist (Hurst et al. 2012). The prevalence and infection intensity of *P. minibicornis* and *C. shasta* may also change as host-parasite dynamics change with the reintroduction of new hosts into the upper basin, especially when these hosts will have migrated through an area where both parasites are significant contributors to fish mortality. Therefore, information on pathogens below and above dams should be monitored before and after dam removal to assess changes in pathogen dynamics, and high-risk locations such as the Williamson River, should be intensively monitored following the removal of dams and subsequent re-establishment of anadromous fishes.

3.4.1 Fish Health Monitoring Activities

A regular monitoring program for fish health should be conducted to test for the presence of type I, Type II *C. shasta*, *P. minibicornis*, viruses (especially IHNV), bacteria (Columnaris and BKD), *Myxobolus cerebralis, Ichthyophthirius multfiliis* and other parasites following dam removal in areas where it is known that anadromous fishes exist. The tools for monitoring fish health should include wild fish surveys, water sampling, sentinel cages, and carcass sampling. These tools will allow for the detection of novel pathogens introduced by fishes as well as assess impacts to anadromous fishes from pathogens that currently exist in the upper basin. Fresh, dead, and moribund fish samples that are collected during the monitoring program should be sent to the ODFW Fish Health Services Laboratory in Corvallis for analysis. Juvenile screw traps, weirs, and collection facilities will be strategically located throughout the Upper Klamath Basin (see

Figure 3-10) to facilitate the collection of samples for fish health assessments. Samples from carcass surveys should also be collected for fish health analysis. Pre-dam removal studies involving fish health samples collected from resident Redband Trout in the Upper Klamath Basin have been or are currently being conducted and will serve as baseline conditions for post-dam removal comparison associated with anadromous fish repopulation.

3.5 Steelhead Trout

Monitoring re-establishment of steelhead trout into the Upper Klamath Basin deserves its own section due to the possible difficulties of identifying them among current resident Redband Trout populations present above the dams in the Klamath River as well as in Upper Klamath Lake and its tributaries. Due to the high productivity of Upper Klamath Lake and the Klamath River, adult Redband Trout in these waterbodies can grow to large sizes. The population of Redband Trout in the mainstem Klamath River from JC Boyle Dam to Keno Dam have a mean fork length of 14.5 inches. Redband trout over 29 inches are periodically caught by anglers in the Klamath River below Keno Dam, most likely migrants from Upper Klamath Lake (Bill Tinniswood, ODFW, Personal communication). The adfluvial Redband Trout that are caught in Upper Klamath Lake, which spawn in spring-fed tributaries (Crystal Creek, Wood River, Williamson River, and Sprague River) have a mean fork length of 22.3 inches (Figure 3-15). The mean fork length of steelhead trout found in the Lower Klamath Basin from the mouth to Iron Gate 19.9 inches. When “half-pounders”, steelhead trout that return to freshwater in the year of initial ocean entry (Hodge et al. 2014), are segregated out, mean fork lengths are 16.4 inches for half-pounders and 24.2 inches for non-half pounders (Hodge et al. 2016). Due to the potential overlap in lengths of resident Redband Trout and steelhead trout, distinguishing between the two life histories based on size will be challenging if not impossible. Therefore, other techniques may need to be implemented to determine the presence of steelhead trout in the Upper Klamath Basin.

The use of scale and otolith strontium isotope ($^{87}Sr/^{86}Sr$) analysis was used to characterize life history diversity, maternal origin (anadromous or nonanadromous), and migratory history (anadromous or nonanadromous) in wild *O. mykiss* in the Lower Klamath Basin by Hodge et al. (2016). Their results identified 38 life history categories at maturity, which differed in duration of freshwater and ocean rearing, age at maturation, and incidence of repeat spawning. Hodge et al. (2016) was able to determine that anadromous and non-anadromous *O. mykiss* can produce progeny of the alternate form (partial migration) in the Lower Klamath Basin. A genetic analysis using microsatellites conducted by Pearse et al. (2011) revealed that Redband Trout populations in Upper Klamath Lake are genetically distinct from coastal *O. mykiss*. However, populations of Redband Trout found below Keno Dam and some tributaries above Upper Klamath Lake (Cherry Creek, Rock Creek) are closely related to coastal populations of *O. mykiss* found in the Lower Klamath Basin (below Iron Gate Dam). Studies have also demonstrated that Redband Trout isolated above impassable dams retain the potential for producing anadromous life histories (Thrower and Joyce 2004; Holecek et al. 2012; Wilzbach et al. 2012). The combined results of these studies suggest that there are at least two potential mechanisms for the repopulation of steelhead trout into the Upper Klamath Basin. The first mechanism could be lower basin steelhead trout migrating past the former dams and producing offspring amongst themselves or inter-breeding with resident Redband Trout and producing anadromous offspring. The second mechanism could be the potential of Redband Trout above the dams to produce offspring with an anadromous life history, with those individuals then having the opportunity to out-migrate to the ocean and then return to the Upper Klamath Basin.

Figure 3-15. Adfluvial Redband Trout found in Upper Klamath Lake and tributaries can attain lengths of over 750 mm (30 inches). Due to their size, visually distinguishing Redband Trout from steelhead trout will be difficult. Photo by Jason Ching.

We recommend that when large Redband Trout and steelhead trout are co-occurring in sympatry, determination of anadromous forms of *O. mykiss* be made by using microchemistry of otoliths, scales and/or fin rays following the methods used by Zimmerman and Reeves (2000 and 2002), Hodge et al. (2016), and Wells et al. (2000). Scales should also be collected from *O. mykiss* and follow methods described by Davis and Light (1985) to determine life history landmarks, such as seawater entry and spawning events, similar to analysis that was conducted by Hodge et al. (2016) in the Lower Klamath Basin.

Tissue samples should also be collected for genetic analysis to determine the source of individuals similar to Pearse et al. (2011) or through more fine scale methods such as single-nucleotide polymorphism (SNP) analysis (Campbell et al. 2015). Genetic investigations should also be conducted to determine if anadromous vs. resident life histories can be determined through genetic analysis. The combination of these analyses will allow for the determination of whether or not steelhead trout are accessing and utilizing habitat above the former dams as well as determine what additional life histories are possibly being expressed by *O. mykiss* (Pearse et al. 2014). Genetic analyses should include investigations into specific genes that are expressed by differences in run timing (winter vs summer-run; Prince et al. 2017). Acquiring samples for life history determination could be attained by multiple methods. Hook and line sampling for adults has shown to be effective in the Klamath River for Redband Trout and should be effective for steelhead trout. A video weir with an option for capture in Spencer Creek would allow for trapping and sampling steelhead trout migrating up Spencer Creek. The ability to capture and sample fish at Keno Dam and/or Link River Dam will allow for sampling of steelhead trout as they migrate to Upper Klamath Lake and its tributaries. Carcasses encountered during redd surveys during the spawning season should be sampled (scales, tissue, otoliths) for life history determination. However, few steelhead trout carcasses are expected given iteroparity and kelting. Out-migrating juveniles will be trapped at locations where juvenile downstream traps are deployed, and a subsample of juveniles should be sampled to determine maternal origin, which can be determined through otolith microchemistry (Zimmerman and Reeves 2002), and potentially genetically (Pearse et al. 2014). Monitoring steelhead trout will need to be adaptable given the many uncertainties associated with how repopulation could occur (top down, bottom up, or both), and should focus on acquiring samples described above on as many suspected steelhead trout forms of *O. mykiss* in the Upper Klamath Basin as possible.

3.5.1 Resident O. mykiss Pre-Dam Removal Baseline Studies

Due to the complexities and uncertainties regarding monitoring steelhead trout, baseline studies involving resident forms of *O.* mykiss (sometimes referred to as Redband Trout) should occur prior to dam removal. Resident *O. mykiss* baseline studies will help determine how steelhead trout might utilize newly accessible upper basin habitat as well as help understand potential genetic introgression among resident and anadromous populations.

Recommended baseline studies prior to dam removal:

- Genetic assessment of *O. mykiss* populations above and below the existing hydropower dams to be removed.
- Increased understanding of current resident *O. mykiss* life histories in the Upper Klamath Basin with a focus on the Klamath River and Spencer Creek.
- Survey of spawning resident *O. mykiss* activity including distribution, timing, and physical characteristics of redd construction
- Investigations of behavior, movement, and survival of juveniles in tributaries above Upper Klamath Lake.

Spencer Creek (rkm 371) is a major tributary to the Klamath River between J.C. Boyle Dam (slated for removal) and Keno Dam. It is the first major tributary of the Klamath River that steelhead trout will encounter above the site of JC Boyle Dam and is a tributary that the current Redband Trout population below Keno Dam utilizes for spawning habitat. We recommend that a video weir be installed on Spencer Creek prior to dam removal. This video weir will allow for investigations on the run timing, size distribution, and abundance of Redband Trout that spawn in this tributary. Redband Trout spawning surveys should also be conducted in Spencer Creek to help identify potential habitat that may also be suitable for steelhead trout.

Oregon Department of Fish and Wildlife conducts spawning surveys in tributaries above Upper Klamath Lake where adfluvial Redband Trout spawn and Oregon State University is currently conducting extensive research investigating the movement and behavior of adult adfluvial Redband Trout in Upper Klamath Lake. These investigations will provide important baseline information to determine any behavioral changes, following the re-establishment of steelhead trout. However, little is known about utilization of habitat, migration, and survival of juvenile Redband Trout in tributaries above Upper Klamath Lake. We recommend that baseline studies investigate the life histories and behavior of juvenile Redband Trout in tributaries above Upper Klamath Lake, especially in the Sprague River system where the majority of stream habitat (453 km current, potential habitat) exists and mainstem habitat is characterized as having extremely warm water temperatures (> 22°C) with areas of cold, groundwater-fed refugia.

Genetic characterization of resident *O. mykiss* populations prior to dam removal is important for three main purposes. First, baseline genetic information on current populations will allow for comparisons to determine the occurrence and prevalence of introgression among resident and anadromous populations. Genetic characterization of resident *O. mykiss* was conducted in the Elwha River Watershed prior to and following dam removal, and the results demonstrated how a genetic baseline can be used as a conservation management tool to monitor the repopulation of steelhead trout (Winans et al. 2017; Fraik et al. 2021). Second, genetic information will allow for determining the source population(s) of steelhead trout re-inhabiting areas above the former dams (Fraik et al. 2021). Knowing the source population(s) will help guide where conservation and restoration programs should focus their efforts to help restore the anadromous life history of *O. mykiss* in the Upper Klamath Basin. Lastly, genetic analysis will allow tests for potentially adaptive differences among populations. We recommend that a systematic approach be taken to collect tissue samples of *O. mykiss* populations above and below the dams prior to their removal. If funding for analysis is not readily available, tissue samples could be stored in the Oregon State Fisheries Genetic Lab repository and database until funding to conduct the analysis becomes available.

3.6 Pacific Lamprey

Four resident species and one undescribed species of lampreys occur in the Klamath River watershed above Iron Gate Dam (Table 3-8). Two of the three parasitic forms of resident lampreys found in the Upper Klamath Basin (Klamath River Lamprey and Klamath Lake Lamprey) will occur in sympatry with Pacific Lamprey in habitat above the former dam sites. Anadromous Pacific Lamprey and resident lampreys may be difficult to distinguish from each other due to common phenotypic characteristics as adults (Figure 3-16), and especially as juveniles. New developments in genetic analysis have the potential to distinguish anadromous lamprey forms from their resident counterparts (see Hess et al. 2014 and 2015). Baseline studies prior to dam removal should investigate this potential among lampreys in the Klamath River Basin, as well as investigate the distribution of resident lampreys.

Table 3-8. Summary table of resident lamprey species (Genus: *Entosphenus*) currently found in the Klamath River watershed above Iron Gate Dam.

Species	Common Name	Feeding mode	Adult length (mm)	Distribution
lethophagus	Pit-Klamath Brook Lamprey	Non-parasitic	<210 (Moyle 2002)	Tributaries to Upper Klamath Lake
similis	Klamath River Lamprey	Parasitic	140 – 270 (Moyle 2002)	Upper Klamath Lake, Klamath River below Keno Dam and tributaries
folletti	Northern California (Modoc) Brook Lamprey	Non-Parasitic	170 – 230 (Renaud 2011)	Lost River sub-basin
minimus	Miller Lake Lamprey	Parasitic	72-145 (Lorion et al. 2000)	Miller Lake watershed and headwaters of Williamson River and Sycan River
Unresolved taxonomy	Klamath Lake Lamprey	Parasitic	350 - 400 (ODFW 2016)	Upper Klamath Lake and tributaries

Lampreys captured above the former dams during regular fish monitoring practices should be measured (total body length), photos taken on measuring board, and a non-lethal tissue sample be taken for genetic analysis and species identification. Due to the potential difficulties of identifying Pacific Lamprey from resident species (e.g., Goodman et al. 2009; Docker et al. 2016), genetic identification may be the only option to determine if, when, where, and how Pacific Lamprey are repopulating the Upper Klamath Basin. Electrofishing that targets larval/juvenile Pacific Lamprey should also be conducted when it is thought that adults have entered a specific stream. Larval and/or juvenile lampreys are even more difficult to identify than adults are, and again genetic identification should be conducted through the analysis of non-lethal tissue samples. Lampreys, both adult and juveniles are also known to be caught in juvenile rotary screw traps that are specifically targeting juvenile salmonids (Moser and Paradis 2017). Because of these results, the locations and operation of juvenile salmonid screw traps will take into account the opportunity to also capture Pacific Lamprey.

Figure 3-16. Physical characteristics are similar between Pacific Lamprey (*Entosphenus tridentatus*; top; photo credit: Ben Clemens), and Klamath Lake Lamprey captured in a trap net in 2011 in the northern lobe of Upper Klamath Lake (Agency Lake) (*Entosphenus* sp.; bottom; photo credit: Bill Tinniswood).

4. A STRATEGY FOR ACTIVELY REINTRODUCING SPRING-RUN CHINOOK SALMON INTO THE OREGON PORTION OF THE UPPER KLAMATH BASIN[1]

4.1 The Purpose of Active Reintroduction

Active reintroduction is intended to provide a means of repopulating spring-run Chinook Salmon into suitable, historical habitat above Link River Dam (rkm 414.4; rm 257.5; includes Upper Klamath Lake and its tributaries). The goal of this active reintroduction is to release hatchery-reared, pathogen-screened spring-run Chinook Salmon juveniles that originate from the Klamath Basin into suitable tributaries of Upper Klamath Lake. Any hatchery program associated with this reintroduction shall be defined as and follow policy of a Conservation Hatchery Program. The objective is to produce enough returning adults from released juveniles to eventually create viable, self-sustaining population(s) of spring-run Chinook Salmon in the Upper Klamath Basin. It is important to emphasize that the end goal of this active reintroduction program effort, while initiated though a conservation hatchery-based approach is premised on the termination of the hatchery component as quickly as possible. The long-term supplementation of an Upper Klamath Basin spring-run Chinook Salmon population is not the intent nor objective of this reintroduction effort. A two-phased approach, in which the first phase involves investigative studies, is the most logical strategy to achieve the reintroduction objective at this time.

The purpose of this section is to first describe available habitat, potential life histories that may be expressed, upstream migrating conditions for adults, and available Klamath Basin donor stocks; and lastly, the methods and strategies for a two-phased approach to active reintroduction.

The spring-run Chinook Salmon reintroduction strategy will be limited by any budgetary constraints, availability of facilities, and the availability of a donor source of fish/gametes.

4.2 Conservation Hatchery Program

Any use of a fish hatchery program to reintroduce spring-run Chinook Salmon into the Upper Klamath Basin will be defined as a Conservation Hatchery Program. The program will be guided by the description and conceptual approach proposed by *A Conceptual Framework for Conservation Hatchery Strategies for Pacific Salmonids* (Flagg and Nash 1999) and shall follow ODFW policy regarding fish hatchery management (OAR 635-007-0542 thru 635-007-0545). Flagg and Nash (1999) define a conservation hatchery as a tool for providing demographic assistance in the rebuilding of naturally spawning populations, while limiting the genetic and ecological impacts of hatchery fish on wild fish by producing fish with wild-like attributes.

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[1] **Additional information relevant to the active reintroduction of spring-run Chinook Salmon can be found in the technical memorandum *Background information to active reintroduction of spring-run Chinook Salmon to areas above Keno, OR* (Huntington 2019).**

Oregon Department of Fish and Wildlife's Conservation Hatchery subsection of the Hatchery Program Management Plan (OAR 635-007-0545 subsection 11) states:

"Conservation hatchery programs operate to maintain or increase the number of naturally produced native fish without reducing the productivity (e.g., survival) of naturally produced fish populations. Conservation hatchery programs shall integrate hatchery and natural production systems to provide a survival advantage with minimal impact on genetic, behavioral and ecological characteristics of targeted populations. Implementation shall proceed with caution and include monitoring and evaluation to gauge success in meeting goals and control risks. Long-term conservation success shall be tied to remediating causes of the decline that resulted in the need for hatchery intervention. Once goals are met then the hatchery program will be discontinued."

The ODFW conservation hatchery program employed as part of the active reintroduction of spring-run Chinook Salmon into the Upper Klamath Basin above Link River Dam will be for "Restoration" as defined by OAR 635-007-0545 subsection 11(b):

"… outplants suitable non-local hatchery produced or naturally produced native fish to establish a population in habitat currently vacant for that native species using the best available broodstock."

Any ODFW use of a conservation hatchery for reintroduction purposes in the Upper Klamath Basin shall utilize ODFW's Klamath Hatchery, perhaps with specific improvements deemed necessary to allow it to serve this purpose. The Klamath Hatchery is located on Crooked Creek in the Wood River sub-basin, near the town of Fort Klamath. Potentially, other tribal facilities that have not yet been identified could be utilized for reintroduction purposes as well.

4.3 Habitat above Link River Dam and its Potential Use by Spring-Run Chinook Salmon

4.3.1 Available Habitat

Aquatic habitat in the Upper Klamath Basin includes many streams that are entirely sourced by cold groundwater, high elevation streams fed by precipitation (primarily snowmelt), and some consist of a mix of both groundwater and precipitation sources. Adding to this variety of habitat, the major streams of the upper basin flow into the very large (~ 28,000 hectares), hypereutrophic waterbody of Upper Klamath Lake. There have been multiple estimates of the quantity and quality of Chinook Salmon habitat above Link River Dam, first by Fortune et al. (1966) and then by Chapman (1981), PacifiCorp (2005), and Huntington and Dunsmoor (2006b). There has also been a recent effort to develop a more refined understanding of how spring-run Chinook Salmon might fit into this habitat, with an emphasis on migratory corridors, life history expression in diverse thermal environments, and fish use of Upper Klamath Lake (Huntington et al. *in prep*). We have compiled the above-mentioned estimates along with unpublished data from CBI, The Klamath Tribes, and ODFW, to classify stream reaches that have potential spawning habitat and/or juvenile rearing habitat above Link River Dam. These classifications are shown spatially in Figure 4-1 and quantified in Table 4-1. These broad classifications will help direct the locations of reintroductions. Further refined classification and quantification of available habitat is warranted and needed to estimate the potential adult salmon capacity and juvenile production of available habitats above Upper Klamath Lake but is beyond the scope of this document.

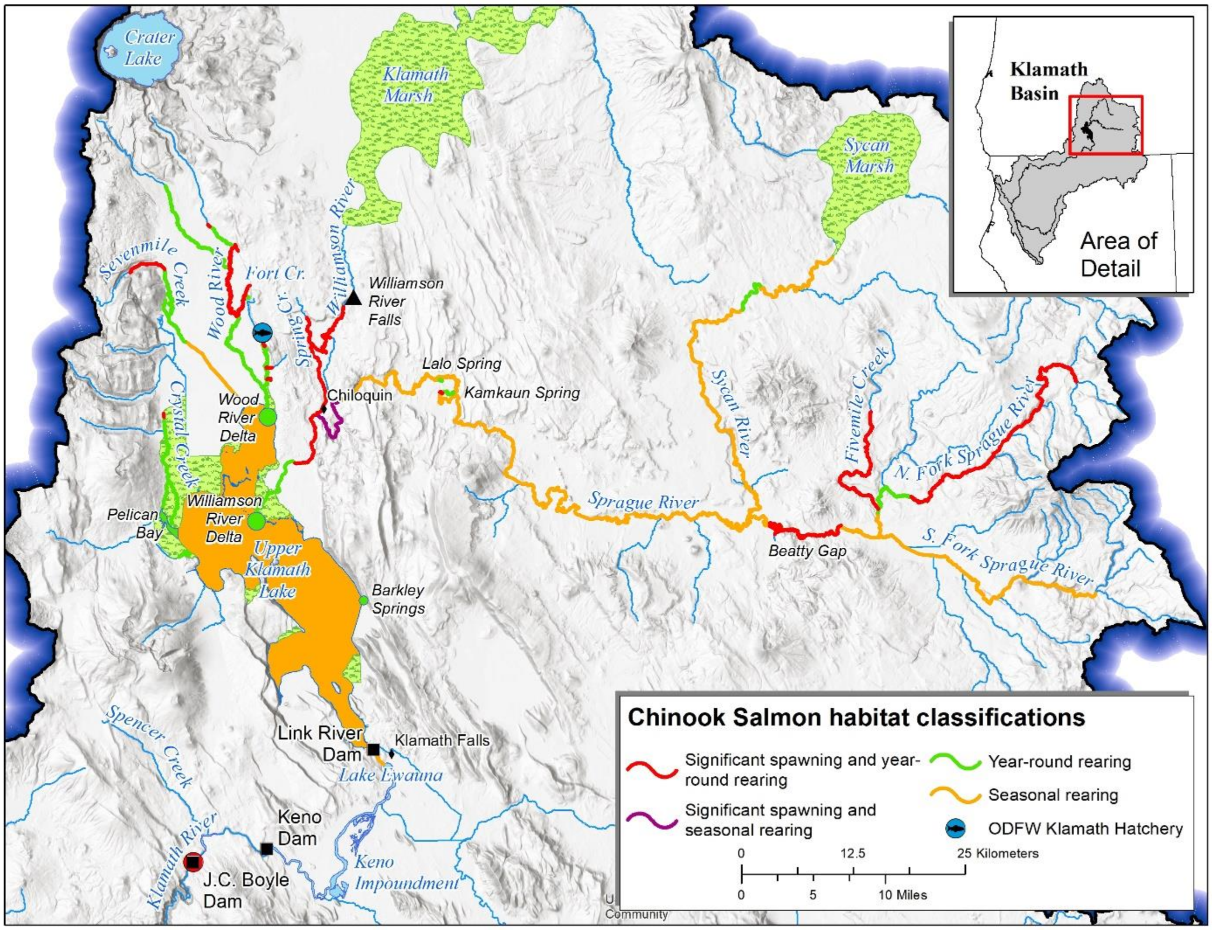


Figure 4-1. Potential Chinook Salmon habitat in the Upper Klamath Basin, above Link River Dam (rkm 414.4; rm 257.5). Habitat designation is based on Fortune et al. (1966); Chapman (1981); PacifiCorp (2005); Huntington and Dunsmoor (2006b); water temperature data from FLIR surveys (Watershed Sciences, 2000, 2008); Benjamin et al. (2016); and unpublished data by CBI, The Klamath Tribes, and ODFW.

Table 4-1. Potential amount of Chinook Salmon habitat in the Upper Klamath Basin, above Link River Dam (rkm 414.4; rm 257.5). Designation is based on Fortune et al. (1966); Chapman (1981); PacifiCorp (2005); Huntington and Dunsmoor (2006b); water temperature data from FLIR surveys (Watershed Sciences, 2000, 2008); Benjamin et al. (2016), and unpublished data by CBI, The Klamath Tribes, and ODFW.

System/waterbody	Habitat suitable for year-round use by Chinook salmon[1]		Habitat seasonally unsuitable for Chinook salmon absent refugia[1]		Comments
	Kilometers (miles)	Hectares	Kilometers (miles)	Hectares	
Upper Klamath Lk	---	---	28.9 (17.9)	28,538.6	Seasonally severe conditions
Williamson R Delta[3]	---	39.3	---	---	Lake-associated refuge
Wood R Delta[3]	---	6.7	---	---	Lake-associated refuge
Pelican Bay	---	84.3	---	---	Lake-associated refuge
Crystal/Rec Cr	19.3 (11.9)	62.2	---	---	Lake-associated refuge
Harriman Spr	1.1 (0.7)	5.6	---	---	Lake-associated refuge
Odessa Cr	1.2 (0.7)	4.7	---	---	Lake-associated refuge
Short Cr	0.6 (0.4)	3.9	---	---	Lake-associated refuge
Barkley Spr	0.4 (0.2)	3.0	---	---	Lake-associated refuge
Sucker Spr	---	0.1	---	---	Lake-associated refuge
Williamson R	34.8 (21.6)	148.2	---	---	
Spring-fed tributaries[2]	5.9 (3.7)	20.0	---	---	Spring Cr, Sunnybrook Cr, Larkin Cr
Sprague R	16.8 (10.4)	36.2	123.4 (76.7)	415.2	
Spring-fed tributaries[2]	5.1 (3.7)	11.1	---	---	River-associated refugia
N Fk Sprague R	45.7 (28.4)	50.9	3.8 (2.4)	6.2	
Fivemile Cr	21.6 (13.4)	11.8	---	---	
S Fk Sprague R	---	---	35.7 (22.2)	42.9	Severe limitations on Chinook use
Sycan R	5.1 (3.2)	6.5	55.6 (34.5)	78.6	Severe limitations on Chinook use
Wood R	35.0 (21.7)	67.2	---	---	
Spring-fed tributaries[2]	19.8 (12.3)	23.3	---	---	Crooked Cr and Fort Cr systems
Other tributaries	27.7 (17.2)	14.4	---	---	Annie Cr and Sun Cr
Sevenmile Cr	19.7 (12.2)	15.7	9.7 (6.0)	15.7	Includes Sevenmile Canal
Spring-fed tributaries[2]	2.7 (1.7)	2.0	---	---	Short Cr and Blue Spr Cr
Totals	262.5 (163.1)	617.1	257.1 (159.8)	29,097.2	

[1] Habitat suitable for year-round use or where the fish are likely to be seasonally dependent on refugia if present, based on evaluations of available data on temperature and water quality conditions.

[2] spring-fed tributaries are those whose flow volume is entirely (or very nearly so) attributable to a headwater spring. Such streams are common in portions of this basin.

[3] Habitat within the Williamson River Delta and Wood River Delta were estimated from aerial photos and expert knowledge of these areas. Further investigations into the total year-round usage of these areas of UKL is needed.

4.3.2 Key Temperature Characteristics of the Available Habitat

The Upper Klamath Basin has a wide spectrum of water temperature and quality characteristics, which will likely influence the life history diversity of reintroduced Chinook Salmon (Figure 4-2). The timing of spring-run Chinook Salmon spawning, emergence, growth rates of rearing juveniles, and patterns of juvenile movement are likely to differ among streams and major spawning areas. In this regard, fish spawning in different thermally influenced streams on the same date in the upper basin may have offspring emerging as many as five months apart (Figure 4-2). Eggs incubated in the spring-sourced water available at the ODFW Klamath Hatchery would emerge as fry on dates that would only match some of the spawning areas and plausible

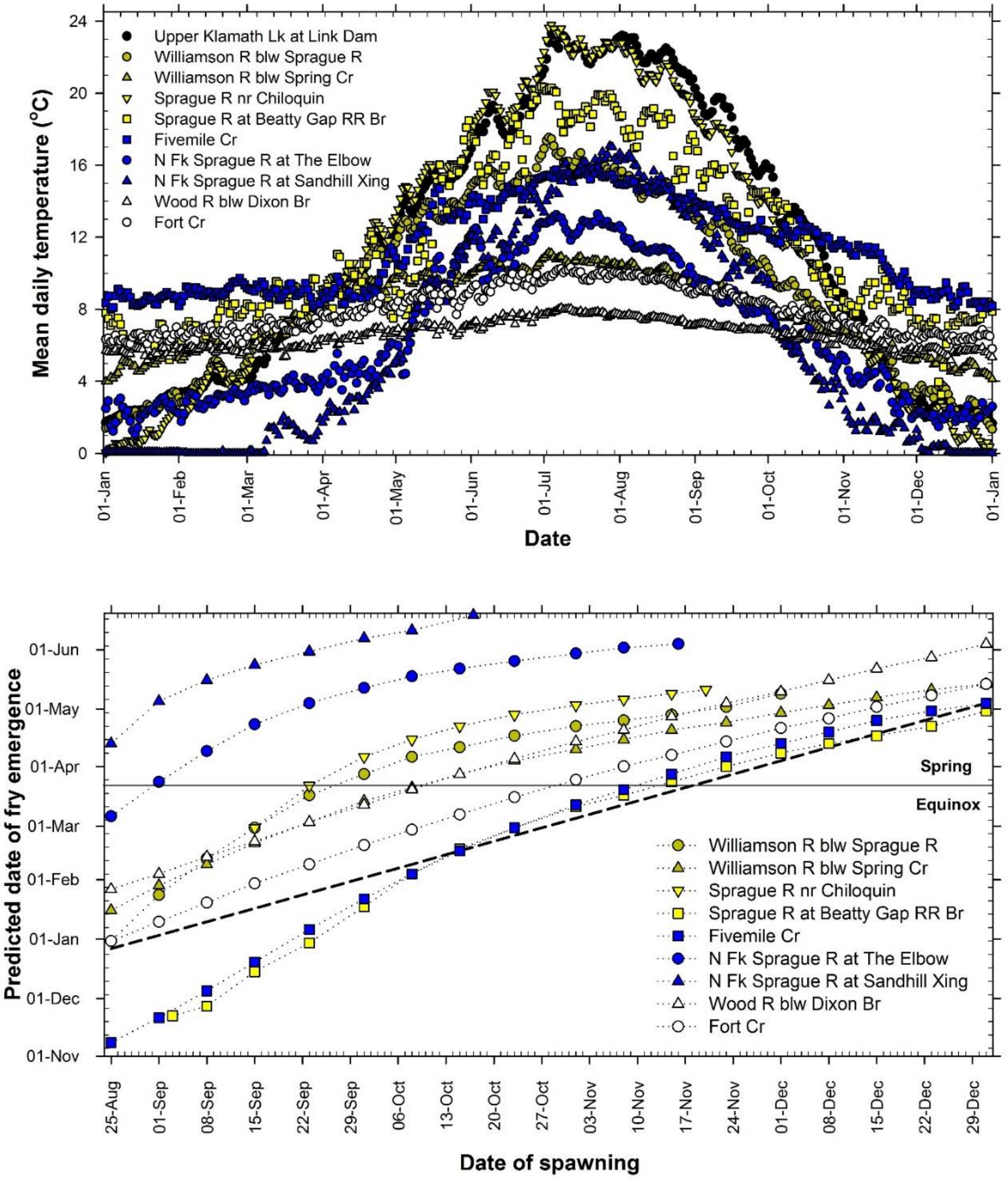


Figure 4-2. Mean annual thermal regimes for 10 sites in the Upper Klamath Basin above Link River Dam (above) and relationships predicted between Chinook Salmon spawn timing and fry emergence for the 9 of these sites on potential spring-run Chinook Salmon streams using Model 4 from Beacham and Murray (1990) (below). The dashed diagonal line represents spawning-to-emergence patterns for the coldest water (7.8 °C) currently available at ODFW Klamath Hatchery near Fort Klamath, OR. Adapted from Huntington et al. (in prep). Streams where temperature data were collected are depicted in Figure 4-1.

emergence dates (some Wood River tributaries, Williamson River tributaries, Fivemile Creek, and groundwater spring influenced reaches of the Sprague River). One possible solution to this problem is the addition of a chiller at the hatchery, which would cool water during incubation, thus slowing down the time to emergence at the hatchery to something more similar to groundwater/snow-melt sourced systems (North Fork Sprague River).

4.4 Life History Expression by Juvenile Spring-Run Chinook Salmon

Chinook Salmon are well known for the diversity of their life histories (Healy 1991; Quinn 2018). This diversity reflects a complex interplay between their rearing environments, relationships between fish size, growth rates, and seasons of the year (day length/photoperiod), and environmentally mediated genetic regulation of physiological processes that affect downstream migration and readiness to enter the ocean (Healy 1991; Quinn 2018).

As previously mentioned, the Upper Klamath Basin spring-run Chinook Salmon habitats provide a unique and diverse mix of thermal environments that will affect the emergence timing, feeding opportunities, and downstream dispersal patterns of juveniles. Upper Klamath Lake adds to this environmental diversity. We anticipate seeing many of the rearing and movement patterns expressed by spring-run Chinook Salmon in the Lower Klamath Basin, including early migrant fry, possibly sub-yearling (Type I) smolts, autumn (Type II) smolts, and yearling (Type III) smolts. In addition, due to the hydrography and diverse thermal environment of the upper basin, the expression of additional life histories is possible.

We have adopted a modified version of the conceptual and descriptive model of potential juvenile spring-run Chinook Salmon life histories and associated migratory pathways that Schroeder et al (2016) used to describe the dispersal patterns of young salmon in the Willamette Basin, Oregon (Figure 4-3). The model will be modified further as needed to best-fit observations made subsequent to the return of spring-run Chinook to the Upper Klamath Basin.

4.5 Adult Migration Conditions for Spring-Run Chinook Salmon Returning to the Upper Klamath Basin

4.5.1 Adult Holding Conditions for Spring-Run Chinook Salmon in The Upper Klamath Basin

The extended period that adult spring-run Chinook Salmon spend in freshwater is considered one of the most frequent constraints on their presence or abundance at the southern end of their range, particularly due to a need for cool to cold water temperatures during summer (Bjornn and Reiser 1991; Nehlsen et al. 1991). Thermal conditions are highly variable among streams in the Upper Klamath Basin, but streams fed by groundwater appear to provide the coolest and most climate-resistant water temperatures in the Klamath-Trinity system (Huntington 2012). Summer water temperatures suited for holding adult spring-run Chinook Salmon through summer are found in many areas above Link River Dam, particularly the Williamson River and its tributary Spring Creek, the Wood River system, and in the large refuge system associated with Pelican Bay (northwest Upper Klamath Lake). Habitat cool enough to hold significant numbers of spring-run Chinook Salmon through summer in the Sprague River system, however, is separated

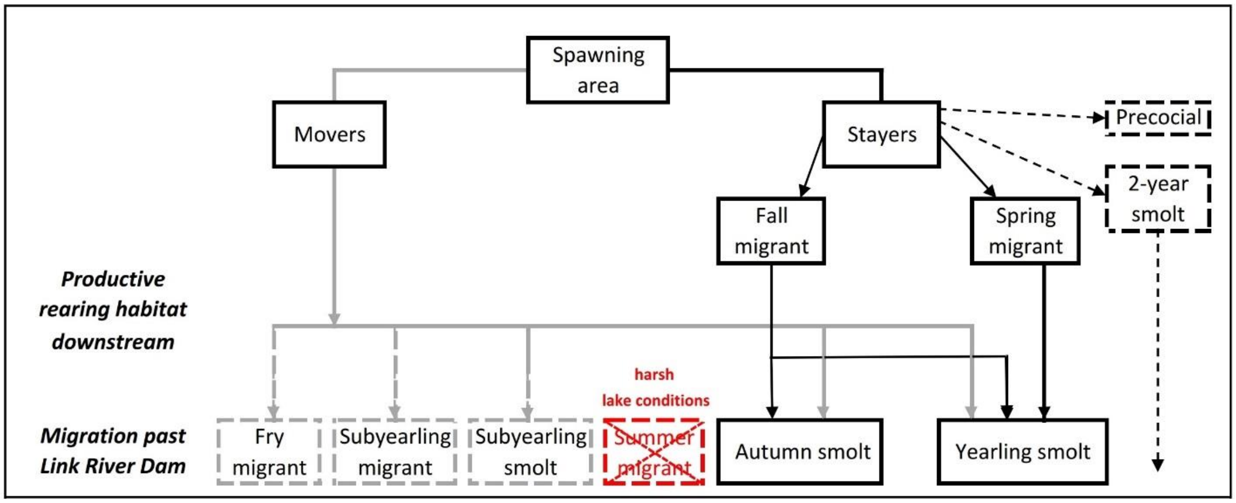


Figure 4-3. Migratory pathways that juvenile spring-run Chinook Salmon may follow from spawning areas in Upper Klamath Lake tributaries downstream to Link River Dam (rkm 414.4; rm 257.5) at the outlet of Upper Klamath Lake, OR. Pathways are given for two types of fish, those that rear in spawning areas ("stayers" = black lines) and those that migrate from spawning areas as fry to rear in productive habitat downstream ("movers" = gray lines). Pathways shown by dashed lines await confirmation when the fish are reintroduced. Adapted from Schroeder et al. (2016).

by sizeable distances and concentrated at Kamkaun Spring, near or within Beatty Gap, and in the North Fork Sprague River watershed (Huntington 2012).

4.5.2 Inter-annual Variation in Spring-Run Chinook Salmon Escapements

Spring-run Chinook Salmon populations in the Klamath-Trinity and Rogue River (a similar, adjacent basin used as a comparison) Basins exhibit high levels of annual variability in adult escapement (Figure 4-4). Coefficients of variation in escapement during the 1990-2015 period were 0.637 for the Salmon River (CA) population, 0.922 for the hatchery-influenced Trinity River (CA) population, and 0.590 for the Rogue River (OR) population (CDFW 2018; ODFW 2018). This variation has the potential to make management of a reintroduction effort challenging due to its emphasis on natural production. Lags between adult returns from smolt releases and returns of natural-origin fish have the potential to create mismatches between intended levels of population support and what might occur naturally. An adaptive management approach to this issue when it is deemed appropriate will help balance the needs of hatchery smolt releases as well as addressing the needs of naturally produced juveniles.

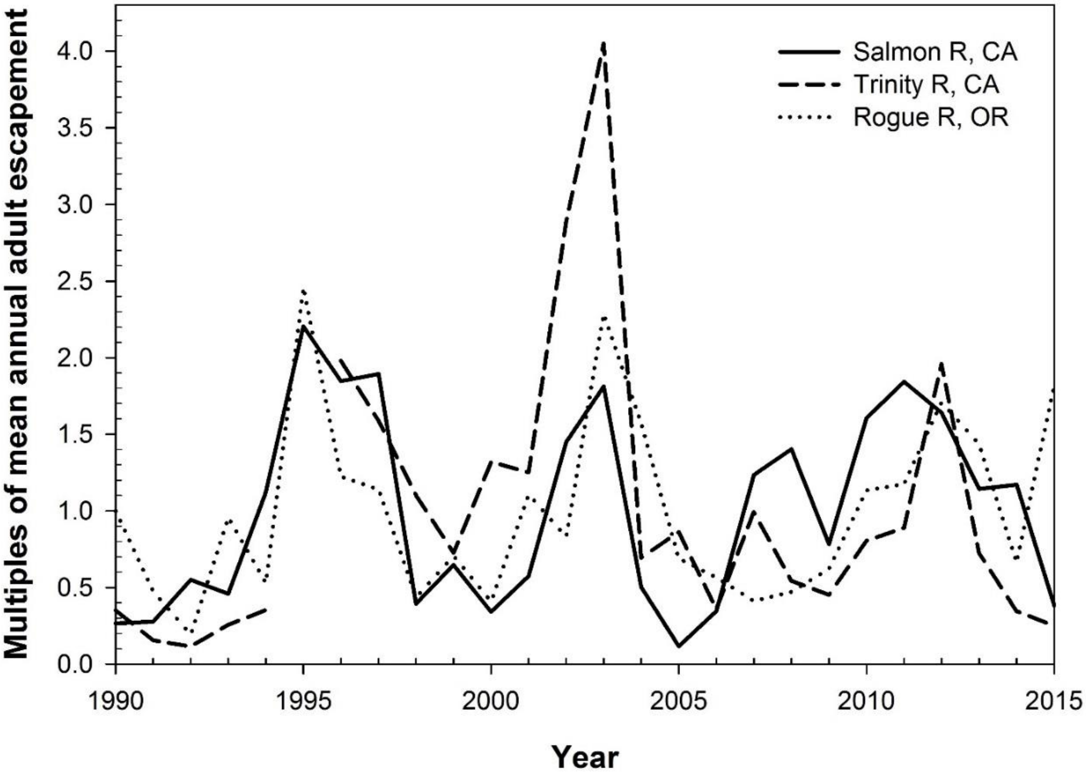


Figure 4-4. Annual escapements of naturally spawning spring-run Chinook Salmon normalized to mean escapement for the Salmon River (mean = 674), Trinity River mainstem above Junction City (mean = 8,224), and Rogue River above Gold Ray (mean = 8,431), 1990-2015. Sources: Sources: CDFW (2018) and ODFW (2018).

4.6 Klamath Basin Stocks Available for Active Reintroduction

An in-basin stock(s) of spring-run Chinook Salmon will be used for Upper Klamath Basin active reintroduction efforts. Currently, the availability of in-basin stocks is limited to two Klamath River sub-basins, the Trinity River and Salmon River, as described in the *Approaches to Reintroduction* section (see Spring-run Chinook Salmon in 2.6.1 and Figure 2-3). The genetic structure of Chinook Salmon populations in the Klamath River Basin is primarily influenced by geography, consisting of three major genetic groups separated by geographic regions (lower Klamath River below the confluence of the Trinity River, Upper Klamath River, and the Trinity River; Kinziger et al. 2013). Gene flow between the two geographical regions of the Trinity River and Upper Klamath River (Klamath River and tributaries upstream of Trinity River confluence to Iron Gate Dam), which form the Upper Klamath and Trinity Rivers ESU is described as a one-dimensional, linear, stepping-stone model where gene exchange occurs between adjacent populations (Kinziger et al. 2013). The fact that this geographic genetic structure exists is astounding given the intensity of hatchery supplementation spanning more than half a century in the basin. Maintaining this genetic structure is a basin-wide priority, and is one of the main factors, which also includes the cultural significance of Klamath salmon, as to why an in-basin stock(s) will be used for reintroduction efforts.

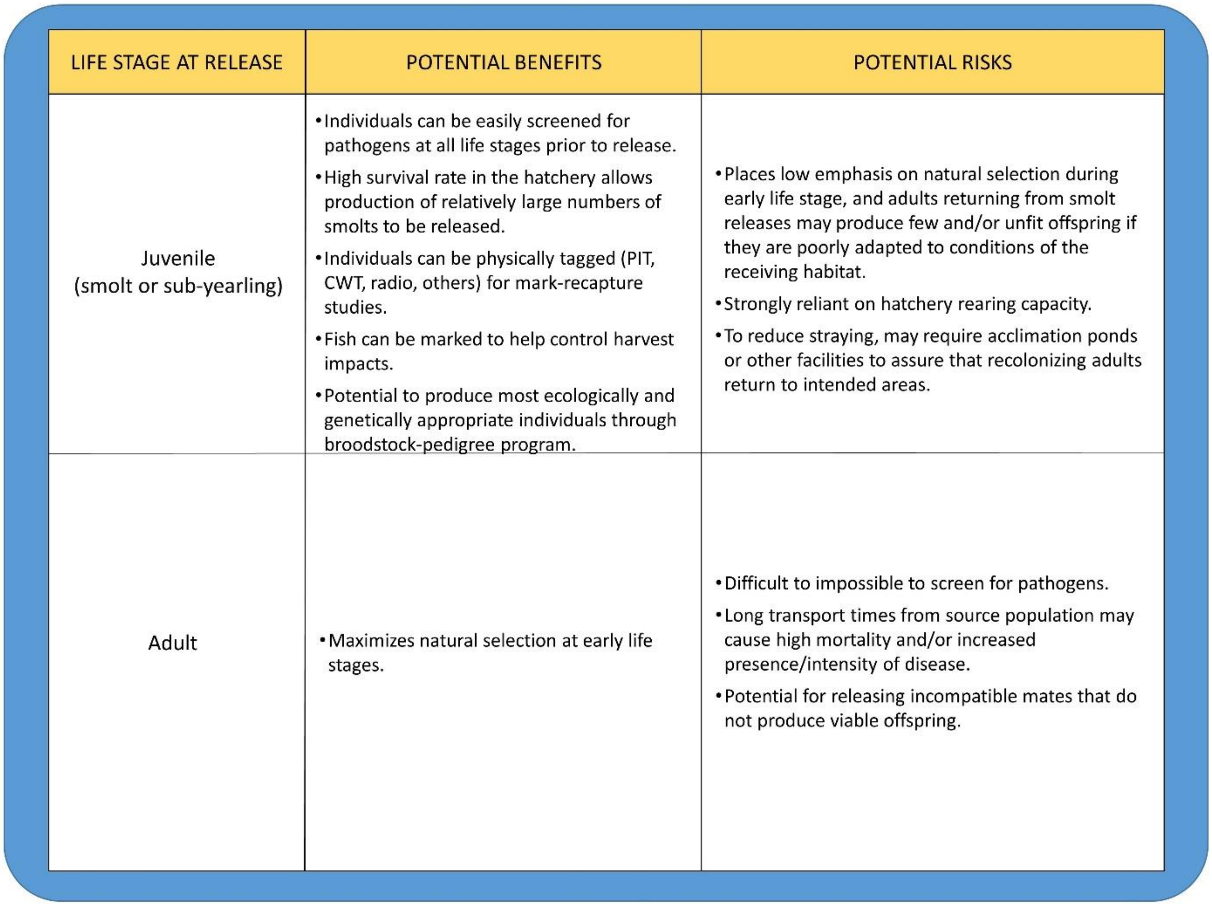
In addition to the geographically influenced genetic structure of Chinook Salmon in the Klamath Basin, a single locus (GREB1L), as well as a genome-wide region on a single chromosome has been identified as being associated with the timing of freshwater entry or Chinook Salmon ecotype (commonly referred in this document as spring-run vs. fall-run; referred to in other documents as pre-mature and mature migration phenotype) (Prince et al. 2017; Narum et al. 2018; Carlos Garza, NMFS, Personal Communication). This region of strongest association for ecotype is prevalent throughout the coastal range of Chinook Salmon (Prince et al. 2017; Carlos Garza, NMFS, Personal Communication). In the Klamath River Basin, the genotypes associated with this region are in near equilibrium where homozygous individuals for the spring-run ecotype are still present (Trinity River Basin and Salmon River Basin) (Carlos Garza, NMFS, Personal Communication). Chinook Salmon that enter the Klamath River estuary in the spring (spring-run) express a homozygous genotype at the region of strong association for spring run timing, while individuals that enter in the late-summer through fall (fall-run) express a homozygous genotype at the region of strong association for fall run timing, and individuals that are heterozygous express an intermediate timing of entry into the estuary (summer-run) (Carlos Garza, NOAA/NMFS, Personal Communication). Genetic analysis of ancient DNA from archeological sites in the Upper Klamath Basin, investigating a gene associated with run timing, supports the historical evidence of spring-run Chinook using habitat in the Williamson and Sprague Rivers (Thompson et al. 2019).

The average run size of spring-run Chinook Salmon is substantially higher in the Trinity River sub-basin than the Salmon River sub-basin (14,874 vs. 674; for more details see *Chinook Salmon* in 2.6.1). Initially, Trinity River spring-run Chinook will be used to propagate juveniles for active reintroduction into the Upper Klamath Basin. If, during certain years, the run of spring-run Chinook Salmon in the Salmon River is relatively robust, and it is deemed advantageous and scientifically appropriate, individuals sourced from this stock could be incorporated into the reintroduction effort. Another potential option to be considered is a program in which Upper Klamath River fall-run Chinook Salmon and Trinity River spring-run Chinook Salmon are selectively bred over a 6–8-year process to produce a spring-run homozygous genotype fish that retains 5/8 Upper Klamath River ancestry (Carlos Garza, NOAA/NMFS, Personal Communication).

4.7 Methods for Actively Reintroducing Spring-Run Chinook Salmon

Two common methods for actively reintroducing Chinook Salmon into previously occupied habit include the release of juveniles (smolts or sub-yearlings) propagated from captured adults (typically captured at a hatchery) and the release of captured adults into the receiving habitat. Both of these methods come with their own inherent benefits and risks, which are unique among reintroduction programs and situations. In particular, adult fish transferred from lower basin streams carry a higher potential of introducing novel pathogens into the upper basin habitats. The unique diversity, endemism, and value (both culturally and recreationally) of native, resident fishes in the Upper Klamath Basin heightens the concern and potential impacts of inadvertently introducing fish pathogens during the initial stages of the reintroduction. Table 4-2 summarizes the potential benefits and risks associated with releasing smolts or sub-yearlings vs. releasing adults into the Upper Klamath Basin.

Table 4-2. Potential benefits and risks matrix of release methods for actively reintroducing spring-run Chinook Salmon into the Upper Klamath Basin. Methods involving the release of early life stages allows for careful screening against fish pathogens not present in the Upper Klamath Basin. Releases using adult fish is not currently considered feasible given the lack of screening for pathogens and risks associated with introducing pathogens not currently present in the Upper Klamath Basin.



LIFE STAGE AT RELEASE	POTENTIAL BENEFITS	POTENTIAL RISKS
Juvenile (smolt or sub-yearling)	• Individuals can be easily screened for pathogens at all life stages prior to release. • High survival rate in the hatchery allows production of relatively large numbers of smolts to be released. • Individuals can be physically tagged (PIT, CWT, radio, others) for mark-recapture studies. • Fish can be marked to help control harvest impacts. • Potential to produce most ecologically and genetically appropriate individuals through broodstock-pedigree program.	• Places low emphasis on natural selection during early life stage, and adults returning from smolt releases may produce few and/or unfit offspring if they are poorly adapted to conditions of the receiving habitat. • Strongly reliant on hatchery rearing capacity. • To reduce straying, may require acclimation ponds or other facilities to assure that recolonizing adults return to intended areas.
Adult	• Maximizes natural selection at early life stages.	• Difficult to impossible to screen for pathogens. • Long transport times from source population may cause high mortality and/or increased presence/intensity of disease. • Potential for releasing incompatible mates that do not produce viable offspring.

Juvenile Releases

One advantage of using juveniles raised in a conservation hatchery is that the high egg-smolt survival rates allow production of large numbers of fish to be released to initiate or support adult returns. Hatchery-raised juveniles can also be marked with Passive Integrated Transponder (PIT) tags, telemetry tags, CWT and other physical tags, which will allow for rigorous studies on their survival, movement behavior, and success of outmigration through waterbodies in the Upper Klamath Basin and through the Klamath River to the Ocean. Coded-wire tags also allow an assessment of the relative survival of different releases by their recovery in fisheries (ocean and in river). Juveniles can also be marked in such a way that they can be identified when returning as adults, thereby enabling managers with information that can be used to minimize harvest impacts in ocean fisheries and in freshwater at the time of adult return.

One disadvantage of using smolt releases includes unnatural selective pressures from the hatchery environment, which can lead to decreased survival and nonadaptive behavior in the wild. Propagating fish in a crowded hatchery environment can also heighten the risk of epizootic events along with the potential problem of accurately determining when juveniles are smolting and ready for release. In addition, rearing young fish in a hatchery is a labor-intensive process in terms of staffing and costs.

As part of the strategy for releasing smolts, the use of acclimation ponds or facilities should be used at release sites whenever feasible. The use of acclimation ponds prior to smolt release exposes fish to olfactory cues on which imprinting occurs during smoltification and can improve adult homing to release sites, lowering straying rates to something closer to natural levels (Hasler et al. 1978; Clarke et al. 2010). Clarke et al. (2012) found that an extended acclimation period prior to releasing spring-run Chinook Salmon smolts may improve survival to adulthood when the smolts have been reared in groundwater supplied hatcheries (like ODFW's Klamath Fish Hatchery).

Juvenile release timing will be important because it is likely to affect migration behavior, survival, and adult return rates. Aligning release size and location with what might occur naturally becomes increasingly difficult as the period of juvenile rearing in the hatchery is extended. Releasing smolt-sized individuals versus younger juveniles may be the quickest way to get a larger number of adult spawners to repopulate available habitat due to higher juvenile survival rates of smolts. It is important to note that returning adults from the released juveniles will be the first spring-run Chinook Salmon to repopulate the Upper Klamath Basin.

Smolts and sub-yearlings raised in a hatchery can be screened for pathogens from the time they are gametes, through hatchery rearing, to time at release. Because of this, releasing hatchery raised smolts and/or sub-yearlings represents the method with the lowest potential risk associated with introduction of novel fish pathogens into the Upper Klamath Basin (Table 4-2). Initially, the method used to repopulate spring-run Chinook Salmon into the Oregon portion of the Upper Klamath Basin will be the release of hatchery raised smolts or sub-yearlings into suitable streams above Upper Klamath Lake (Figure 4-1).

Fertilized eggs will be transported from Trinity River Hatchery or from another appropriate facility/location in the lower basin to ODFW's Klamath Hatchery on Crooked Creek (and/or other appropriate facility), 8 miles west of Chiloquin just off Highway 62 at latitude 42.6514° and longitude -121.9464° (ODFW 2019). Eggs will be incubated, fry emerged and ponded, and juveniles reared at the Klamath Hatchery (and/or other appropriate facility) until time of release. All hatchery produced fish will be marked (fin clip or other clip) and ideally all will be injected with a CWT tagged. Initially, smolts and/or sub-yearlings will be released in the Wood River, Williamson River (downstream of Williamson River Falls), and North Fork Sprague River and their tributaries. Areas of release should occur in stream reaches identified as having significant spawning and year-round rearing habitat (see Figure 4-1).

Adult Releases

Initially, adult spring-run Chinook Salmon will not be released into the Oregon portion of the Upper Klamath Basin. The method of releasing adults represents the highest potential risk of introducing novel fish pathogens into the Upper Klamath Basin (Table 4-2). In the future, once adult Chinook Salmon have volitionally migrated upstream through the Klamath River into tributaries of Upper Klamath Lake, and it is scientifically and logistically sound and screening adults becomes more effective than it is currently, the release of adults as a method for repopulation could be considered.

4.8 A Two-Phased Approach to Spring-Run Chinook Salmon Reintroduction

The approach for reintroducing spring-run Chinook Salmon to suitable, historical habitat in tributaries above Upper Klamath Lake will consist of two phases. The actions taken in both phases will be adaptable as decisions to proceed or change direction will be informed by monitoring and evaluation of actions (Figure 4-5). Phase 1 will include studies involving the investigation of survival, movement, passage, and release methods of tagged juveniles, while also improving supportive conservation hatchery methods. Abundances of releases during Phase 1 will be relatively small but large enough to make conclusions about juvenile outmigration based on the data collected (thousands to tens of thousands of individuals). Strategies for reintroduction studies will be watershed and/or release site specific. Following decisions informed by the results of Phase 1, transition to Phase 2 will involve increasing fish releases (>100,000 smolt sized juveniles released per year) with the intent to produce a significant number of returning adults and make progress toward the objective of repopulating habitat in the upper basin to harvestable levels. Decisions to transition to Phase 2 will be watershed and/or release site specific (e.g., it could be decided to transition to Phase 2 in the North Fork Sprague River while reintroduction studies are still being conducted in the Williamson River). Monitoring and Evaluation of returning adults and the natural production of juveniles will follow the strategy described in section 3.

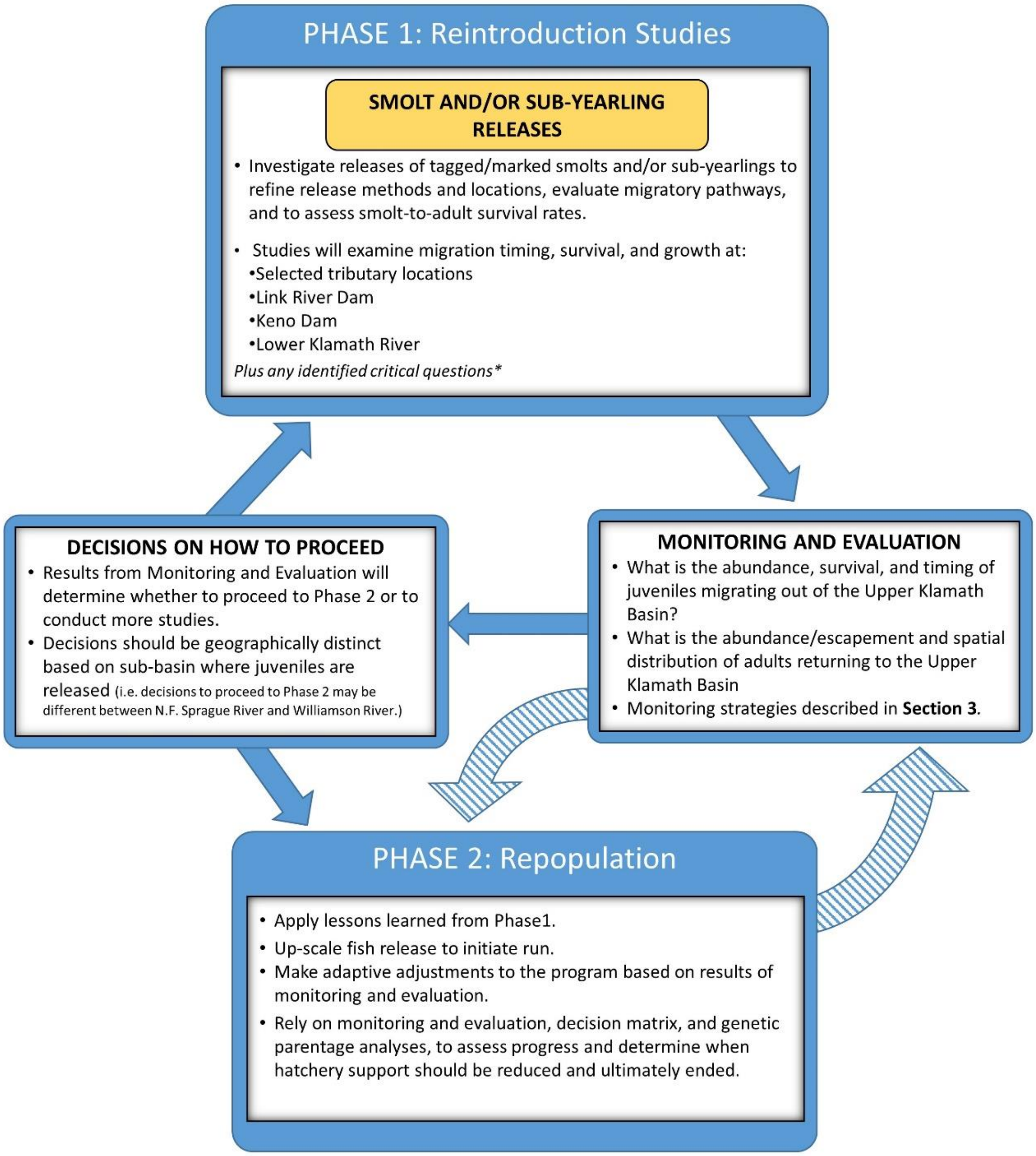


Figure 4-5. Adaptive management framework for actively reintroducing spring-run Chinook Salmon to the Upper Klamath Basin, Oregon. Active reintroduction will begin with relatively small releases of smolts and/or sub-yearlings in Phase 1 (Reintroduction Studies), decisions to move to Phase 2 (repopulation phase) or to continue with additional studies will be based on the results of the monitoring and evaluation during Phase 1. Progress towards self-sustaining populations will be informed by Monitoring and Evaluation of juveniles and returning adults (diagonal line arrows).

*Could involve targeted studies to identify limitations and narrow uncertainties regarding stock selection, release methods, pathogen resistance, hatchery rearing practices, or others.

4.8.1 Phase 1: Reintroduction Studies

The goal of Phase 1 of the Active Reintroduction effort will be to conduct studies that yield results important to moving the reintroduction effort toward Phase 2, repopulation. These studies will involve mark-recapture methods to investigate survival and movement of released hatchery-reared juveniles outmigrating from their stream of release, through Upper Klamath Lake, through Link River Dam, and through Keno Dam, and potentially to the ocean. During this phase all fish will be marked (e.g., PIT, CWT) and a statistically appropriate proportion will also be tagged with telemetry transmitters prior to release. The objective of Phase 1 is to determine survival, movement behavior, and success of hatchery-reared juveniles migrating out of the Upper Klamath Basin. Detections (recaptures) of released fish will occur at stationary PIT tag arrays, stationary telemetry receivers, land-based mobile or aerial telemetry surveys, and/or downstream juvenile traps. The results of Phase 1 studies will help inform and refine release methods (location, age at release, time of release, appropriate abundance, etc.), assess migratory pathways (especially through Link River Dam and Keno Dam), assess fish health, and potentially smolt-to-adult survival rates.

Fish Releases

<u>Juvenile releases</u>

Goal: Release tagged (telemetry and/or PIT, CWT) juvenile spring-run Chinook Salmon into suitable tributaries of Upper Klamath Lake. Detect released individuals at stationary PIT/telemetry stations strategically placed in streams and key bottle-necked migratory corridors, such as Link River Dam and Keno Dam and/or by mobile telemetry or active capture. Ideally, detections of returning adults or captures in the ocean fisheries would be possible.

Objective: Assess movement behavior, survival, health, and migration success of hatchery raised spring-run Chinook Salmon at critical locations such as entry into Upper Klamath Lake, Link River Dam, Keno Dam, and the Lower Klamath River. Depending on the abundance of juveniles released, assessments of smolt-to-adult survival could be made.

Location: Release juveniles in stream reaches with significant Chinook Salmon spawning and year-round rearing habitat (see Figure 4-1) in the Williamson, Wood River, and North Fork Sprague sub-basins.

Estimated duration: 4-5 years will allow for considerable information about out-migration success. Within 8 years, several release cohorts will have been encountered in fisheries or potentially returned as spawners.

Sample size: The number of fish released will determine the level of goals and associated objectives that could be achieved. Releases of 10,000 – 50,000 fish should have the ability to assess movement behavior, survival, health, and migration success from their release point to downstream of Keno Dam and locations in-between. Releases of over 50,000 fish should have a greater potential to also assess smolt-to-adult survival, either through detection in the fishery or through spawner escapement. A scaled approach with small initial releases (10,000 – 50,000 fish) progressing towards larger releases (>50,000) within a few years based on results may be the most efficient and feasible approach. Implementation details will depend on availability of gametes from the donor stock and funding resources needed to operate the program, including potential hatchery infrastructure needs. To meet the goals and associated objectives hatchery-raised juveniles should be large enough to be tagged with telemetry and/or PIT tags, and CWT.

Releases of juveniles will focus primarily on determining the success and/or failures of methods to actively reintroduce spring-run Chinook Salmon into tributaries of Upper Klamath Lake, while also determining an appropriate estimate for releases in Phase 2 (based on juvenile survival and potentially adult returns). Ideally, the release studies will involve the following:

1. Collect appropriate amount of fertilized spring-run Chinook Salmon gametes from Trinity River Hatchery (or other appropriate location in Klamath Basin) and transfer to ODFW's Klamath Hatchery (or other appropriate alternative facility) for rearing.

2. Tag juveniles at rearing facility when they are an appropriate size. All fish to be released will be implanted with a CWT and PIT tagged and a sub-sample tagged with telemetry transponders (acoustic and/or radio). A physical mark (such as a fin clip) should be considered prior to release to distinguish these fish among Chinook Salmon in the lower basin.

3. Release juveniles in reaches with suitable spawning and year-round rearing habitat in the Williamson River, Wood River, and North Fork Sprague River Watersheds (see fig 4-1). If deemed necessary, acclimation facilities should be used to hold fish for an appropriate length of time at release sites to improve imprinting of foster stream. Releases should be done at a justified and logistically sound time.

4. Conduct monitoring activities to assess the downstream migration of released juveniles, as well as their subsequent return migration as adults. Evaluation of mark-recapture data will be used to assess timing and survival through the migratory corridor as well as collect smolt-to-adult return survival data.

5. Conduct fish health assessments on a subset of recaptured juveniles if feasible.

<u>Releases of other life stages</u>

Releasing individuals at different life stages than those described above may be considered in the future depending on the results of the active reintroduction program efforts in establishing spring-run Chinook Salmon in the Upper Klamath Basin. Any shifts to releases of life stages other than juveniles would be preceded by a review of program effectiveness informed by information developed through monitoring efforts outlined in this plan.

4.8.2 Phase 2: Repopulation

Phase 2 of the active reintroduction effort will begin once Phase 1 studies have progressed to the point of sufficiently identifying the more effective methods and most suitable release sites. The primary goal of the Phase 2 effort will be to further initiate the run(s) using what was learned in Phase 1, and to adaptively manage an extended reintroduction process intended to yield self-sustaining natural runs of spring-run Chinook Salmon.

Returning adult spring-run Chinook Salmon will be monitored following the natural repopulation strategy and follow the guidelines in *Section 3* (Strategy for Monitoring) of this document. Genetic parentage analyses in assessing the development of upper basin runs will be a key tool in assessing the methods of active reintroduction. Other key biological indicators recommended by the Klamath River Expert Panel on the *Scientific Assessment of Two Dam Removal Alternatives on Chinook Salmon* include (per Goodman et al. 2011):

- Survival (recruitment) of PIT-tagged juvenile Chinook salmon returning to Keno Dam
- Characteristics of spawning sites selected by returning Chinook salmon
- Juveniles produced per female
- Survival through Upper Klamath Lake, Keno Impoundment/Lake Ewauna
- Juvenile migration timing and growth at each life stage

Real-time management of supplementation during the active reintroduction program will need to be highly flexible during Phase 2 because of the anticipated variability in salmon abundance. A hypothetical, visual example of what progress might look like is given in Figure 4-6. The run would go through an initiation stage strongly influenced by hatchery-origin fish, then would move through a transitional stage where support from the conservation hatchery was withdrawn in order to produce a self-supporting stage where it functions and sustains itself absent hatchery support. The exact years and patterns shown in the figure are arbitrary, but the large inter-annual variation in adult abundance is what should be expected. Figure 4-6 was constructed based on the variability seen within the Lower Klamath Basin in the return rates of hatchery-origin smolts and spawning escapements of existing natural spring-run Chinook Salmon populations in the Klamath Basin.

The strategy for monitoring and evaluating the repopulation of spring-run Chinook Salmon from active reintroduction efforts will follow those described in Section 3. Ultimately, the decision to cease the release of fish should be informed by parameters associated with viable salmonid populations as described by McElhany et al. (2000) and others (see section 3.2.3 of this document). Decisions to cease active measures should also be made independently among each sub-basin (Williamson, Wood, and Sprague Rivers). This criterion should be flexible and ideally become more refined following the results of Phase 1 studies. Constraints involved with the number of juveniles that are available to release each year, coupled with logistical, and potential ecological constrains (informed by Phase 1), may result in repopulation efforts occurring one sub-basin at time.

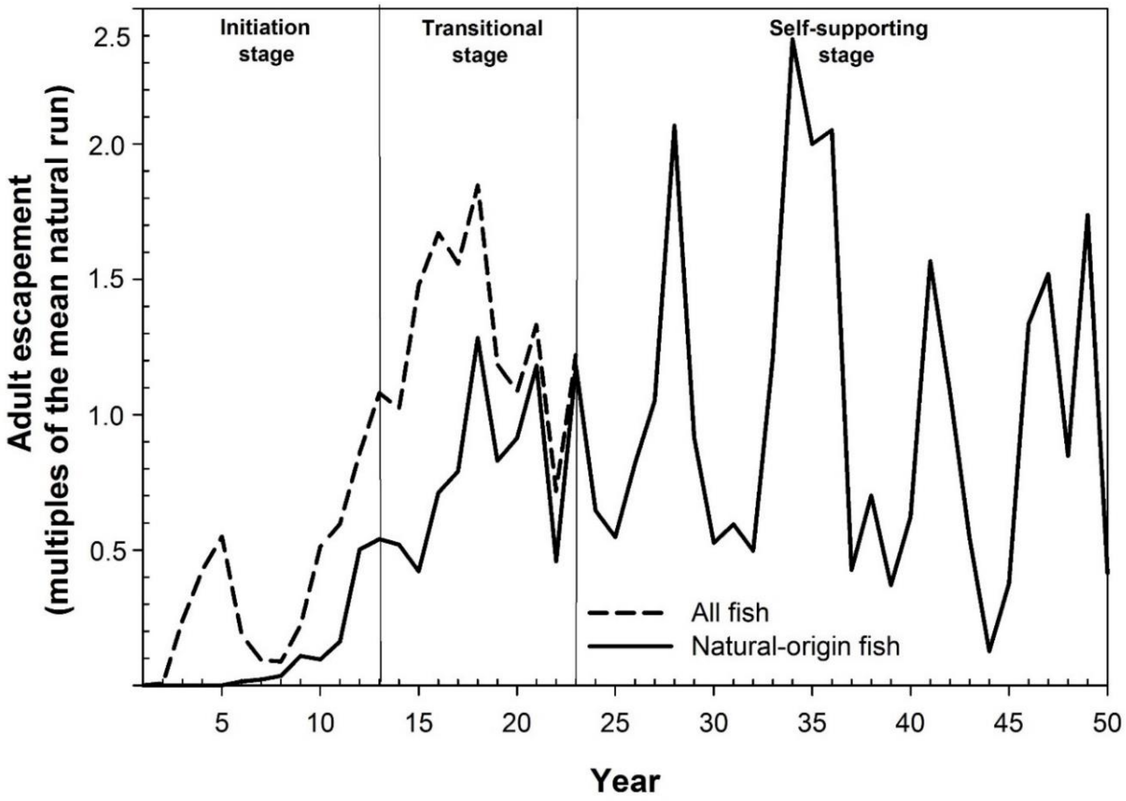


Figure 4-6. Hypothetical escapements of adult spring-run Chinook Salmon in response to an active reintroduction effort involving releases of hatchery-reared juveniles during Phase 2 (Repopulation Phase). Dashed-line represents both hatchery-origin and natural-origin fish, and the solid line represents natural-origin fish only.

5. SHORT AND LONG-TERM REPORTING

Information related to implementing this plan will be aggregated, reported, and posted in a publicly accessible ODFW website as available. In addition, an assessment will be conducted at the end of each species Repopulation Phase (fall-run Chinook = 12 years, Coho Salmon = 9 years, steelhead trout = 15, Pacific Lamprey = 15). The purpose of these assessments is to inform the decision-making process to determine whether or not active measures need to be undertaken to assist repopulation of these four species. Assessments will also strive to identify where key issues or uncertainties described in section 1.3, or other constraints, are hindering the ability of any of these four species to re-establish in new habitat. Summary reports of assessment results will be posted in the same publicly accessible ODFW website as other reporting documents for the plan.

Reporting on the results and progress of Phase 1 Reintroduction Studies of spring-run Chinook Salmon will occur as information becomes available. Phase 1 results will inform the adaptive management framework (Figure 4-5), which will guide the decisions to either conduct additional studies or move to Phase 2 (Repopulation Phase).

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