Klamath River Renewal Project

Third Administrative Draft

Definite Plan for Decommissioning

Appendix I - Aquatic Resources Measures

Draft & Confidential
For States and PacifiCorp Review Only

KLAMATH RIVER RENEWAL CORPORATION

May 2018

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Table of Contents

List of Tables

List of Figures

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EXECUTIVE SUMMARY

The Klamath River Renewal Corporation (KRRC) convened an Aquatic Technical Work Group (ATWG) comprised of agency and tribal fisheries scientists to review the aquatic resource (AR) mitigation measures included in the Klamath Facilities Removal Final EIS/EIR (2012 EIS/R; U.S. Bureau of Reclamation (USBR) and California Department of Fish and Game (CDFW) 2012), determine the appropriateness of the 2012 AR measures, and develop updated AR measures in accordance with ATWG input.

Through a series of nine meetings with the ATWG between April 28 and August 15, 2017, review of recent similar dam removal projects, and new scientific information that has been developed since the 2012 EIS/R, updated AR measures are proposed to be implemented as part of the Project.

The proposed AR measures include:

AR-1 Mainstem Spawning – A monitoring and adaptive management plan will be developed and implemented to offset reservoir drawdown effects on mainstem spawning of anadromous salmonids and Pacific lamprey. Tributary-Klamath River confluences in the Hydroelectric Reach (i.e., the Klamath River and tributaries from Iron Gate Dam [RM 192.9] to the upstream extent of J.C. Boyle Reservoir [RM 233.0]) and in the Iron Gate Dam to Cottonwood Creek (RM 184.9) reach will be monitored for 2 years post-dam decommissioning to ensure fish passage between tributaries and the Klamath River. Obstructions will be removed to restore volitional passage between the Klamath River and tributaries. A spawning habitat evaluation will also be completed on the Klamath River and four tributaries in the Hydroelectric Reach. If spawning habitat post-reservoir drawdown does not meet target metrics, spawning gravel augmentation will be completed on the mainstem. If tributary spawning gravel habitat is less than the target values following reservoir drawdown, the ATWG will convene to prioritize additional habitat restoration actions that will be undertaken to increase the amount of tributary habitat available to compensate for the loss of steelhead redds.

AR-2 Outmigrating Juveniles - To offset reservoir drawdown effects on outmigrating juvenile anadromous salmonids and Pacific lamprey, a sampling, salvage, and relocation effort will be completed to relocate juvenile salmonids, particularly yearling coho salmon, from the Klamath River between Iron Gate Dam and the Trinity River confluence during the fall prior to reservoir drawdown. An adaptive management plan will also be developed to assess and restore tributary-mainstem connectivity in the Hydroelectric Reach and the 8-mile reach from Iron Gate Dam downstream to Cottonwood Creek. The second component of the monitoring and adaptive management plan will include monitoring water quality conditions at 13 key tributary confluences. The ATWG will convene when tributary water temperatures reach 17°C (7-day average of the daily maximum values) and Klamath River suspended sediment concentration exceeds 1,000 mg/L. Based on ATWG guidance, a multi-day salvage effort for juvenile fish may be conducted at the Shasta and Scott rivers and single day salvage efforts at each other tributary confluence area by a 4-person crew and 2 transport trucks. Salvage effort will be coordinated with the ATWG and will reflect water quality conditions in the tributary confluences, outmigrating juvenile salmonid numbers, and other environmental conditions as necessary.

AR-3 Fall Pulse Flows – Increasing flows during the fall prior to reservoir drawdown was intended to promote Chinook salmon and coho salmon migration into spawning tributaries to reduce the effect of reservoir drawdown on spawning grounds. Due to water availability uncertainty and typical fall flows, the use of fall pulse flows would likely be ineffective in reducing the effects of suspended sediment on migrating and spawning salmon, steelhead, and green sturgeon.

AR-4 Iron Gate Fish Hatchery – To reduce the number of hatchery-reared juvenile coho salmon exposed to high suspended sediment levels, coho salmon will be released from Iron Gate Hatchery into the Klamath River 2 weeks later than the typical release schedule. Water quality monitoring stations established prior to reservoir drawdown will be used to determine when conditions in the mainstem Klamath River are suitable for the release of hatchery-reared coho salmon.

AR-5 Pacific Lamprey – The 3 km reach of the Klamath River downstream from Iron Gate Dam was proposed for Pacific lamprey ammocoete salvage and relocation in the 2012 EIS/R. Recent surveys have found very low ammocoete abundances between Iron Gate Dam (RM 192.9) and the Shasta River confluence (RM 179.3). Based on the assessment completed by KRRC and reviewed by ATWG, dam removal effects to Pacific lamprey ammocoetes in the 3 km reach downstream from Iron Gate Dam are anticipated to be minimal, and therefore, no action is recommended for Pacific lamprey ammocoetes.

AR-6 Sucker Rescue and Relocation – The dam decommissioning project will result in lethal impacts to Lost River and shortnose suckers inhabiting the Klamath River reservoirs. Since the two sucker species are lake-type suckers, Hydroelectric Reach sucker populations will not persist following the dam decommissioning. An adaptive management plan including sampling, salvage, and relocation of Lost River and shortnose suckers will be conducted in the Hydroelectric Reach reservoirs. Suckers will be translocated to appropriate recipient waterbodies that will ensure the translocated suckers, which are of unknown genetic composition, will not mix with Lost River and shortnose sucker recovery populations in Upper Klamath Lake. Less than 10 percent of the Hydroelectric Reach sucker populations are likely to be salvaged and relocated.

AR-7 Freshwater Mussels – Freshwater mussels located in the 8-mile long from Iron Gate Dam downstream to the Cottonwood Creek confluence, are anticipated to experience high mortality due to suspended sediment concentrations and bedload deposition. KRRC will prepare a reconnaissance, salvage, and translocation plan for approximately 15,000 to 20,000 mussels located in the deposition reach. Less than 10 percent of the freshwater mussel populations inhabiting the Klamath River downstream from Iron Gate Dam are likely to be salvaged and relocated

Chapter 1: Introduction

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1. INTRODUCTION

In 2012, the Department of the Interior developed the Klamath Facilities Removal Final EIS/EIR (hereafter, "2012 EIS/R"; U.S. Bureau of Reclamation [USBR] and California Department of Fish and Game [CDFG] 2012) to disclose the potential effects of removing four dams on the Klamath River (Project). The 2012 EIS/R identified significant short-term effects to the aquatic biological community. The 2012 EIS/R included aquatic resource (AR) plans to attempt to mitigate the possible short-term adverse effects of dam decommissioning. The Klamath River Renewal Corporation (KRRC) assembled an Aquatic Technical Work Group (ATWG) comprised of resource agencies, and tribal fisheries scientists in 2017 to review the previous AR measures, determine the feasibility and effectiveness of those plans, and to provide input on refined proposed actions that would best meet the intent of the previous AR mitigation measures. The ATWG included fisheries scientists representing California Department of Fish and Wildlife (CDFW), Oregon Department of Fish and Wildlife (ODFW), U.S. Fish and Wildlife Service (USFWS), National Oceanic and Atmospheric Administration (NOAA Fisheries, Yurok Tribe, Hoopa Valley Tribe, Karuk Tribe, and The Klamath Tribes.

Through a series of nine meetings between April 28 and August 15, 2017, the KRRC and the ATWG reviewed recent similar dam removal projects and new scientific information that has been developed since the 2012 EIS/R in order to update the 2012 AR measures. Updated AR measures are proposed to be implemented as part of the removal of four dams located on the Klamath River (Project). These measures are subject to consultation with aquatic resource agencies and negotiation of the final Biological Opinions for the Project.

Project effects are anticipated to be short-term in nature, with long-term benefits ultimately outweighing the Project impacts to the aquatic biological community. The aquatic effects will primarily occur from the release of reservoir sediment during reservoir drawdown. The purpose of Appendix H is to review the 2012 EIS/R AR measures, lessons learned from other large dam removal projects, and provide the rationale for revising the AR plans in order to reduce the short-term effects on aquatic resources.

Chapter 2: Dam Removal Benefits and Effects

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2. DAM REMOVAL BENEFITS AND EFFECTS

This section identifies benefits that have been noted for other dam removal projects in the Pacific Northwest and the anticipated long-term benefits to the Klamath River ecosystem that will occur with Klamath River dam decommissioning.

2.1 Benefits of Recent Dam Removals in the Pacific Northwest

Removal of large dams from rivers in the western United States, has also been completed to, among other things, restore ecosystem processes. Ecosystem response to large scale dam removal projects in Oregon, Washington, California and Montana has been monitored to gain a better understanding of geomorphic and ecological trends following dam removal. The following section provides an overview of recent post-dam removal studies from the Pacific Northwest.

2.1.1 Fish Access to Historical Habitat

Several studies document fish passage benefits associated with restoring access to historical habitat through dam removal efforts. The following references relate fish passage restoration benefits to adult salmon dispersal.

Following the installation of a fish ladder at Landsburg Dam in 2003, both Chinook salmon and coho salmon voluntarily recolonized 33 kilometers (km) of upstream habitat in the Cedar River, Washington, after more than 100 years of extirpation. The total density of salmonids roughly doubled in the mainstem closest to the dam 3 years after ladder installation (Kiffney et al. 2009), while dispersal of anadromous fish into tributary habitats occurred more slowly over the next 5 years (Burton et al. 2013). Both the proportion of all redds found in upstream reaches and the proportion of upstream spawners that were born in those reaches increased over time, demonstrating the successful transition from recolonization to self-sustaining upstream populations (Anderson et al. 2015).

Tule fall Chinook salmon were translocated to upstream reaches of the White Salmon River, Washington in the same year as the removal of the Condit Dam in 2011. Translocations were intended to circumvent the disruption of downstream spawning habitat by temporary sediment flows resulting from dam breaching, while natural migration was allowed in subsequent years. Roughly 10 percent of the Chinook population spawned upstream of the former dam site in the year following removal and both total escapement in the river and the proportion of returning fish born in upstream reaches is increasing over time (Engle et al. 2013; Hatten et al. 2015; Allen et al. 2016; Liermann et al. 2017).

In the Elwha River, Washington, the Elwha Dam and Glines Canyon Dam limited anadromy to the lower Elwha River. Removing the Elwha and Glines Canyon dams provided access to an additional 40 miles of mainstem river habitat as well as tributaries. In 2012, Chinook salmon had access to the area above Elwha Dam for the first time in a century. A total of 203 Chinook redds (396 live and dead adults) were documented upstream of Elwha Dam, with the former Aldwell Reservoir (river kilometer [Rkm] 7.9-12.4) and the main stem Middle Elwha from Rkm 17.2-18.1 (above the former Elwha Dam site) accounting for 44 percent of the redd locations, respectively, in 2012. In 2013, based on SONAR estimates (Denton et al. 2014), the total escapement of Chinook salmon (4,243 adults) approximately doubled over the 20 year average. This doubling resulted in observations of Chinook salmon spawning in all habitats, including the Middle Elwha, with the majority of redds (73 percent) located above the former Elwha Dam (McHenry et al. 2017).

Other work on the Elwha River found that hatchery coho salmon had a very high affinity for the hatchery and spawners released into tributaries upstream of the Elwha Dam produced offspring that returned to the natal release tributaries to spawn as adults (T. Williams, NOAA Fisheries, personal communication 2017). After five years, wild-origin coho salmon made up greater than 50 percent of spawners observed in the tributary with adequate coho spawning and rearing habitat. In addition, in the Cedar River, WA, when access was provided to historically used habitat coho salmon colonized the area quickly and dispersal of juvenile coho salmon was significant

At two dam removal sites on the Rogue River in southern Oregon, fall run Chinook salmon used spawning habitat that was formerly inaccessible under reservoirs in the first fall following dam removal. The conversion of former reservoir habitat to riverine habitat, and associated bedload/gravel movement, improved spawning habitat quality in the former reservoir sites. At the former Savage Rapids Dam site, 91 redds were documented within the extent of the former reservoir the first full fall after dam removal. At the former Gold Ray Dam site, 37 redds were documented within the bounds of the former reservoir in 2010, and over twice that many redds were identified within the former reservoir in 2011 (Oregon Department of Fish and Wildlife [ODFW] 2011).

From these previous studies, scientists have found that Chinook and coho salmon exploration of new habitat is an innate component of salmon breeding behavior. Coho salmon movement upstream of a former passage barrier on the Cedar River led to juvenile movement and dispersal which was recognized as an important component of the colonization process (Anderson et al. 2013). Ensuring juvenile passage in the watershed is necessary for juvenile imprinting and the future broadening of adult spawner returns throughout reconnected historical habitats. Additionally, hatchery-origin Chinook salmon have been found to have higher stray rates relative to their wild counterparts (Burton et al. 2013) and as the concept applies to the Klamath River, Iron Gate Hatchery-influenced fall Chinook salmon may rapidly recolonize the Klamath River upstream of Iron Gate Dam. In short, restoring access to lost habitat is a critical conservation strategy (Anderson and Quinn 2007 cited in T. Williams, NOAA Fisheries, and personal communication 2017).

Beyond the benefits of recolonization for fish populations themselves, recolonization of previously inaccessible reaches also restores the flow of marine-derived nutrients to upstream portions of the watershed resulting in an overall boost to ecosystem nutrient budgets and productivity (Tonra et al. 2015).

2.2 Anticipated Lower Klamath Project Benefits and Effects

The dam decommissioning project will provide long-term ecosystem benefits to the Klamath River Basin. The following anticipated long-term benefits discussion is largely taken from the 2012 EIS/EIR (USBR 2012) and *the Klamath Dam Removal Overview Report for the Secretary of the Interior: An Assessment of Science and Technical Information* (Department of the Interior, U.S. Department of Commerce and National Marine Fisheries Service [NOAA Fisheries] 2013).

2.2.1 Access to Historical Habitat

Iron Gate Dam located at river mile (RM) 192.8 blocks access to the Upper Klamath Basin for three anadromous salmonid species, Pacific lamprey, and freshwater mussels. Facilities removal will restore access to approximately 81 miles of suitable riverine, side channel, and tributary habitat in the Klamath River Hydroelectric Reach (i.e., the Klamath River and tributaries from Iron Gate Dam [RM 192.9] to the upstream extent of J.C. Boyle Reservoir [RM 233.0]; Table 2-1), and 49 tributaries accounting for over 420 miles of historical aquatic habitat throughout the basin upstream of Iron Gate Dam. More specifically, facilities removal will allow access to historical habitat totaling over 75 miles for coho salmon, 300 miles for Chinook salmon (Huntington 2004), and 400 miles for steelhead (Huntington 2004; 2006). In addition to increasing the quantity of available habitat, unique habitats will also be accessible with dam decommissioning. Groundwater-fed areas throughout the Upper Klamath Basin (Table 2-2) are resistant to water temperature increases caused by changes in climate (Hamilton et al. 2011), potentially buffering climate change effects to coldwater salmonids.

Table 2-1 Potential historical habitat availability by species with removal of the Klamath River Hydroelectric Reach dams

Species	Potential Historical Habitat Availability (mi)
Chinook salmon	300
Coho salmon	76
Steelhead	420
Pacific lamprey	>420

Table 2-2 Estimated groundwater discharge (springs) into upper Klamath River systems

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 River to Sprague River	202
Upper Klamath Lake	Spring in Upper Klamath Lake Including Malone, Crystal, Sucker, and Barclay	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**
NOAA Fisheries 2013		

Historical anadromous fish population estimates suggest the potential productivity of the Klamath Basin upstream from Iron Gate Dam (RM 192.9). Hamilton et al. (2011) summarized previous spawning surveys and population estimates. The Klamath River and tributaries upstream from Iron Gate Dam historically supported up to 149,000 spawning fall Chinook salmon and up to 30,000 spawning steelhead (Table 2-3).

Table 2-3 Historical and potential production estimates for fall Chinook salmon, coho salmon, and steelhead in the Klamath River Basin

Reach	Species	Median Estimate	Estimate Range	Note
Lower Klamath Basin to Copco Dam	Fall Chinook Salmon		168,000[4] – 175,000[5]	Estimates based on historical spawning escapement and spawning surveys.
	Coho	15,400[4]	20,000[5] – 70,000[5]	122°04’20”
	Steelhead	300,000[5]	221,000[4] – 750,000[5]	122°22’05”
Iron Gate Dam to Copco Dam	Fall Chinook Salmon	2,301[3]	1,113[6] – 18,925[5]	Based on historical spawning data and spawning habitat potential.
	Steelhead	1,144[3]		
Copco Dam to Upper Klamath Lake	Fall Chinook Salmon	10,000[1]	2,2920[2] – 19,207[3]	Based on historical spawning data and spawning habitat potential.
	Steelhead	9,550[3]		

1 FERC 2007
2 Fortune et al. 1966
3 Chapman 1981
4 CDFG 1965
5 Coots 1977
6 FERC 1963

Chinook Salmon

Dam decommissioning will benefit fall Chinook salmon by restoring access to over 300 miles of historical habitat (Table 2-4) in the Klamath Basin upstream from Iron Gate Dam (improving water quality, increasing flow variability downstream from Iron Gate Dam, and reducing disease. Over time, Chinook salmon returns upstream of Keno Dam could be substantial, although fish passage at Keno Dam and habitat quality improvements in the Upper Klamath Basin will be necessary to realize recovery potential.

Table 2-4 Estimated Klamath River mainstem, side channel, and tributary habitat under the Hydroelectric Reach reservoirs, and the number of contributing tributaries in each reservoir

Reservoir	Mainstem Habitat (mi)	Side Channel Habitat (mi)	Tributary Habitat (mi)	Contributing Tributaries (#)
Iron Gate	10.96	-	4.00	52
Copco	11.05	1.99	2.43	18
J.C. Boyle	5.35	-	0.30	10
Total	**27.36**	**1.99**	**6.73**	**80**
Source: Cunanan 2009				

Coho Salmon

With dam decommissioning coho salmon are expected to rapidly recolonize habitat upstream of Iron Gate Dam, as observed after barrier removal at Landsburg Dam in Washington (Kiffney et al. 2009) and the Elwha River dams in Washington (Liermann et al. 2017). Assuming coho salmon distribution will extend up to Spencer Creek after dam removal; coho salmon from the upper Klamath River population will reclaim approximately 76 miles of habitat: approximately 53 miles in the mainstem Klamath River and tributaries (DOI 2007; NOAA Fisheries Service 2007) and approximately 23 miles currently inundated by the reservoirs (Cunanan 2009).

Coho salmon colonization of the Klamath River between Keno and Iron Gate dams by the upper Klamath coho salmon population would likely improve the viability of SONCC coho salmon by increasing abundance, diversity, productivity and spatial distribution.

Steelhead

Dam removal would restore access to over 420 miles of historical steelhead habitat upstream of Iron Gate Dam (Huntington 2004; 2006). Because of their ability to navigate steeper gradient channels and spawn in smaller, intermittent streams (Platts and Partridge 1978), and their ability to withstand a wide range of water temperatures (Cech and Myrick 1999; Spina 2007), steelhead distribution in the basin could expand to a greater degree (over 420 miles; Huntington 2004; 2006) than that of any other anadromous salmonid species. FERC (2007) concluded that implementing fish passage would help to reduce the adverse effects to steelhead associated with lost access to upstream spawning habitats. Hamilton et al. (2011) also concluded that restored access to historical habitat above the dams would benefit steelhead runs.

Lamprey

Pacific lamprey is the only anadromous lamprey species in the Klamath Basin, although five other resident lamprey species are also present in the system. Access to habitat upstream of Iron Gate Dam could benefit Pacific lamprey by increasing their range and distribution in the Klamath River Basin, providing additional spawning and rearing habitat upstream and downstream of Iron Gate Dam, and increasing their abundance. Dam decommissioning is anticipated to expand the current range of Pacific lamprey to areas upstream of Iron Gate Dam (FERC 2007). Restoration of natural hydrologic conditions will improve rearing conditions for lamprey ammocoetes that are currently affected by periodic peaking flows that dewater habitat and strand ammocoetes.

2.2.2 Water Quality and Water Temperature

Removal of the reservoirs will decrease residence time from several weeks to less than a day, resulting in improved water quality and a more natural temperature regime. Reservoir removal would also increase the benefits of tributaries and springs such as Fall, Shovel, and Spencer creeks and Big Springs, that will flow directly into the mainstem Klamath River, creating patches of cooler water (see Table 2-2) that could be used as temperature refugia by fish during summer and fall, as well as providing slightly warmer winter water temperatures conducive to the growth of salmonids (Hamilton et al. 2011). Removal of the facilities would result in a 2-10°C decrease in water temperatures during the fall months and a 1-2.5°C increase in water temperatures during spring months (PacifiCorp 2004a; Dunsmoor and Huntington 2006; NCRWQCB 2010a).

Elimination of the thermal lag caused by the existing reservoirs, will result in water temperatures more in sync with historical fish migration and spawning periods for the Klamath River, warming earlier in the spring, and cooling earlier in the fall compared to existing conditions (Hamilton et al. 2011). Warmer springtime temperatures would result in fry emerging earlier (Sykes et al. 2009), encountering favorable temperatures for growth sooner than under existing conditions, which could support higher growth rates and encourage earlier emigration downstream, thereby reducing stress and disease (Bartholow et al. 2005; FERC 2007). In addition, fall Chinook salmon spawning in the mainstem during fall would no longer be delayed (reducing pre-spawn mortality), and adult migration would occur in more favorable water temperatures than under existing conditions. For example, groundwater inputs in the J.C. Boyle Bypass Reach are anticipated to account for 30 to 40 percent of the total summer flow following dam removal. Groundwater inputs will have a positive effect on water temperature, benefiting both anadromous and resident fish and other aquatic organisms in the Klamath River.

In addition to restoring a more natural thermal regime, facilities removal will result in overall increases in dissolved oxygen, increased diel variability in dissolved oxygen, and lower microbial oxygen demand due to decreased organic load. The conversion of an additional 22 miles of reservoir habitat to riverine and riparian habitat would improve water quality by restoring the nutrient cycling and aeration processes provided by a natural channel.

2.2.3 Hydrograph

With the removal of facilities in the Hydroelectric Reach, Klamath River flows will mimic the natural hydrograph. Fish migration patterns, riparian plant community processes, and sediment and debris transport mechanisms are anticipated to benefit from a more natural hydrograph.

2.2.4 Disease

Fish diseases are widespread in the mainstem Klamath River during certain time periods, and in certain years disease prevalence has been shown to adversely affect productivity of Chinook and coho salmon. High infection rates by the myxozoan parasite *C. shasta* have been documented in emigrating juvenile salmon populations during spring and early summer in the Klamath River (True et al. 2016 *cited in* USFWS 2016), which have been linked to population declines in fall Chinook Salmon (Fujiwara et al. 2011; True et al. 2013). Fish infected by *C. shasta* are also prone to mortality caused by other pathogens such as *Parvicapsula minibicornis*, to predation, and compromised osmoregulatory systems that are essential for successful ocean entry (S. Foott personal communication *cited in* USFWS 2016).

C. shasta infection rates of juvenile Chinook salmon are influenced by *C. shasta* spore densities, water temperature, and juvenile salmonid residence time in area of high spore densities. Table 2-5 includes a summary of juvenile Chinook salmon prevalence of infection over 10 years at the Kinsman rotary screw trap location (RM 147.6), located 45 river miles downstream from Iron Gate Dam (RM 192.8). The Kinsman trap is located between the Shasta River and the Scott River, a reach of the Klamath River often referenced as the “infectious zone” (USFWS 2016).

Table 2-5 Summary of estimates of annual-level C. shasta infection prevalence for wild and/or unknown origin juvenile Chinook salmon passing the Kinsman rotary screw trap site (RM 147.6)

Year	Origin	Prevalence of Infection	Infected Population Estimate Lower Confidence Limit	Infected Population Estimate	Infected Population Estimate Upper Confidence Limit
2005	All	0.41	0.26	0.38	0.47
2007	All	0.28	0.07	0.1	0.15
2008	All	0.6	0.43	0.51	0.58
2009	All	0.5	0.5	0.58	0.66
2010	Wild/Unknown	0.12/0.15	0.02	0.04	0.07
2011	Wild	0.2	0.07	0.11	0.17

Year	Origin	Prevalence of Infection	Infected Population Estimate Lower Confidence Limit	Infected Population Estimate	Infected Population Estimate Upper Confidence Limit
2012	Wild/Unknown	0.06/0.00	0.04	0.08	0.14
2013	Wild	0.18	0.03	0.06	0.09
2014	Wild	0.67	0.12	0.18	0.26
2015	Wild/Unknown	0.66/0.96	0.2	0.29	0.39

Source: USFWS 2016

The lower and upper confidence limits account for the estimation uncertainty in abundance and weekly prevalence of infection rates

Facilities removal is expected to reduce fish disease impacts to adult and juvenile salmon especially downstream from Iron Gate Dam. Among the salmon life stages, juvenile salmon tend to be most susceptible to *P.minibicornis* and *C. shasta* (Beeman et al. 2008). The main factors contributing to risk of infection by *C. shasta* and *P. minibicornis* include availability of habitat (pools, eddies, and sediment) and microhabitat characteristics (static flow and low velocieties) for the polychaete intermediate host; polychaete proximity to spawning areas; increased planktonic food sources from Hydroelectric Reach reservoirs; water temperatures greater than 15°C (Bartholomew and Foott 2010); and juvenile salmonid residence time in the infectious zone (USFWS 2016).

Facilities removal will restore natural channel processes including channel bed scour and sediment transport. Annual channel bed scour will disturb the habitat of the polychaete worm that hosts *C. shasta* (FERC 2007). Reducing polychaete habitat will likely increase abundance of smolts by increasing outmigration survival, particularly for juvenile coho salmon life-histories (FERC 2007).

Dam removal will also broaden the distribution of adult pre-spawn fall Chinook salmon, reducing crowding and the concentration of disease pathogens that currently occurs in the reach between Iron Gate Dam and the Shasta River (USFWS 2016). Lastly, a broader spawning distribution will also influence the distribution of post-spawn adult carcasses that contribute the bulk of the myxospores that enable the *C. shasta* life cycle within the infectious zone. Distributing adult carcasses over a longer reach of the Klamath River corridor will reduce myxospore densities likely leading to lower juvenile salmonid infection rates in the winter and spring rearing period (USFWS 2016).

2.2.5 Nuisance Algae

Facilities removal would eliminate optimal growing conditions for toxin-producing nuisance algal species, alleviating the transport of high seasonal concentrations of algal toxins to the Klamath River downstream from Iron Gate Dam. Nuisance algae reduction will also decrease the associated bioaccumulation of microcystin in fish tissue for species downstream from the Hydroelectric Reach. While some microcystin may be transported downstream from large blooms occurring in Upper Klamath Lake, the levels are anticipated to be lower than those currently experienced due to the prevalence of seasonal in-reservoir blooms. Overall, bioaccumulation of algal toxins in fish tissue would be expected to decrease in the Klamath River downstream from Iron Gate Dam and would be beneficial.

2.2.6 Sediment and Debris Transport

In the long term, restoration of sediment and debris transport through the Hydroelectric Reach will decrease substrate size and increase the supply of wood debris, an important structural component that influences aquatic habitat diversity. Bedload sediment movement and transport are vital to create and maintain functional aquatic habitat. The river will eventually drive enhanced habitat complexity due to a more natural flow and reconnected bedload transport regime that will mean the restoration of spawning gravels and early rearing habitat downstream from Iron Gate Dam. Pools would likely return to their pre-sediment release depth within one year (USBR 2012), and the river is predicted to revert to and maintain a pool-riffle morphology providing suitable habitat for fall-run Chinook salmon.

In summary, the Klamath Dams decommissioning project will have long-term ecosystem. Primary ecosystem benefits include restored aquatic organism access to historical habitat upstream of Iron Gate Dam (Huntington 2004; 2006); a more natural hydrograph, temperature regime (PacifiCorp 2004; Dunsmoor and Huntington 2006), and nutrient cycling; reduced prevalence of aquatic diseases such as *Ceratomyxa shasta* (Bartholow et al. 2004; Federal Energy Regulatory Commission [FERC] 2007; U.S. Fish and Wildlife Service [USFWS] 2016) and nuisance algae, and restored sediment transport and debris loading (USBR and CDFG 2012).

2.3 Klamath River Species-specific Benefits

The following sections describing the anticipated Klamath River species-specific benefits are largely taken from NOAA Fisheries (2013).

2.4 Anticipated Klamath River Dam Decommissioning Short-term Effects

Short-term effects from the dam decommissioning to the biological community include high suspended sediment concentrations (Greig et al. 2005, Levasseur et al. 2006; USBR 2011), high bedload transport and deposition, and low dissolved oxygen concentrations (Reclamation and CDFG 2012). Effects are anticipated to impact both mobile and sedentary organisms (e.g., freshwater mussels and lamprey ammocoetes), with the greatest effects on sedentary organisms that are unable to seek refuge from poor water quality. The following sections provide more details on anticipated short-term reservoir drawdown effects presented in the 2012 EIS/R (USBR and CDFG 2012).

2.4.1 Suspended Sediment Effects

The dam decommissioning project could release up to 1.2 - 2.9 million metric tons of fine sediment (sand, silt, and finer) downstream from Iron Gate Dam (RM 192.9) over a two-year period (USBR 2011). Suspended sediment concentrations are expected to exceed 1,000 mg/l for weeks, with the potential for peak concentrations exceeding 5,000 mg/l for hours or days depending on hydrologic conditions during reservoir drawdown (USBR and CDFG 2012). The downstream transport of this sediment, currently stored in reservoir deposits, is anticipated to affect downstream habitats as both suspended sediment and bedload. Biological effects may impact salmonids and Pacific lamprey through gill abrasion and clogging, decreased forage efficiency, and other behavioral effects like delayed migration timing. Deposition of suspended sediments is anticipated to impact salmonid spawning grounds by smothering incubating eggs (Greig et al. 2005; Levasseur et al. 2006), impeding intergravel flow thereby affecting egg and fry development, and impacting fry emergence due to gravel clogging. Fine sediment deposition in slower off-channel habitats may also block connectivity between the Klamath River and off-channel habitats such as mainstem side channels, important habitats for juvenile fish rearing and coho salmon spawning.

2.4.2 Bedload Effects

Bedload mobilized by the dam decommission project is anticipated to affect the Klamath River between Iron Gate Dam (RM 192.9) and Cottonwood Creek (RM 184.9). Bedload deposition is anticipated to result in the burial of spawning habitat, freshwater mussel beds, and lamprey ammocoete rearing areas. Dam-released sediment will also increase the proportion of sand in the channel bed, thereby decreasing salmonid fry and lamprey ammocoete survival. The bed material within the reservoirs and from Iron Gate Dam to Cottonwood Creek is expected to have a high content (30 to 50 percent) of sand immediately following reservoir drawdown until a flushing flow moves the sand sized material out of the reach (USBR 2012). A sufficient flushing flow of at least 6,000 cfs and lasting over several days to weeks is expected to be necessary to return the Klamath River bed composition to one dominated by cobble and gravel with a sand content less than 20 percent. After the flushing flow, the river bed is expected to maintain fractions of sand, gravel, and cobble similar to natural conditions, and be sufficient to support biological communities that use the former effected reach. suitable for Pacific lamprey.

2.4.3 Dissolved Oxygen Effects

Release of reservoir sediments is also anticipated to result in depressed dissolved oxygen concentrations that will affect the biological community in the affected reach. Due to high organic concentration of the reservoir sediments, dissolved oxygen depletion is anticipated to result from the microbial breakdown of released organics. Direct effects of low dissolved oxygen levels include fish mortality, reduced growth and impaired development, reduced swimming performance, altered behavior, and reduced reproductive potential. Mobile fish will likely seek out areas of higher dissolved oxygen and improved water quality downstream of the affected reach, in tributaries and tributary confluence areas with the Klamath River, and in areas with faster flowing water with a higher rate of oxygen transfer at the water-air interface. Less mobile organisms are unable to move from impaired water quality so are more susceptible to low dissolved oxygen effects.

2.4.4 Effects Analysis

Hydraulic and sediment modeling was completed to predict flow and sediment transport characteristics in part to predict potential biological effects associated with the dam decommissioning (USBR 2011; Section 8 and 9). Modeling results are very sensitive to watershed hydrology, both in flow magnitude and runoff pattern (USBR 2011). To account for the range of potential effects that could occur during the dam decommissioning project, two scenarios were analyzed with the goal of predicting the potential impacts to fish that have either a 50 percent (effects likely to occur) or 10 percent (unlikely to occur, or worst-case) probability of occurring (USBR and CDFG 2012; Vol. I, Section 3.3).

Due to the uncertainties associated with biological response to the anticipated high suspended sediment concentrations levels and low dissolved oxygen over extended time periods, the KRRC evaluated the 2012 EIS/R worst-case scenario effects for developing the updated AR plans. The 2012 EIS/R considered short-term (less than 2 years) and long-term (more than 2 years) effects to Klamath River aquatic species. Short-term effects were determined to be either significant or less-than-significant for the species covered by the AR plans (Table 2-6). Mitigation was anticipated to reduce short-term effects for fall Chinook salmon and Lost River and shortnose suckers (from significant to less-than-significant), but did not change the determination of significant project effects for the other species. The dam decommissioning was anticipated to have long-term benefits for all aquatic species (except green sturgeon) including those determined to have significant short-term effects (2012 EIS/R Vol. I, pp. 3.3-129 to 3.3-177).

Table 2-6 2012 EIS/R included proposed mitigation actions for species anticipated to experience short-term effects from the dam decommissioning project

Species	Short-term Effects Determination	Mitigation Proposed	Short-term Effects Determination After Mitigation	Proposed Mitigation Effective	Long-term Effects Determination
Fall Chinook Salmon	Significant	Yes	Less-than-significant	Yes	Beneficial
Coho Salmon	Significant	Yes	Significant	No	Beneficial
Steelhead	Significant	Yes	Significant	No	Beneficial
Pacific Lamprey	Significant	Yes	Significant	No	Beneficial
Lost River & Shortnose Suckers	Significant	Yes	Less-than-significant	Yes	Beneficial
Green Sturgeon	Significant	Yes	Significant	No	Less-than-significant
Freshwater Mussels	Significant	Yes	Significant	No	Beneficial
Source: USBR and CDFG 2012					

Chapter 3: AR-1 Mainstem Spawning

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3. AR-1 MAINSTEM SPAWNING

The objective of AR-1 is to address dam decommissioning effects on anadromous fish that migrate and spawn in the mainstem Klamath River and its tributaries. The original 2012 EIS/R AR-1 plan focused on trapping and hauling adult migratory anadromous salmonids and Pacific lamprey and relocating fish to areas of the basin less affected by dam decommissioning effects. The updated AR-1 includes implementation of a monitoring and adaptive management plan to monitor and ensure habitat connectivity and spawning habitat availability. The adaptive plan includes: 1) monitoring and ensuring tributary-mainstem connectivity at select tributaries in the Hydroelectric Reach and in the 8-mile long bedload deposition reach between Iron Gate Dam (RM 192.9) and Cottonwood Creek (RM 184.9); and 2) survey/quantification of spawning habitat in the Klamath River and tributaries in the Hydroelectric Reach from Iron Gate Dam to Keno Dam, and augmenting spawning gravel if existing spawning habitat is less than the area to support 2,100 Chinook redds on the mainstem and 179 steelhead redds in Hydroelectric Reach tributary streams. The updated AR-1 represents the best available actions and opportunities to offset Chinook salmon and coho salmon spawning redds lost during reservoir drawdown, and migrating adult steelhead and Pacific lamprey affected by reservoir drawdown.

3.1 Proposed Updated AR-1

Based on a review of the original AR-1 presented in Section 3.2, input from the ATWG, and recent fisheries literature, the KRRC concluded that an updated AR-1 is necessary to offset the anticipated short-term effects of dam decommissioning on mainstem Chinook salmon and coho spawning, and migrating adult steelhead and Pacific lamprey migration. The updated AR-1 includes the development and implementation of a monitoring and adaptive management plan with on-going input from the ATWG. The plan includes monitoring and ensuring tributary-mainstem connectivity and spawning habitat availability. The monitoring and adaptive management plan has two specific actions.

- **Action 1:** Tributary-mainstem confluences, four sites in the Hydroelectric Reach and five sites in the 8-mile reach from Iron Gate Dam (RM 192.9) to Cottonwood Creek (184.9), will be evaluated for 2-years from the onset of reservoir drawdown. If present, confluence obstructions will be actively removed during the 2-year evaluation period to ensure volitional passage for adult Chinook salmon, coho salmon, steelhead, and Pacific lamprey.
- **Action 2:** A spawning habitat evaluation of the Hydroelectric Reach and newly accessible tributaries following reservoir drawdown will be completed. A target of 44,100 yd2 of mainstem spawning gravel will be required to offset the effects to 2,100 mainstem-spawning fall Chinook salmon redds. If mainstem spawning gravel availability is less than the target values following reservoir drawdown, spawning gravel augmentation will be completed in the former Klamath River reservoirs and Hydroelectric Reach. A target of 4,700 yd2 of tributary spawning gravel is required to offset the effects to 179 tributary-spawning steelhead redds. If tributary spawning gravel habitat is less than

the target values following reservoir drawdown, the ATWG will convene to prioritize additional habitat restoration actions that will be undertaken to increase the amount of tributary habitat available to compensate for the loss of steelhead redds.

The proposed actions are intended to ensure adult salmonid and Pacific lamprey access to mainstem and tributary spawning habitat in the Hydroelectric Reach following dam decommissioning. The following sections provide additional detail on the proposed actions.

3.1.1 Action 1: Tributary-Mainstem Connectivity

The following sections provide information on the monitoring and adaptive management plan pertaining to tributary-mainstem connectivity.

Tributary-Mainstem Connectivity Monitoring

To ensure that spawning habitat is accessible following reservoir drawdown, fish passage monitoring and adaptive actions will occur at the confluence areas of key Klamath River tributaries and side channels upstream and downstream of Iron Gate Dam. Tributary confluences in the Hydroelectric Reach may be affected by sediment deposits and debris obstructions as the reservoir are drawdown. Tributary deltas may create fish passage barriers that would limit upstream migration of anadromous salmonids and Pacific lamprey.

Based on hydraulic and sediment transport modeling completed by USBR (Section 9.2.1.4; 2011), sediment deposition during reservoir drawdown is predicted from Bogus Creek (RM 192.4) downstream to Cottonwood Creek (RM 184.9). From Bogus Creek downstream to Willow Creek (RM 187.8), approximately 1.5 feet of sediment deposition is anticipated. From Willow Creek downstream to Cottonwood Creek, deposition of less than 1 foot is expected. Areas downstream of Cottonwood Creek are expected to have only minor deposition with deposits less than 0.25 feet (USBR 2011). No additional deposition is predicted in the Bogus Creek to Cottonwood Creek reach following dam decommissioning.

Species that would be potentially affected by obstructed tributary connections include steelhead and Pacific lamprey during the winter and spring of the drawdown year, and Chinook salmon and coho salmon in the fall of the drawdown year. Further, depending on erosion rates of reservoir sediments, tributary confluence areas in the reservoir areas may not create volitional fish passage conditions following drawdown.

Tributary confluences to be monitored in the 2-year period following dam decommissioning include Bogus Creek, Dry Creek, Little Bogus Creek, Willow Creek, and Cottonwood Creek. Tributaries in the Bogus Creek to Cottonwood Creek reach were selected as they are recognized as influential tributaries (e.g., historical fisheries importance or important freshwater sources) in the mid-Klamath River (Soto et al. 2008). Hydroelectric Reach tributaries to be monitored include Spencer Creek (RM 230.5), Shovel Creek (RM 209.0), Fall Creek (RM 198.9), and Jenny Creek (RM 196.8). These tributaries were selected based on having historical or potential habitat for adult salmonids (Huntington 2006).

Tributary Connectivity Maintenance

Tributary obstructions that limit fish passage will be remedied through appropriate manual or mechanical means. Example removal methods may include removing sediment using hand tools or hydraulic equipment. Removed material will be placed in the mainstem Klamath River downstream of the tributary confluence or on the adjacent floodplain.

3.1.2 Action 2: Spawning Habitat Evaluation

The following sections provide information on the monitoring and adaptive management plan pertaining to mainstem and tributary spawning habitat availability.

Spawning Habitat Target Metrics

Spawning gravel area targets for Chinook salmon and steelhead were developed based on typical spawning redd dimensions for the two species and the anticipated loss of Chinook salmon redds and adult steelhead due to reservoir drawdown. Fortune et al. (1966) used 21 square yards (yd^2) and 26 yd^2 of suitable gravel per Chinook salmon redd and steelhead redd, respectively, to calculate spawning potential in areas of the Klamath River and selected tributaries upstream of Iron Gate Dam (Table 3-1). Based on an anticipated loss of 2,100 Chinook salmon redds downstream from Iron Gate Dam and a 21 yd^2 area per redd, 44,100 yd^2 of spawning gravel is necessary to offset the loss of 2,100 Chinook salmon redds. Based on recent winter steelhead counts, an estimated 358 adult steelhead representing 179 spawning redds will be affected by dam decommissioning. Applying Fortune et al. (1966) steelhead redd dimensions, 4,700 yd^2 of tributary spawning habitat will be needed to offset the loss of 358 winter steelhead.

Table 3-1 Anticipated redd loss due to project effects for fall Chinook salmon and winter steelhead, surface area per redd, and the anticipated spawning habitat area needed to address redd loss for fall Chinook salmon and steelhead adult production

Metric	Fall Chinook Salmon	Winter Steelhead
Anticipated redd loss due to project effects	2,100	179[1]
Surface area per spawning redd (yd^2)	21	26
Spawning habitat area to address redd loss (yd^2)	44,100	4,700
[1]Updated anticipated winter steelhead loss based on peak steelhead return of (631 in 2001) to Iron Gate Hatchery between 2000-2016 (CDFW 2016). Expected mortality calculated using the methodology contained in the 2012 EIS/R (631*0.80*0.71=358). The 358 adult steelhead were converted to 179 redds that would be lost due to adult steelhead mortality		

Spawning Habitat Monitoring

To quantify the available spawning habitat upstream of Iron Gate Dam, field surveys and remote sensing efforts will be implemented following reservoir drawdown. Boat or aerial surveys will be conducted on the mainstem Klamath River between Iron Gate Dam (RM 192.9) and Keno Dam (RM 238.2) during the summer following reservoir drawdown to determine the amount of mainstem spawning habitat in the Hydroelectric Reach suitable for immediate spawning.

Tributary streams will be walked from their mouths to the first natural fish passage barrier to estimate amount of available spawning habitat following reservoir drawdown (Table 3-2 The area of available spawning habitat will be estimated from the mouth to the first natural barrier. If artificial (manmade) fish passage barriers are located during the tributary reach reconnaissance, they will be noted as potential restoration actions to increase the availability of tributary spawning habitat.

Table 3-2 Hydroelectric Reach tributaries to be assessed for existing

Tributary	Tributary Confluence Location at the Klamath River (River Mile)	Tributary Length to First Barrier (miles)
Jenny Creek	196.8	1.0
Fall Creek	198.9	1.2
Shovel Creek	209.0	2.7
Spencer Creek	230.5	9.0

Response to Spawning Habitat Availability

KRCC will prepare a report summarizing the spawning habitat surveys and outline and prioritize actions to augment spawning habitat if the existing spawning habitat amounts to less than the 44,100 yd^2 of mainstem and 4,700 yd^2 of tributary spawning habitat targets in the Hydroelectric Reach. KRRC will consult with ATWG for input on potential spawning gravel augmentation locations in the mainstem and on other tributary habitat restoration actions in tributaries to increase the availability of spawning habitat. Currently, if existing spawning habitat does not meet targets, spawning gravel augmentation will be completed in the mainstem Klamath River between Shovel Creek (RM 209.0) and the upstream extent of Copco Reservoir (RM 208.0). Mainstem gravel would be added at a rate of 7.0 cy (21 yd^2 x 1 ft depth) per compensatory mainstem redd. Augmented gravel is anticipated to be redistributed with subsequent high flows, broadening potential spawning habitat over larger areas of the treated mainstem reaches. Tributary spawning habitat restoration actions to be completed in Jenny Creek, Shovel Creek, Fall Creek, and/or Spencer Creek could include removal of artificial fish passage barriers, or placement of large woody debris to trap and retain spawning gravels. Spawning gravel augmentation will be prioritized based on anticipated spawning habitat benefits.

In summary, the updated AR-1 includes development and implementation of a monitoring and adaptive management plan. The plan will direct the evaluation of tributary-mainstem connectivity in the Hydroelectric Reach and the Klamath River deposition reach between Iron Gate Dam and Cottonwood Creek. Tributary confluences will be monitored for 2-years following dam decommissioning and tributary obstructions that block fish passage will be addressed over the 2-year period. Mainstem and tributary spawning habitat in the Hydroelectric Reach will be monitored post-reservoir drawdown and will be augment with supplemental spawning gravel or enhanced through additional restoration actions if spawning habitat area metrics are not met by existing habitat conditions following reservoir drawdown.

3.2 Summary of the 2012 EIS/R AR-1, Dam Removal Benefits and Effects, and Recent Fisheries Literature

The following sections review the components of the 2012 EIS/R AR-1 measure, anticipated dam removal effects and benefits on AR-1 species, and recent fisheries literature relative to mainstem spawning. This information is presented in support of the updated AR-1 measure.

3.2.1 AR-1 Affected Species

Species identified in AR-1 include:

- Coho salmon *(Oncorhynchus kisutch)* – Southern Oregon/Northern California Coastal (SONCC) evolutionary significant unit (ESU): Federally Threatened; California Threatened; Tribal Trust Species
- Chinook salmon *(O. tshawytscha)* – Upper Klamath-Trinity Rivers ESU - Fall Run: California Species of Special Concern; Tribal Trust Species
- Chinook salmon *(O. tshawytscha)* – Upper Klamath-Trinity Rivers ESU – Spring Run: California Species of Special Concern; Tribal Trust Species
- Steelhead *(O. mykiss)* – Klamath Mountains Province distinct population segment (DPS) – Summer Run: California Species of Special Concern; Tribal Trust Species
- Steelhead *(O. mykiss)* – Klamath Mountains Province DPS – Winter Run: Tribal Trust Species
- Pacific lamprey *(Entosphenus tridentatus)*: California Species of Special Concern; Tribal Trust Species

3.2.2 Anticipated Dam Decommissioning Effects on AR-1 Species

Short-term effects of dam removal (from both suspended sediment and bedload movement) were predicted to result in high mortality of fall Chinook salmon and coho salmon embryos and pre-emergent alevin within redds that are constructed in the mainstem Klamath River downstream from Iron Gate Dam (RM 192.9) in the fall of prior to reservoir drawdown (USBR and CDFG 2012). Approximately 2,100 fall Chinook salmon redds and approximately 13 SONCC coho salmon redds were predicted to be affected during reservoir drawdown. Additionally, steelhead and Pacific lamprey migrating within the mainstem Klamath River after December 31 prior to the reservoir drawdown year are anticipated to be directly affected by suspended sediment. Table 3-3 includes the likely and worst-case effects to adult anadromous fish species downstream from Iron Gate Dam.

Table 3-3 2012 EIS/R anticipated effects summary for migratory adult salmonids and Pacific lamprey

Species	Life Stage	Likely Effects	Worst Effects
Coho Salmon	Adult Spawning	Loss of 13 redds (0.7-26%)1	Loss of 13 redds (0.7-26%)1
Chinook Salmon - Fall	Adult Spawning	Loss of 2,100 redds (8%)1	Loss of 2,100 redds (8%)1
Steelhead - Summer	Migrating Adults	No anticipated mortality	Loss of 0-130 adults (0-9%)1
Steelhead - Winter	Migrating Adults	Loss of up to 1,008 adults (14%)1	Loss of up to 1,988 adults (28%)1
Pacific Lamprey	Adult Migration and Spawning	High mortality (36%)2	High mortality (71%)2

Source: USBR and CDFG 2012
[1] Range of potential year class loss based on the average number of redds associated with the evaluated population(s).
[2] The 2012 EIS/R predicted Pacific lamprey mortality based on mortality models developed for suspended sediment impacts to salmonids. Model output did not include the number of predicted Pacific lamprey mortalities.

The following sections include descriptions of species-specific effects adapted from the 2012 EIS/R (USBR and CDFG 2012; Vol. I, pp. 3.3-129 to 3.3-168).

Coho Salmon

The wide distribution and use of tributaries by both juvenile and adult coho salmon will likely protect the population from the worst effects of the dam decommissioning. However, direct mortality is anticipated for redds and smolts from the upper Klamath River, mid-Klamath River, Shasta River, and Scott River population units. No mortality is anticipated for the Salmon River, Trinity River, and Lower Klamath River populations under the most likely or worst-case scenarios. Based on substantial reduction in the abundance of a year class in the short-term, the effect of the dam decommissioning was found to be significant for the coho salmon from the Upper Klamath River, Mid-Klamath River, Shasta River, and Scott River population units.

Based on spawning surveys conducted from 2001 to 2005 (Magneson and Gough 2006), 6 to 13 redds could be affected during reservoir drawdown. The anticipated loss of redds from the Upper Klamath River coho salmon population unit was based on the peak count of redds surveyed in all years (13 redds counted in 2001). Mainstem Upper Klamath River coho redd surveys completed between 2001 and 2016 yielded 6 redds on average and no redds in 2009. A total of 38 mainstem redds were documented between 2001-2005, with two-thirds of those redds being found within 12 miles of the dam (NMFS 2010). Many of the redds anticipated to be affected by the dam decommissioning are thought to be from returning hatchery fish (NOAA 2010). To preserve existing genetic characteristics and to reduce the threat of demographic extinction, under the Iron Gate Hatchery's hatchery genetic management plan (HGMP), all adult coho salmon not used as broodstock have been returned to the Klamath River to spawn naturally since 2010. Many of these hatchery-origin adult coho salmon stray into Bogus Creek and the Shasta River to spawn while the remainder are thought to spawn in the Klamath River below Iron Gate Dam. Therefore, based on the range of escapement estimates in Ackerman et al. (2006), 13 redds could represent anywhere from 0.7 to 26 percent of the naturally returning spawners in the Upper Klamath River Population Unit, and likely much less than 1 percent of the natural and hatchery returns combined (Magneson and Gough 2006; USFWS, unpublished data, 2017).

Chinook Salmon – Fall Run

Fall Chinook salmon use the mainstem Klamath River for spawning, rearing, and as a migratory corridor. Direct mortality is predicted for fall Chinook salmon redds and some smolts. The effect of suspended sediment concentrations on juvenile fall Chinook salmon from the dam decommissioning is expected to be relatively minor because of variable life histories, the large majority of age-0 juveniles that remain in tributaries until later in the spring and summer, and because many of the fry that out-migrate to the mainstem come from tributaries in the mid-or lower Klamath River, where suspended sediment concentrations resulting from the dam decommissioning are expected to be lower due to dilution from tributaries.

Suspended sediment is predicted to result in 100 percent mortality of fall Chinook salmon eggs and fry spawned in the mainstem Klamath River during the fall prior to the reservoir drawdown year. Much of the overall effect on fall Chinook salmon will depend on the relative proportion of mainstem spawners during the fall prior to the reservoir drawdown year. Based on redd surveys using a mark and re-sight methodology from 1999 through 2009 (Magneson and Wright 2010), an average of 2,100 redds from hatchery and naturally returning adults are constructed in the mainstem Klamath River and represents approximately 8 percent of the total, basin-wide escapement (USBR and CDFG 2012).

Steelhead – Summer and Winter

High suspended sediment concentrations resulting from the dam decommissioning are anticipated to affect winter steelhead migrating during the winter and spring of the drawdown year, particularly for the portion of the population that spawns in tributaries upstream of the Trinity River (RM 43.4). For that portion of the population, effects are anticipated on adults, run-backs, half-pounders, any juveniles rearing in the mainstem, and out-migrating smolts. However, the broad spatial distribution of steelhead in the Klamath Basin and their flexible life history suggests that some steelhead will avoid the most serious effects of the dam decommissioning by remaining in tributaries for extended rearing, rearing farther downstream where suspended sediment concentrations should be lower due to dilution, and/or moving out of the mainstem into tributaries and off-channel habitats during winter to avoid periods of high suspended sediment concentrations.

Additionally, the life history variability observed in steelhead means that, although numerous year classes will be affected, not all individuals in any given year class will be exposed to project effects. Some portion of the progeny of those adults that spawn successfully would also rear in tributaries long enough to not only avoid the highest suspended sediment concentrations, but may also not return to spawn for up to 2 years, when suspended sediment resulting from the dam decommissioning should be greatly reduced. The high incidence of repeat spawning among summer steelhead, ranging from 40 to 64 percent (Hopelain 1998) should also increase that population's resilience to dam decommissioning effects. Dam decommissioning modeling results suggest the loss of up to 1,988 winter steelhead redds and up to 130 summer steelhead redds (however, see updated steelhead population data in Section 3.2.3).

Pacific Lamprey

Dam decommissioning would have short-term effects on Pacific lamprey related to high suspended sediment concentrations, bedload sediment transport and deposition, and impaired water quality (particularly low dissolved oxygen levels). Overall, because multiple year classes of Pacific lamprey rear in the mainstem Klamath River at any given time, and since adults will migrate upstream over the entire year, including the reservoir drawdown period when effects from the dam decommissioning will be most pronounced, effects on Pacific lamprey adults and ammocoetes are anticipated to be substantial. However, because of their wide spatial distribution and varied life history, most of the population, (which is distributed from at least California along the Pacific Rim to Japan; Goodman and Reid 2012), would not be affected by the dam decommissioning. In addition, Pacific lamprey are considered to have low fidelity to their natal streams (FERC 2006), and may not enter the mainstem Klamath River if environmental conditions are unfavorable during the reservoir drawdown period. Migration into the Trinity River and other lower Klamath River tributaries may also increase during the reservoir drawdown period because of poor water quality in the upper Klamath River. Low site fidelity and a prevalence of tributary ammocoetes also increases the potential for Pacific lamprey recolonization of mainstem habitats following dam decommissioning.

3.2.3 2012 EIS/R AR-1 Actions

The 2012 EIS/R AR-1 plan (Vol. I, pp. 3.3-242 to 3.3-243) directed the capture and relocation of adult spawning condition salmonids and Pacific lamprey to mitigate dam decommissioning effects. A weir and trap system was proposed for installation directly upstream of the Shasta River (RM 179.3), where the mainstem Klamath River is narrow enough to effectively trap migrating salmonids. This location was also specified to ensure that fish returning to key tributaries downstream of, and including the Shasta River, would not be interrupted. The weir was proposed to be installed at the beginning of the fall migration and fished past the initial dam drawdown period until high flows would require the trap be dismantled. Trap operation would occur intermittently to allow volitional passage of fish upstream of the trap location and would coincide with pulses of fish moving through the system. Trapped fish would then be transported and released either into under-seeded tributaries downstream of Iron Gate Dam (e.g., Scott River [RM 145.1]), or into tributaries or the mainstem Klamath River upstream of J.C. Boyle Reservoir (RM 233.0) if consistent with post-dam decommissioning management goals.

If necessary, additional surveys in the mainstem Klamath River downstream of Shasta River were proposed to locate coho salmon spawning in the mainstem. Any identified adult coho salmon and Chinook salmon, steelhead, or Pacific lamprey could be captured using dip nets, electrofishing, or seines and transported to tributary habitat. Spawning surveys would be conducted in December prior to reservoir drawdown, immediately prior to the first release of sediment associated with dam removal.

3.2.4 KRRC Review of AR-1 for Feasibility and Appropriateness

The KRRC assessed the feasibility and appropriateness of AR-1 through multiple planning meetings held with the ATWG between May and August 2017. During these meetings, new information on Klamath River fisheries was presented and information on other dam removal projects conducted in the western United States was reviewed to understand how the aquatic ecosystem might respond as discuss above. Major concerns discussed by KRRC and ATWG regarding the 2012 AR-1 included:

- Feasibility of a weir and trap system during high flows and winter conditions.
- High anticipated mortality associated with trapping, handling, hauling, and releasing adult spawning condition fall Chinook salmon and coho salmon.
- Impacts to wild fish populations inhabiting streams used to relocate captured fish.
- Adult coho salmon location at time of the reservoir drawdowns.
- Chinook salmon with a high hatchery influence would be most affected by the reservoir drawdowns.
- 2012 EIS/R baseline population estimates and effects uncertainty.

The following sections provide additional information regarding AR-1 feasibility and appropriateness, based on fisheries literature and ATWG input.

Weir and Trap System Feasibility

The 2012 EIS/R proposed weir and trap location was above the Shasta River confluence (RM 179.3) with the Klamath River. AR-1 guidance anticipated that the weir would be removed periodically to allow for passage of coho salmon and fall Chinook salmon above the weir to the upper Klamath River and its tributaries, and Iron Gate Hatchery (RM 192.4). The KRRC and ATWG concluded that fall rains will increase river flows and will require weir and trap removal from the river. Periods of increasing flow would also likely correspond with the greatest quantities of fish moving into the upper Klamath River. The weir system would likely not be operational during the reservoir drawdown period when winter-spring steelhead and Pacific lamprey migration increases with high flows. Therefore, the weir system would be ineffective at mitigating effects to migrating winter steelhead and Pacific lamprey during periods of high flows.

The KRRC and ATWG concluded that it would likely be infeasible to trap and haul the large number of fish that could be encountered in the upper Klamath River in an efficient, safe, and cost-effective manner, and that if fish were relocated into tributary streams downstream of Iron Gate Dam prior to reservoir drawdown, there was a high probability that many of those fish would re-enter the Klamath River and spawn in the affected area. The number of returning coho salmon and fall Chinook salmon in the fall prior to reservoir drawdown will depend on several factors including year class strength, ocean conditions, ocean and lower river fisheries, and Klamath River water quality conditions during the spawning migration. While the number of fish that return to Iron Gate Hatchery (RM 192.4) vary widely, the average number of fish returning to the

Klamath River upstream of the Shasta River confluence (RM 179.3) is substantial (Table 3-2) and would make trapping efforts intensive. For example, to trap the typically small numbers of natural origin coho salmon or winter steelhead upstream of the Shasta River confluence, there would be substantial effort to handle and sort large numbers of spawning condition hatchery fall Chinook salmon that may not be relocated. Given poor water quality conditions typical during the late summer migration, intensive fish handling, sorting, and transport could result in significant stress and mortality of the target species, as described below.

Ultimately, the KRRC concluded that trapping using a weir style system, handling, and hauling a substantial portion of the typical returns to the upper Klamath River would be ineffective. There have also not been similar efforts conducted on other large dam removal projects to provide more certainty with this action.

Table 3-4 Fall Chinook salmon, coho salmon, and winter steelhead return metrics for Iron Gate Hatchery from 2000 to 2016

Return Metric	Fall Chinook Salmon	Coho Salmon	Winter Steelhead
Maximum Return	72,474	2,573	631[1]
Average Return	20,229	855	242
Minimum Return	8,176	70	4

Source: CDFW 2016

[1] The peak winter steelhead return to Iron Gate Hatchery from 2000 to 2016 was 631 fish. Using the 2012 EIS/R calculation method, 80 percent of fish returning to Iron Gate Hatchery migrate upstream after December 15th. Under the worst-case scenario, 71 percent of mortality is predicted to occur due to the dam decommissioning project. The 2012 EIS/R used a dataset published in 1994 (Busby et al. 1994) that included larger winter steelhead returns than have occurred over the last 27 years.

Mortality Associated with Trapping, Handling, Hauling, and Releasing Adult Spawning-condition Fall Chinook Salmon and Coho Salmon

The KRRC and ATWG concluded that spawning condition coho salmon and Chinook salmon will begin to reach the proposed weir location at RM 179.3 in late summer and early fall when water quality conditions are generally poor and fish are susceptible to pre-spawn mortality due to stress and/or disease. Fish would potentially be more susceptible to disease and parasites associated with low flows, high water temperatures, and fish crowding. Given the expected condition of pre-spawn fish and poor water quality, the added stress associated with trapping, handling, hauling, and releasing captured fish is expected to result in high mortality of translocated fish.

Fish condition at the time of trapping influences mortality potential (Keefer et al. 2010). Primary injury and mortality events prior to fish transport are often associated with debris accumulation in the trap box, fish reaction to anesthesia, handling stress, and over-crowding in the trap box. Fish in overcrowded transport tanks may expire due to low oxygen concentrations and warm water temperatures. In a trap and haul study on the San Joaquin River in California, adult fall Chinook salmon were trapped and transported in November.

Of the 119 fish that were handled, 4 percent of fish died prior to transport and 8 percent died during transport (Bigelow et al. 2013). A trap and haul study that evaluated effects on adult, sexually mature fall Chinook salmon reported mortality of 19 percent (Geist et al. 2016), substantially higher than a comparison experiment using adult rainbow trout (Mesa et al. 2013 *cited in* Geist et al. 2016). In a study of transport and pre-spawn mortality of adult fall Chinook salmon in the Willamette River, Keefer et al. (2010) found that adult spring Chinook salmon that were captured, transported, and out-planted above barrier dams in the Willamette River, Oregon was 48 percent, ranging from 0 to 93 percent for individual release groups. Mortality rates strongly correlated with fish condition and water temperature.

Delayed post-release, pre-spawn mortality has also been detected in other projects, with mortality likely related to transport stress rather than water quality or disease issues which would manifest in more rapid (hours) or longer term (weeks) mortality, respectively (Mann et al. 2011).

In summary, the KRRC concluded the potential handling mortality and reduced spawning success associated with an intensive trap and haul program could result in significant losses of fall Chinook salmon and coho salmon and counter the expected benefits of a trap and haul effort.

Impacts to Wild Fish Populations Inhabiting Relocation Streams

The KRRC and ATWG expressed concerns regarding the relocation of fall Chinook salmon and coho salmon that are highly influenced by Iron Gate Hatchery genetics to tributaries potentially inhabited by wild fish with limited hatchery influence. The KRRC and ATWG also concluded that there would be few viable options for recipient tributary streams based on genetics and disease concerns.

The original AR-1 was in part intended to assist in the reintroduction of anadromous salmonids upstream of Iron Gate Dam. Contrary to ODFW's draft reintroduction plan (2008), ODFW is currently developing a reintroduction strategy for anadromous fish reintroduction to the Upper Klamath Basin (T. Wise, ODFW, personal communication). The strategy, while in development, is expected to rely primarily on natural recolonization of the Klamath River and associated tributaries downstream from Upper Klamath Lake, and tributaries in the Upper Klamath Lake watershed. CDFW is likewise concerned with introducing transplanted coho salmon and fall Chinook salmon of unknown genetics and disease condition into wild populations that spawn in the Klamath River and tributaries.

Chinook salmon exhibit substantial population genetic structure across the species' geographic range including the Klamath River Basin (Kinziger et al. 2013). Chinook salmon in the Klamath River Basin exhibit a complex genetic structure defined primarily by basin geography. The Iron Gate Hatchery (RM 192.4) has a profound influence on Klamath River fall Chinook salmon in the vicinity of the hatchery. Kinziger et al. (2013) found the proportion of naturally spawning fall Chinook salmon of Iron Gate Hatchery origin decreased with distance from the hatchery. Natural origin Chinook sampled in Bogus Creek (RM 192.4), Shasta River (RM 179.3), and the Scott River (RM 145.1) had decreasing proportions of hatchery genetics with increasing distance from the hatchery. Fall Chinook salmon spawning between Iron Gate Dam (RM 192.9) and the Shasta River (RM 179.3) exhibit the greatest introgression of Iron Gate Hatchery fish genes.

The influence of Iron Gate Hatchery genetics on fall Chinook salmon is greatly diminished by the Scott River (RM 145.1).

In light of these considerations, relocating fall Chinook salmon from downstream of Iron Gate Dam to Klamath River tributaries would be restricted to tributaries between Iron Gate Dam and the Shasta River to minimize genetic effects to tributary populations. However, moving fish with a higher proportion of hatchery-influenced genetics farther from the hatchery has the potential to extend the hatchery's introgressive influence to downstream fall Chinook salmon populations that are outside of the direct influence of Iron Gate Hatchery (Kinziger et al. 2013). Additionally, streams between Iron Gate Dam (RM 192.9) and the Shasta River (RM 179.3) that support fall Chinook spawning are currently limited by water availability and quality during the fall spawning migration period.

In summary, the KRRC and ATWG concluded that relocating fall Chinook salmon and coho salmon of unknown genetic composition to the Klamath River upstream of Iron Gate Dam or to under-seeded tributaries near Iron Gate Dam presents an unacceptable genetic risk (and possibly disease risk) to other populations potentially dominated by wild fish.

Adult Coho Salmon Location at Time of the Reservoir Drawdowns

The KRRC and ATWG concluded that since coho salmon primarily spawn in Klamath River tributaries, adult coho salmon will largely be unaffected by poor water quality conditions associated with reservoir drawdown in the mainstem Klamath River. Additionally, it is believed that the small numbers of coho that do spawn in the mainstem river are mostly of hatchery origin (NOAA 2014). Expected mortality associated with trapping, handling, hauling, and releasing adult coho salmon would stress fish that would not be affected by reservoir drawdown if these fish were instead allowed to reach their spawning tributaries (e.g., Bogus Creek). The reservoir drawdown schedule was also in part developed to account for coho salmon entry into tributaries to minimize dam decommissioning effects. Attempting to capture small numbers of mainstem spawning coho salmon would likely impact greater numbers of coho than would be impacted by dam removal activities.

Overall, the KRRC and ATWG concluded a trap and haul program as prescribed in the 2012 EIS/R would negatively affect coho salmon that would otherwise migrate to their native tributary streams in the upper Klamath River.

2012 EIS/R Baseline Population Estimates and Project Effects Uncertainty

Effects to adult fish outlined in the 2012 EIS/R included approximations and assumptions that were based on limited data on Klamath River anadromous salmonids and Pacific lamprey populations; incorporated a conservative analysis of fish avoidance behavior to the anticipated water quality conditions; and in part included a worst-case scenario analysis of dam removal effects on adult salmonids and Pacific lamprey. The following sections provide updated population information for winter steelhead and Pacific lamprey, and identify project effects uncertainty that should be considered in updating the effects determinations.

Steelhead Population Update

Steelhead data for the Klamath River Basin upstream of the Trinity River are limited. Population data for winter steelhead in the 2012 EIS/R were based on Iron Gate Hatchery returns published in 1994 (Busby et al. 1994). In a strong return year based on the 1994 dataset, 3,500 adult winter steelhead returned to Iron Gate Hatchery (USBR and CDFG 2012). The 2012 analysis estimated that there would be 71 percent mortality to 80 percent of those fish based on run timing and effects of suspended sediment. Using updated winter steelhead counts for the Iron Gate Hatchery from 2000 to 2016 (Table 3-2), the peak and average numbers of adult winter steelhead returning to Iron Gate Hatchery were 631 and 242 steelhead, respectively. In 2016, steelhead returns to the hatchery were zero (CDFW 2016). If returns to Iron Gate Hatchery are indicative of the broader winter steelhead population, the precipitous decline suggests a lower number of winter steelhead are likely to be impacted during facilities removal and therefore a lower protection goal should be established for addressing effects to adult winter steelhead. Using the same methodology to establish the anticipated mortality to winter steelhead as contained in the 2012 EIS/R, but applied to the 2000-2016 steelhead return data, effects to steelhead would result in a loss of 358 and 138 steelhead on a peak and average year, respectively.

Video monitoring conducted in Bogus Creek and the Shasta River by CDFW between 2007 and 2016 also provides context to the recent abundance of upper Klamath steelhead populations. Average returns of adult steelhead counted by video were 53 and 102 steelhead for Bogus Creek and the Shasta River, respectively, during the 10-year period. However, many of those years video monitoring was terminated in December or January and did not capture the full steelhead migration period. In years where video monitoring or a combination of video counts and SONAR counts covered the full migration period (2013 and 2016 for Bogus Creek and 2012, 2015, and 2016 for Shasta River) total steelhead counted averaged 94 for Bogus Creek and 194 for the Shasta River (CDFW, unpublished data, 2017). Likewise, no steelhead have been produced at Iron Gate Hatchery since 2012 (K. Pomeroy, CDFW, personal communication, 2017). These numbers are indicative of the low returns of hatchery and natural origin steelhead in the upper Klamath River.

Pacific Lamprey Population Update

Recent genetic analysis of Pacific lamprey suggests no significant population structure exists across populations or regions, indicating a high degree of historical gene flow even across expansive distances of the northern Pacific Rim (Goodman and Reid 2012). Weak population structure and low site fidelity may reduce the short-term effects to Pacific lamprey identified in the 2012 EIS/R. Because the metapopulation is now believed to be relatively undifferentiated across the species' range, the percentage of adult and larval Pacific lamprey that will be affected by the dam decommissioning relative to the population as a whole will be insignificant.

Project Effects Uncertainty

Studies suggest that high suspended sediment concentrations (Newcombe and Jensen 1996; Chapman et al. 2014; Kjelland et al. 2015) and low dissolved oxygen concentrations (Bjorn and Reiser 1991; Washington Department of Ecology [WDOE] 2002; Carter 2005) affect adult salmonid behavior. Adult salmonid behavioral changes to high suspended sediment concentrations include avoidance of turbid waters in homing adult anadromous salmonids. Physiological effects of high turbidity include physiological stress and respiratory impairment, damage to gills, reduced tolerance to disease and toxicants, reduced survival, and direct mortality (Newcombe and Jensen 1996). Concentration and duration of elevated suspended sediment, as well as other factors including water temperature, disease, and river flow, influence the effect of suspended sediment on salmonids.

The effects of low dissolved oxygen levels, eutrophication, or turbidity on natural populations of Pacific lamprey adults and ammocoetes are unknown. Adult steelhead and Pacific lamprey entering the Klamath River during reservoir drawdown and dam removal would encounter poor water conditions and would be expected to avoid poor water quality by either entering tributary streams or using habitats less affected by high suspended sediment concentrations (e.g., tributary confluences or off-channel areas). For instance, in 2012 during dam deconstruction on the Elwha River, a high proportion (44 percent) of Chinook salmon redds were documented in two clear water tributaries (Indian Creek and Little River), while surveys conducted following dam removal activities (2014-2016) resulted in over 95 percent of Chinook redds constructed in the mainstem river. The high proportion of tributary spawning by fall Chinook salmon in 2012 suggests that these streams provided refugia from the effects of dam removal (McHenry et al. 2017). There is increasing evidence that fish will modify their behavior to avoid areas of high suspended sediment concentrations levels immediately following dam removal, thereby reducing the impact of reduced water quality on their populations. This is consistent with ecological and evolutionary theories that predict that fish evolve behaviors to avoid episodic events resulting is poor water quality, such as landslides, fires, and other naturally occurring processes.

The approach presented in the 2012 EIS/R to determine the anticipated effects assumed that fish would not exhibit any of these behavioral responses and instead suffer mortality by voluntarily remaining in areas that had lethal concentrations of suspended sediment for extended periods of time.

Effects to adult fall Chinook salmon are muted by the fact that any cohort is made up of several age classes of adult spawners. Adult returns the year following dam removal will be comprised of age-2, 3, and 4 fish that will be in the ocean during the dam decommissioning process. Benefits of dam decommissioning that are expected to be evident the first year following dam decommissioning include increased mainstem and tributary spawning habitat, reduction in disease-induced mortality, and reduction or elimination of redd-superimposition in spawning areas downstream of Iron Gate Dam (N. Hetrick, USFWS, personal communication, 2017). The improved conditions for fall Chinook salmon following dam decommissioning will bolster multiple age classes in the short and long-term, producing larger overall adult run sizes even with the anticipated short-term effects of the dam decommissioning.

3.3 AR-1 Summary

The Klamath River dam decommissioning project is anticipated to have significant short-term effects, but long-term benefits for fall Chinook salmon, coho salmon, winter steelhead, and Pacific lamprey. The 2012 EIS/R AR-1 mitigation plan included installing a weir and trap system on the Klamath River immediately upstream from the Shasta River confluence. The trap was proposed to be operated periodically to trap and haul fish for release into under-seeded tributaries upstream and downstream from Iron Gate Dam. The ATWG highlighted several concerns associated with the 2012 AR-1 plan, including trapping feasibility, handling mortality, potential genetic and disease effects of relocated fish on wild populations, disruption of adult coho salmon migration to spawning tributaries, and uncertainty of anticipated effects of the Project on adult salmonids and Pacific lamprey. The ATWG stated that these concerns could result in the original AR-1 mitigation effort being ineffective at reducing the Project's impacts and potentially introducing additional risks to adult anadromous salmonids and Pacific lamprey populations. Therefore, the ATWG determined that additional options in the form of an updated AR-1 are warranted.

The updated AR-1 plan, includes the development and implementation of a monitoring and adaptive management plan to offset the dam decommissioning effects on mainstem spawning. AR-1 actions include a 2-year tributary confluence monitoring effort and addressing sediment and debris obstructions that block volitional upstream passage from the Klamath River into tributaries. The second action includes a spawning habitat evaluation on the Klamath River and tributaries in the Hydroelectric Reach. If existing spawning habitat conditions do not meet target metrics, spawning gravel augmentation will be completed on both the mainstem and key tributaries in the Hydroelectric Reach.

Chapter 4: AR-2 Juvenile Outmigration

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4. AR-2 JUVENILE OUTMIGRATION

The objective of AR-2 is to address dam decommissioning effects on juvenile anadromous fish in the Klamath River downstream from Iron Gate Dam. The original 2012 EIS/R AR-2 plan focused on trapping and hauling juvenile anadromous salmonids and Pacific lamprey from 13 key tributaries prior to juvenile entry into the mainstem Klamath River during dam decommissioning. Trapped fish would be hauled and released into the Klamath River downstream from the Trinity River confluence where suspended sediment concentrations will be diluted by tributary inputs to sublethal concentrations. The updated AR-2 includes three actions including: sampling and salvaging yearling coho salmon from the Klamath River from Iron Gate Dam (RM 192.9) downstream to the Trinity River confluence (RM 43.4), and relocating captured fish to constructed off-channel ponds prior to reservoir drawdown; monitoring and ensuring tributary-mainstem connectivity; and monitoring juvenile salmonids and water quality conditions at the 13 key tributaries, and salvage and relocating juvenile salmonids if water quality thresholds are exceeded. The updated AR-2 actions are the best opportunities to offset juvenile anadromous fish losses during reservoir drawdown.

4.1 Proposed Updated AR-2

Based on a review of the original AR-2 presented in Section 4.2, input from the ATWG, and recent fisheries literature, the KRRC concluded an updated AR-2 is necessary to offset the anticipated short-term effects of dam decommissioning on outmigrating juvenile fish. The updated AR-2 includes three actions targeting juvenile salmonids.

- **Action 1:** Sampling and salvage of overwintering juvenile coho salmon from the Klamath River between Iron Gate Dam (RM 192.9) and the Trinity River (RM 43.4) confluence prior to reservoir drawdown. Sampling and salvage sites will focus primarily on alcoves, side channels, and backwatered floodplain features adjacent to the mainstem Klamath River. Up to 500 juvenile coho salmon are anticipated to be caught and relocated to off-channel ponds in order to protect this small, but important life history strategy in ESA-listed coho salmon population.
- **Action 2:** A monitoring and adaptive management plan will be prepared with input from the ATWG to monitor tributary-mainstem connectivity. Tributary-mainstem confluences, four sites in the Hydroelectric Reach and five sites in the 8-mile reach from Iron Gate Dam (RM 192.9) to Cottonwood Creek (RM 184.9), will be evaluated for 2-years from the onset of reservoir drawdown. If present, confluence blockages will be actively removed during the 2-year evaluation period to ensure volitional passage for juvenile Chinook salmon, coho salmon, steelhead, and Pacific lamprey. Juvenile salmonids are expected to benefit from dam decommissioning by restoring access to at least 13.9 miles of key tributary rearing habitats in the Hydroelectric Reach and several recognized thermal refugia areas including Jenny and Fall creeks.
- **Action 3:** The third action of the monitoring and adaptive management plan will include monitoring juvenile salmonids and water quality conditions in 13 key tributary confluences between Iron Gate

Dam (RM 192.9) and the Trinity River (RM 43.4). Tributary water temperatures and mainstem suspended sediment concentrations will be monitored beginning March 1 of the drawdown year. If water quality triggers are exceeded, juvenile salmonids will be salvaged from the tributary confluences and relocated to cool water tributaries, existing off-channel ponds, and/or downstream from the Trinity River confluence.

The proposed actions are intended to reduce Project effects on juvenile salmonids and Pacific lamprey during reservoir drawdown. The following sections provide additional detail on the proposed actions.

4.1.1 Action 1: Mainstem Salvage of Overwintering Juvenile Salmonids

The following sections provide information pertaining to mainstem salvage of overwintering juvenile salmonids, particularly yearling coho salmon.

Reconnaissance

Up to 15 sites between Iron Gate Dam (RM 192.9) and the Trinity River (RM 43.4) will be sampled during December of 2019 to determine the presence and relative abundance of yearling coho salmon. While low numbers of yearling coho salmon (<500) are expected to be encountered, these fish would be particularly vulnerable to the effects of elevated suspended sediment concentrations from reservoir drawdown and represent a small, but important life history strategy in the ESA-listed coho salmon population (T. Soto, Karuk Tribe, personal communication, 2017). Juvenile coho salmon overwintering downstream of the Trinity River will not be targeted for sampling or salvage efforts as water quality conditions associated with the reservoir drawdown period are expected to be similar to existing conditions (USBR and CDFG 2012). Sites upstream of the Trinity River that will be sampled include alcoves, side channels, and backwatered floodplain areas that do not have sufficient tributary inflows to provide refuge from expected high SSC in the mainstem Klamath River during reservoir drawdown. Priority will be given to sites closer to Iron Gate Dam where SSC are expected to be highest. Final site selection for the reconnaissance effort will be determined in consultation with ATWG.

Overwintering Juvenile Salmonids Salvage and Relocation

Following the reconnaissance effort, an overwintering yearling coho salmon relocation effort will be conducted in December prior to reservoir drawdown. Salvage efforts will take place as close to scheduled drawdown as possible to avoid capturing coho salmon that are migrating to overwintering habitats located in tributary streams or in the lower Klamath River below the Trinity River confluence. The number of sites will be based on the results of the 2019 reconnaissance effort although it is anticipated that up to 15 sites will be seined and trapped. A two-day effort with a 4-person crew and transport truck is anticipated at each site. A minimum of two weeks will be allocated to the salvage and relocation effort. The expected total catch of overwintering juvenile coho salmon in mainstem and off-channel habitats of the Klamath River is expected to be less than 500 individuals based on previous sampling efforts conducted by the Yurok Tribe and Karuk Tribe (Hillemeier et al. 2009). Seined and trapped juvenile coho salmon would be transported to existing off-channel ponds located on Seiad Creek (RM 131.9), West Grider Creek (RM 131.8), Horse Creek/ Middle

Creek (RM 116.0), Stanshaw Creek (RM 77.1), and Camp Creek (RM 57.4) or other natural beaver ponds or floodplain channels that are located in close proximity to the salvage sites and that are unaffected by elevated SSCs in the mainstem Klamath River. Coho salmon will be relocated to the off-channel habitat located closest to the salvage site and will be transported by using aerated buckets with lids or by transport truck if necessary. Other native fish captured during the seining and trapping effort, such as juvenile steelhead and juvenile Chinook salmon will be relocated into tributary streams adjacent to the salvage locations. Fish relocated to off-channel ponds will be allowed to volitionally move between ponds and tributary streams.

4.1.2 Action 2: Tributary-Mainstem Connectivity Monitoring

The following sections provide information on the monitoring and adaptive management plan pertaining to tributary-mainstem connectivity.

Tributary-Mainstem Connectivity Monitoring

To ensure that rearing habitat is accessible following reservoir drawdown, fish passage monitoring and adaptive actions will occur at the confluence areas of key Klamath River tributaries and side channels upstream and downstream of Iron Gate Dam. Tributary confluences in the Hydroelectric Reach may be affected by sediment deposits and debris obstructions as the reservoir are drawdown. Tributary deltas may create fish passage barriers that would limit upstream migration of anadromous salmonids and Pacific lamprey.

Based on hydraulic and sediment transport modeling completed by USBR (Section 9.2.1.4; 2011), sediment deposition during reservoir drawdown is predicted from Bogus Creek (RM 192.4) downstream to Cottonwood Creek (RM 184.9). From Bogus Creek (RM 192.4) downstream to Willow Creek (RM 187.8), approximately 1.5 feet of sediment deposition is anticipated. From Willow Creek downstream to Cottonwood Creek, deposition of less than 1 foot is expected. Areas downstream of Cottonwood Creek are expected to have only minor deposition with deposits less than 0.25 feet (USBR 2011). No additional deposition is predicted in the Bogus Creek to Cottonwood Creek reach following dam decommissioning.

Species that would be potentially affected by obstructed tributary connections include outmigrating Chinook salmon, coho salmon, steelhead and Pacific lamprey during and following reservoir drawdown. Further, depending on erosion rates of reservoir sediments, tributary confluences in the reservoir areas may not meet fish passage conditions following drawdown.

Tributary confluences to be monitored in the 2-year period following dam decommissioning include Bogus Creek (RM 192.4), Dry Creek (RM 190.9), Little Bogus Creek (RM 189.8), Willow Creek (RM 187.8), and Cottonwood Creek (184.9). Tributaries in the Bogus Creek to Cottonwood Creek reach were selected as they are recognized as influential tributaries (e.g., historical fisheries importance or important freshwater sources) in the mid-Klamath River (Soto et al. 2008). Hydroelectric Reach tributaries to be monitored include Spencer Creek (RM 230.5), Shovel Creek (RM 209.0), Fall Creek (RM 198.9), and Jenny Creek (RM 196.8).

These tributaries were selected based on having historical or potential habitat for adult salmonids (Huntington 2006).

Tributary Connectivity Maintenance

Unnatural tributary obstructions that limit volitional fish passage will be remedied through appropriate manual or mechanical means. Example removal methods may include removing sediment using hand tools or hydraulic equipment. Removed material will be placed in the mainstem Klamath River downstream of the tributary confluence or on the adjacent floodplain.

4.1.3 Action 3: Rescue and Relocation of Juvenile Salmonids and Pacific Lamprey from Tributary Confluence Areas

The following sections provide information on the monitoring and adaptive management plan pertaining to salvage and relocation of juvenile salmonids from tributary confluence areas.

Tributary and Mainstem Water Monitoring and Juvenile Fish Salvage

A monitoring and adaptive management plan will include monitoring juvenile salmonids and water quality conditions in 13 key tributary confluences between Iron Gate Dam (RM 192.9) and the Trinity River confluence (RM 43.4). Tributaries to be monitored include Bogus Creek (RM 192.4), Dry Creek (RM 190.9), Cottonwood Creek (RM 184.9), Shasta River (RM 179.3), Humbug Creek (RM 173.9), Beaver Creek (RM 163.3), Horse Creek (RM 149.5), Scott River (RM 145.1), Tom Martin Creek (RM 144.6), O'Neil Creek (RM 139.1), Walker Creek (RM 135.2), Grider Creek (RM 132.1), and Seiad Creek (RM 131.9).

Water temperatures in tributary streams will be monitored beginning March 1 of the drawdown year. SSC will be measured continuously following drawdown at water quality stations throughout the mainstem Klamath River including Iron Gate Dam, Seiad Valley, and Orleans. If key tributary water temperatures reach 17°C (7-day average of the daily maximum values), and Klamath River SSCs remain elevated above 1,000 mg/L,the ATWG will convene to organize the logistics for juvenile salvage and relocation efforts. If tributary water temperature trigger of 19°C (7-day average of the daily maximum values) and Klamath River suspended sediment concentration trigger of 1,000 mg/L (7-day sustained daily maximum) are met, a salvage effort will then be completed. The salvage effort would include capturing fish from confluence areas, loading them to aerated transport trucks, and relocating them to cool water tributaries or off-channel ponds including, but not limited to the Seiad Creek complex (RM 131.9). The Seiad Creek complex includes constructed off-channel ponds and connected cool water tributary channels. The complex provides juvenile salmonids with a variety of habitats that they can choose to use. If the number of salvaged fish exceeds the capacity of the Seiad Creek complex, juvenile salmonids may also be relocated to Beaver Creek (RM 163.3), Cade Creek (RM 110.9), Elk Creek (RM 107.2), Tom Martin Creek (RM 144.6), and Sandy Bar Creek (RM 77.8) as well as constructed off-channel ponds located on West Grider Creek (RM 131.8), Camp Creek (RM 57.4), and Stanshaw Creek (RM 77.1). Salmonids other than coho salmon, such as juvenile Chinook salmon and steelhead may be transported to the mainstem Klamath River below the confluence of the Trinity River if suitable tributary habitat is unavailable closer to the salvage sites. A multi-day salvage effort will be conducted at the confluence of the Shasta and Scott rivers and single day salvage efforts will be conducted at other tributary confluence areas by a 4-person crew and 2 transport trucks. Multiple days may be necessary at the Shasta and Scott River confluences based on juvenile salmonid abundance in the two tributaries.

4.2 Summary of the 2012 EIS/R AR-2, Dam Removal Benefits and Effects, and Recent Fisheries Literature

The following sections review the components of the 2012 EIS/R AR-2 measure, anticipated dam removal effects and benefits on AR-2 species, and recent fisheries literature relative to juvenile salmonid outmigration. This information is presented in support of the updated AR-2 measure.

4.2.1 AR-2 Affected Species

Species identified in AR-2 include:

- Coho salmon *(Oncorhynchus kisutch)* – Southern Oregon/Northern California Coastal (SONCC) evolutionary significant unit (ESU): Federally Threatened; California Threatened; Tribal Trust Species
- Chinook salmon *(O. tshawytscha)* – Upper Klamath-Trinity Rivers ESU - Fall Run: California Species of Special Concern; Tribal Trust Species
- Chinook salmon *(O. tshawytscha)* – Upper Klamath-Trinity Rivers ESU – Spring Run: California Species of Special Concern; Tribal Trust Species
- Steelhead *(O. mykiss)* – Klamath Mountains Province distinct population segment (DPS) – Summer Run: California Species of Special Concern; Tribal Trust Species
- Steelhead *(O. mykiss)* – Klamath Mountains Province DPS – Winter Run: Tribal Trust Species
- Pacific lamprey *(Entosphenus tridentatus)* - California Species of Special Concern; Tribal Trust Species

4.2.2 Anticipated Dam Decommissioning Effects on AR-2 Species

Short-term effects of dam removal are expected to result in mostly sublethal, and in some cases lethal, impacts to a portion of the juvenile Chinook salmon, coho salmon, steelhead, and Pacific lamprey that are outmigrating from tributary streams to the Klamath River during late winter and early spring of the drawdown year. Deleterious short-term effects are expected to be caused by high suspended sediment concentrations and low dissolved oxygen levels in the Klamath River from Iron Gate Dam (RM 192.9) downstream to Orleans (RM 59.0). Under the worst-case scenario, lost juvenile production in the Upper Klamath River, Middle Klamath River, Shasta River, and Scott River, includes the loss of up to: 669 fall Chinook salmon smolts, 6,536 coho smolts, 11,207 age-1 steelhead, 9,412 age-2 steelhead (USBR and CDFG 2012). Table

3-1 includes the likely and worst-case effects to anadromous outmigrating juveniles downstream from Iron Gate Dam.

Table 4-1 2012 EIS/R anticipated effects summary for outmigrating juvenile salmonids and Pacific lamprey ammocoetes

Species	Life Stage	Likely Effects	Worst Effects
Coho Salmon	Outmigrating Smolts	Loss of 2,668 (3%)	Loss of 6,536 (8%)
Chinook Salmon - Fall	Type III Smolts	Loss of 0-189 (<0.02%)	Loss of 0-669 (<0.07%)
Steelhead	Age-1+ Rearing1	Loss of up to 8,200 (14%)	Loss of up to 11,207 (19%)
	Age-2+ Rearing	Loss of up to 6,893 (13%)	Loss of up to 9,412 (18%)
Pacific Lamprey	Ammocoetes	High mortality (52%)2	High mortality (71%)2

Source: USBR and CDFG 2012

[1] Under existing conditions there is 20 percent mortality predicted for Age-1+ rearing.

[2]The 2012 EIS/R predicted Pacific lamprey mortality based on mortality models developed for suspended sediment impacts to salmonids. Model output did not include the number of predicted Pacific lamprey mortalities.

The following sections include descriptions of species-specific effects adapted from the 2012 EIS/R (USBR and CDFG 2012; Vol. I, pp. 3.3-129 to 3.3-168).

Coho Salmon

The wide distribution and use of tributaries by both juvenile and adult coho salmon will likely protect the population from the worst effects of the dam decommissioning. However, direct mortality is anticipated for redds and smolts from the upper Klamath River, mid-Klamath River, Shasta River, and Scott River population units. No mortality is anticipated for the Salmon River, Trinity River, and Lower Klamath River populations under the most likely or worst-case scenarios. Based on substantial reduction in the abundance of a year class in the short-term, the effect of the dam decommissioning was found to be significant for the coho salmon from the Upper Klamath River, Mid-Klamath River, Shasta River, and Scott River population units.

Age-1 juveniles that have either successfully over-summered or moved from tributaries into the mainstem in fall could be exposed to much higher suspended sediment concentrations in the mainstem during the winter of facility removal than under existing conditions, and may suffer mortality rates of up to 52 percent under a worst-case scenario (USBR and CDFG 2012). However, many juveniles in the mainstem Klamath River appear to migrate to the lower river to rear and may avoid adverse conditions in the mainstem by using tributary or off-channel habitats during winter, thus reducing their exposure and potential mortality

(Hillemeier et al. 2009; Soto et al. 2009), consistent with the observation that juvenile salmonids avoid turbid conditions (Sigler et al. 1984; Servizi and Martens 1992). This strategy may be even more pronounced under elevated suspended sediment concentrations expected as a result of the dam decommissioning project. Overall, it is not known how many juveniles rear in the mainstem during winter, but it is assumed to be a small (<1 percent) proportion of any of the coho salmon populations (USBR and CDFG 2012).

Coho salmon smolts from the cohort prior to reservoir drawdown are expected to outmigrate to the ocean beginning in late February, although the majority of coho smolts typically outmigrate to the mainstem Klamath during April and May (Wallace 2004). During migrant trapping studies from 1997 to 2006 in tributaries upstream of and including Seiad Creek (Horse Creek, Seiad Creek, Shasta River, and Scott River), 44 percent of coho smolts were captured from February 15 to March 31, and 56 percent from April 1 through the end of June (Courter et al. 2008).

Smolts outmigrating in early spring (prior to April 1), are likely to suffer up to 60 percent mortality under the 2012 EIS/R worst-case scenario (USBR and CDFG 2012). Based on modeled population estimates presented in Courter et al. (2008), the anticipated 60 percent mortality would represent a loss of up to 6,536 smolts from the Upper Klamath River, Shasta River, Scott River, and Middle-Klamath River coho populations.

Smolts outmigrating in late spring (after April 1) would be exposed to lower suspended sediment concentrations, and may experience only slightly worse physiological stress and reduced growth rates compared with existing conditions, even under the worst-case scenario (USBR and CDFG 2012).

Chinook Salmon – Fall Run

Fall Chinook salmon use the mainstem Klamath River for spawning, rearing, and as a migratory corridor. Effects of suspended sediment concentrations on juvenile fall Chinook salmon from dam decommissioning are expected to be relatively minor because of varied life histories. During juvenile salmonid outmigration trapping conducted at Big Bar on the Klamath River between 1997-2000, very few Chinook were captured before the beginning of June (USFWS 2001). The large majority of age-0 juveniles (Type I outmigrants) remain in tributaries until later in the spring and summer when water quality conditions are expected to be improved relative to late winter and early spring. Type II outmigrants typically rear in tributaries before outmigrating to the mainstem Klamath River and estuary in fall (Sullivan 1989). Additionally, many of the fry that outmigrate to the Klamath River originate in tributaries in the mid or lower Klamath River, where suspended sediment concentrations resulting from the dam decommissioning are expected to be lower due to dilution from tributaries (USBR and CDFG 2012). Based on trapping data from Big Bar, approximately 63 percent of Chinook smolts are Type I outmigrants and 37 percent are Type II outmigrants (USFWS 2001).

A small proportion of juvenile Chinook salmon typically remain to rear in the spawning tributaries until outmigrating in late winter and early spring as yearlings (Type III outmigrants). Although fish exhibiting this life history trait would be most susceptible to the effects of suspended sediment concentrations, these fish represent a very small proportion (<1 percent of all production) of the Klamath River fall Chinook salmon population (USFWS 2001). Based on outmigrant trapping in the mainstem Klamath River at Big Bar, around 942,829 Chinook salmon smolts outmigrate each spring, including both hatchery and naturally produced fish (USFWS 2001). Only 31 Type III outmigrating smolts were captured over 4 years, representing approximately 0.1 percent of the total catch. Based on yearly abundance estimates, this equates to approximately 943 total Type III smolts per year (USFWS 2001). Under the 2012 EIS/R worst-case scenario, mortality rates of up 71 percent are predicted during the dam decommissioning, equating to 669 smolts, or approximately 0.07 percent of the total fall Chinook salmon smolt production. Type I and Type II juvenile outmigrants are expected to experience only sublethal effects (USBR and CDFG 2012).

Steelhead – Summer and Winter

Juvenile steelhead rear in the mainstem Klamath River, Klamath River tributaries, and the estuary. Since most (>90 percent) juvenile steelhead smolt at age-2, those juveniles leaving tributaries to rear in the mainstem will be exposed to elevated suspended sediment concentrations resulting from the dam decommissioning through both winter and spring (USBR and CDFG 2012). Based on captures in tributaries and the mainstem, approximately 40 percent of the population rears in tributaries until age-2 (USFWS 2001), and will only be susceptible to mainstem water quality conditions during outmigration. The approximately 60 percent of the rearing population that outmigrates from tributaries as age-0 or age-1 fish, and rears for extended periods in the mainstem upstream of Trinity River, would likely be exposed to much higher suspended sediment concentrations than under existing conditions, with mortality rates up to 100 percent under the worst-case scenario (USBR and CDFG 2012).

Despite these anticipated mortality rates, the broad spatial distribution of steelhead in the Klamath Basin and their flexible life histories suggest that some steelhead will avoid the most serious effects of dam decommissioning by remaining in tributaries for extended rearing, rearing farther downstream where suspended sediment concentrations is expected to be lower due to tributary dilution, and/or moving out of the mainstem into tributaries and off-channel habitats to avoid periods of high suspended sediment concentrations. From past studies, many of these juveniles avoid conditions in the mainstem by using tributary and off-channel habitats during winter, which would reduce their exposure to poor water quality during dam decommissioning (Hillemeier et al. 2009; Soto et al. 2009), consistent with the observation that juvenile salmonids avoid turbid conditions (Sigler et al. 1984; Servizi and Martens 1992). Most smolts outmigrate in the fall, so many juveniles should already be in the estuary or ocean when initial pulses in sediment occur after December 31 prior to reservoir drawdown, or they may migrate out of the mainstem later in the winter after suspended sediment concentrations decrease.

Life history variability observed in steelhead means that, although numerous year classes will be affected, not all individuals in any given year class will be exposed to project effects. Some portion of the progeny of those adults that spawn successfully in winter and spring of the reservoir drawdown year would also rear in tributaries long enough to not only avoid the highest suspended sediment concentrations, but may also not return to spawn for up to 2 years, when suspended sediment resulting from the dam decommissioning should be greatly reduced. The high incidence of repeat spawning among summer steelhead, ranging from 40 to 64 percent (Hopelain 1998), should also increase that population's resilience to dam decommissioning effects.

Pacific Lamprey

Dam decommissioning would have short-term effects on Pacific lamprey related to suspended sediment concentrations, bedload sediment transport and deposition, and impaired water quality (particularly dissolved oxygen). Overall, because multiple year classes of Pacific lamprey rear in the mainstem Klamath River at any given time, and since adults will migrate upstream over the entire year, including January of the reservoir drawdown year when effects from the dam decommissioning will be most pronounced, effects on Pacific lamprey adults and ammocoetes are anticipated to be substantial. However, because of their wide spatial distribution and varied life history, most of the population, (which is distributed from at least California along the Pacific Rim to Japan [Goodman and Reid 2012]), would not be affected by the dam decommissioning. Effects of suspended sediment on lamprey ammocoetes are not well understood and for the 2012 EIS/R analysis were based on using the same anticipated effects for juvenile salmonids. This likely overestimates any effects to lamprey ammocoetes since their preferred rearing strategy is to burrow in fine sediments mixed with organic matter. While some of the actions listed in the proposed updated AR-2 below have the potential to benefit Pacific lamprey ammocoetes, (i.e., tributary connectivity and habitat restoration) no specific actions have been developed to specifically target Pacific lamprey for relocation from the areas affected by bedload or high suspended sediment concentrations. Additional discussion of Pacific lamprey ammocoetes effects is provided in AR-5.

4.2.3 2012 EIS/R AR-2 Actions

The 2012 EIS/R AR-2 plan (2012 EIS/R, Vol. I, pp 3.3-243 to 3.3-245) included water quality monitoring to evaluate Klamath River suspended sediment concentrations. If pre-determined water quality thresholds were triggered, a network of 17 screw traps located on 13 key tributaries would be operated to capture downstream migrants prior to their entry into the mainstem Klamath River. Captured juveniles would be transported and released at sites downstream of the Trinity River or other locations with suitable water quality.

4.2.4 KRRC Review of AR-2 for Feasibility and Appropriateness

The KRRC assessed the feasibility and appropriateness of AR-2 through multiple planning meetings held with the ATWG between May and August 2017. During these meetings, new information on Klamath River fisheries was presented and information on other dam removal projects conducted in the western United States was reviewed to understand how the aquatic ecosystem might respond as discuss above. Major concerns discussed by KRRC and ATWG regarding the 2012 AR-2 included:

- Trapping feasibility and efficiency.
- Potential mortality associated with trapping, handling, hauling, and releasing juvenile salmonids.
- Potential imprinting and straying issues.
- 2012 EIS/R baseline population estimates and effects uncertainty.

The following sections provide additional information regarding AR-2 feasibility and appropriateness based on fisheries literature and ATWG input.

Trapping Feasibility and Efficiency

A wet winter season, such as experienced between January and May 2017, could prevent the installation and operation of rotary screw traps in any of the prospective tributaries due to persistent high flows. Additionally, capture efficiencies for juvenile salmonids in rotary screw traps is highly variable and depends on many factors such as stream width, depth, flow conditions, and time of day of operation. Capture efficiencies of juvenile salmonids using rotary screw traps are typically very low, and would result in a small proportion of the downstream migrants being captured for relocation and release. For example, trapping efficiencies on various salmonids calculated by the USGS during monitoring efforts for the recent Condit Dam removal on the White Salmon River in Washington State ranged from 0 - 10.6 percent (Allen and Connolly 2011). Trapping efforts for juvenile Chinook salmon on Blue Creek in the Klamath Basin by the Yurok Tribe resulted in trapping efficiencies ranging from 0.5 - 51.3 percent, but trapping efficiencies of greater than 10 percent were not achieved until stream flows dropped in mid-June (Antonetti and Partee 2013). By mid-June, water quality conditions in the Klamath River following dam removal are expected to have returned to background condition and further remediation actions are not expected to be necessary (USBR and CDFG 2012).

The ATWG concluded the level of effort, cost, and likely low capture efficiencies do not support the installation of screw traps for capturing outmigrating juvenile fish during dam decommissioning. The ATWG also concluded the concurrent operation of 17 screw traps during spring high flows is not feasible or safe given potential flow conditions and the remoteness of some tributaries.

Potential Mortality Associated with Trapping, Handling, Hauling, and Releasing Juvenile Salmonids

The KRRC and ATWG concluded that although mortality on juvenile salmonids associated with trap and haul operations are typically low, these numbers are based on a variety of environmental factors and logistical considerations and can be highly variable (Serl and Morrill 2010). Transporting juvenile salmonids causes stress in smolts (Barton et al. 1980; Specker and Schreck 1980; Matthews et al. 1986), which may reduce survival if fish are directly released into natural environments (Kenaston et al 2001). In some cases, the mortality associated with screw trapping, handling, trucking, and releasing may exceed the expected mortality associated with dam decommissioning. For instance, under the worst-case scenario, high suspended sediment concentrations and low total DO could result in the direct mortality of up to 669 fall Chinook salmon smolts, less than 1 percent of production (USBR and CDFG 2012). Mortality associated with trapping, handling, transport, and release efforts could potentially result in a similar or greater loss of fall Chinook salmon smolts. The ATWG suggested that outmigrating juvenile fish are well-adapted to avoid lethal sediment concentrations and will likely employ avoidance behaviors to minimize exposure to lethal suspended sediment concentrations and DO levels. The ATWG concluded that large scale efforts aimed at trapping, handling, and releasing juvenile salmonids were likely to cause unnecessary harm to juvenile salmonids.

Potential Imprinting and Straying Issues

The KRRC and ATWG expressed concerns regarding how handling and transport of juvenile salmonids may affect imprinting processes resulting in future straying of returning adults. Juvenile imprinting is influenced by natal stream water chemistry and the juvenile fish's physiological state during rearing and outmigration (Keefer and Caudill 2014). Juvenile fish with extended freshwater residency times, or long-distance migrations, almost certainly experience multiple imprinting events that contribute to homing success of adult spawners. Transporting juvenile fish has been shown to disrupt this 'sequential imprinting' process, and several studies on coho salmon (Solazzi et al. 1991) and Atlantic salmon (Gunnerød et al. 1988; Heggberget et al. 1991) have shown that adult homing success is inversely related to transport distance from rearing sites (Keefer and Caudill 2014).

Therefore, the capture, transport, and release of juvenile fish downstream of the Trinity River could compromise the imprinting process for relocated juvenile fish. Insufficient imprinting to natal streams or the loss of spatially distinct imprinting events during outmigration could potentially increase adult straying rates during future returns and result in the loss of genetic integrity in distinct populations. Future, elevated stray rates could result in a more homogenous distribution of fish returning to the lower Klamath River and also hinder the natural recolonization of areas upstream of Iron Gate Dam.

Overall, the ATWG concluded a screw trap-based trapping program as prescribed in the 2012 EIS/R would be a costly, potentially dangerous effort with uncertain benefits. Tributary trapping could also negatively affect juvenile salmonids by disrupting imprinting processes, causing higher mortality than allowing fish to volitionally leave tributaries, and potentially increasing future returning adult stray rates.

2012 EIS/R Baseline Population Estimates and Project Effects Uncertainty

Effects to juvenile fish outlined in the 2012 EIS/R included approximations and assumptions that were based on limited data on Klamath River anadromous salmonids and Pacific lamprey populations; incorporated a conservative analysis of fish avoidance behavior to the anticipated water quality conditions; and in part included a worst-case scenario analysis of dam removal effects on adult salmonids and Pacific lamprey. The following sections provide updated population information for coho salmon and Pacific lamprey, and project effects uncertainty that should be considered in updating the effects determinations.

Coho Salmon Smolt Population Estimates and Outmigration Timing

KRRC reviewed updated smolt trapping data collected by USFWS and CDFG between 2010 and 2015 on the upper mainstem Klamath River and 2010-2016 on the Scott and Shasta Rivers to determine the typical outmigration timing for age-1+ coho salmon smolts. KRRC also reviewed travel time data to see how quickly juvenile fish typically outmigrate in the spring to avoid long exposure to background suspended sediment concentrations effects.

For rotary screw traps and frame nets operated at the Bogus, I-5, and Kinsman sites on the mainstem Klamath River between 2010 and 2015, 63 percent of age-1+ coho migrated after Julian week 13 (last week in March) (Gough et al. 2015; David et al. 2016; and David et al. 2017). Between 2010 and 2016, 93 percent of age-1+ coho salmon captured by rotary screw trap on the Shasta River outmigrated after the end of March, and on the Scott River, 70 percent of age-1+ coho salmon smolts outmigrated after the end of March during the same time period (Jetter and Chesney 2016). Peak outmigration timing beginning in early April on the Shasta River, typically coincides with decreased flows marked by the start of the irrigation season and is consistent with findings from previous studies (Chesney et al. 2009; Adams 2013; Adams and Bean 2016) from CDFW 2016.

Once in the Klamath River, coho salmon smolts appear to move downstream rather quickly. For example, Wallace (2004) reported that numbers of coho salmon smolts in the Klamath River estuary peaked in May, the same month as peak outmigration from the tributaries (Stillwater Sciences 2010). Radio telemetry studies conducted on wild and hatchery coho salmon smolts in the Klamath River between 2006 and 2009 found a wide variety of travel times for coho salmon smolt outmigrating from Iron Gate Dam to the gaging station near the Klamath River estuary (Beeman et al. 2012). The minimum travel time was 3.77 days and the maximum travel time to reach the estuary was 54.44 days with median values over the 4-year study ranging between 15.11 and 25.93 days. However, the longest residence time for any single reach was from the Iron Gate Dam release site to the Shasta River as tagged fish remained near the release site until they were ready to begin the downstream migration to the Pacific Ocean. Once fish passed the Shasta River, travel times in any individual reach were less than 2 days and coho salmon smolts usually took less than 1 week to fully migrate to the gaging station near the Klamath River estuary (Beeman et al. 2012). Courter (2008) assumed that all fish from a given cohort would migrate to the estuary in 2 weeks, and this assumption is also consistent with travel rates documented by Stutzer et al. (2006). Assuming that juvenile fish outmigrating from tributary streams will either outmigrate rapidly to the Klamath River estuary or will move between clean water tributary areas, it is anticipated that no outmigrating smolts will be exposed to suspended sediment for greater than seven contiguous days.

Minimum travel times presented in Beeman et al. (2012) indicate that juvenile coho salmon could migrate downstream of the highest suspended sediment concentrations effects zone fairly quickly. The 2012 EIS/R analysis assumed coho salmon smolts would be exposed to high suspended sediment concentrations for 20 days during the highest suspended sediment concentrations period (prior to April 1). This assumption resulted in a very high mortality estimate for coho salmon smolts (USBR and CDFG 2012).

Further, because smolt abundance data from all tributaries within the Upper Klamath, Middle-Klamath, Salmon River, and Lower Klamath River populations were not available for the 2012 EIS/R analysis, smolt production estimates modeled by Courter et al. (2008) were used to predict the number of smolts emigrating to the Klamath River from each population. Modeled smolt production estimates were based on tributary habitat conditions and smolt production data for other populations. Recent trends in adult returns to tributaries, the Klamath River, and Iron Gate Hatchery indicate that coho salmon populations continue to decline, and that these modeled estimates are likely higher than current actual population sizes.

In a study of juvenile coho salmon use of thermal refugia along the Klamath River, juvenile coho began to enter thermal refugia as water temperature reached 19°C, numbers of coho salmon present increased up to about 22°C to 23°C, and then declined dramatically as temperatures exceeded 23°C (Sutton and Soto

2012). These results suggest that 23°C is the upper thermal tolerance limit, with either lethal effects to juvenile coho salmon or temperature- related stress that causes the fish to move to different habitats.

By updating the current understanding of coho salmon population estimates and typical juvenile coho salmon outmigration timing from Klamath River, Shasta River, and Scott River coho salmon populations, and by adjusting the potential duration of exposure to reflect typical downstream migration rates, anticipated effects to age-1+ coho salmon smolts may result in substantially lower coho salmon smolt mortality estimates, and in most cases, only result in sub-lethal effects.

Pacific Lamprey Population Update

Recent genetic analysis of Pacific lamprey suggests no significant population structure exists across populations or regions, indicating a high degree of historical gene flow even across expansive distances of the northern Pacific Rim (Goodman and Reid 2012). Weak population structure and low site fidelity may reduce the short-term effects to Pacific lamprey identified in the 2012 EIS/R. Because the metapopulation is now believed to be relatively undifferentiated across the species' range, the percentage of adult and larval Pacific lamprey that will be affected by the dam decommissioning relative to the population as a whole will be insignificant.

Project Effects Uncertainty

Studies suggest that high suspended sediment concentrations (Newcombe and Jensen 1996; Chapman et al. 2014; Kjelland et al. 2015) and low dissolved oxygen concentrations (Bjorn and Reiser 1991; Washington Department of Ecology 2002; Carter 2005) affect salmonid behavior. Juvenile salmonid response to high suspended sediment concentrations includes behavioral changes such as avoidance of turbid waters, and physiological responses such as stress and respiratory impairment, damage to gills, reduced tolerance to disease and toxicants, reduced survival, and direct mortality (Newcombe and Jensen 1996). Concentration and duration of elevated suspended sediment, as well as other factors including water temperature, disease, and river flow, influence the effect of sediment on salmonids.

The effects of low dissolved oxygen levels, eutrophication, or turbidity on natural populations of Pacific lamprey ammocoetes are unknown. Juvenile salmonids and juvenile Pacific lamprey emigrating from tributaries to the Klamath River that encounter poor water conditions are expected to avoid poor water quality by either remaining in tributary streams or using habitats less affected by high suspended sediment concentrations (e.g., tributary confluences and off-channel areas). Many juveniles in the mainstem Klamath River appear to migrate to the lower river to rear and may avoid adverse conditions in the mainstem by using tributary or off-channel habitats during winter, thus reducing their exposure and potential mortality (Hillemeier et al. 2009; Soto et al. 2009), consistent with the observation that juvenile salmonids avoid turbid conditions (Sigler et al. 1984; Servizi and Martens 1992).

The approach presented in the 2012 EIS/R to determine the anticipated effects to outmigrating juveniles assumed that fish would not exhibit any of these behavioral responses and instead suffer mortality by voluntarily remaining in areas that had lethal suspended sediment concentrations for extended periods of time.

4.3 Response to SWRCB Request for Additional Information Related to Suspended Sediment Concentration Effects on Outmigrating Juvenile Salmonids

4.3.1 Introduction

The following information is provided in response to an information request submitted by the California State Water Resources Control Board (SWRCB) to the KRRC regarding the effects of suspended sediment concentrations on outmigrating juvenile salmonids. The goals of this response include reviewing recent juvenile salmonid outmigration data for the Klamath River and select tributaries, comparing outmigration periods to anticipated suspended sediment concentrations from U.S. Bureau of Reclamation (Reclamation) sediment modeling, and assessing potential juvenile salmonid avoidance behaviors related to high suspended sediment concentrations.

Results of our additional analysis suggest juvenile Chinook salmon, coho salmon, and steelhead generally outmigrate from tributaries to the Klamath River after peak suspended sediment concentrations are anticipated to occur. However, early outmigrating juvenile Chinook salmon and coho salmon from the Shasta River and Scott River are most susceptible to anticipated suspended sediment concentrations associated with reservoir drawdown. Fish may reduce their exposure to high suspended sediment levels by seeking clear water tributary confluences, entering clear water tributaries and off-channel ponds, and expediting their downstream migration. Measures to further reduce suspended sediment impacts to early outmigrating salmonids include implementing an adaptive monitoring and salvage plan. The KRRC may also consider initiating reservoir drawdown 2-4 weeks earlier than the current proposed schedule to further minimize effects to early outmigrating Chinook salmon and coho salmon. However, initiating an earlier drawdown would also potentially affect the later portion of the adult coho spawning migration. Additional discussion with the fisheries agencies is warranted if an earlier drawdown is possible.

4.3.2 Klamath River and Tributaries Updated Screw Trap Data and Suspended Sediment Effects

The following section provides an overview of the screw trap and suspended sediment concentration analysis KRRC completed to assess potential reservoir drawdown effects to outmigrating juvenile salmonids.

Screw Trap Data

Screw trap data provided by U.S. Fish and Wildlife Service (USFWS), California Department of Fish and Wildlife (CDFW), Yurok Tribe, and Karuk Tribe (referenced as "acquiring entity") were reviewed and summarized. The screw trap data analysis focused on 2008 to 2015, and provides an updated data set extending the period of record for screw traps data reviewed in preparation of the 2012 EIS/R (Reclamation and CDFG 2012). Screw trap data from the Klamath River and tributaries to the Klamath River (Table 4-2) were reviewed to assess juvenile salmonid outmigration timing and relative abundance. Reported data include both juvenile outmigration population estimates and trap catch numbers. Outmigration estimates were generally provided by the acquiring entities for juvenile fall Chinook salmon due to the sufficient abundance of individuals in the mainstem and tributaries. Outmigration estimates are computed by multiplying the number of caught fish by a correction factor that approximates trap efficiency. Compared to trap catch numbers, outmigration estimates are a better representation of the potential number of outmigrating juvenile salmonids from the watershed upstream from the trap location.

Trap catch represents the actual number of fish captured during trap operation. Trap catch numbers do not include a correction for stream flow or trap efficiency so trap catch numbers are a less reliable predictor of outmigration timing and population size. Trap catch is reported for Chinook salmon, coho salmon, and steelhead. Coho salmon and steelhead catches were generally insufficient for calculating outmigration population estimates. Trap catch data are reviewed to provide a relative indication of juvenile salmonid outmigration timing and magnitude, but data are less reliable for predicting juvenile abundance compared to population estimates. Population estimates and trap catch data are reported by Julian Week to improve data comparability over time and to also compare trap data with suspended sediment concentrations. Figure 4-1 includes a map with highlighted trap and water and suspended sediment modeling stations.

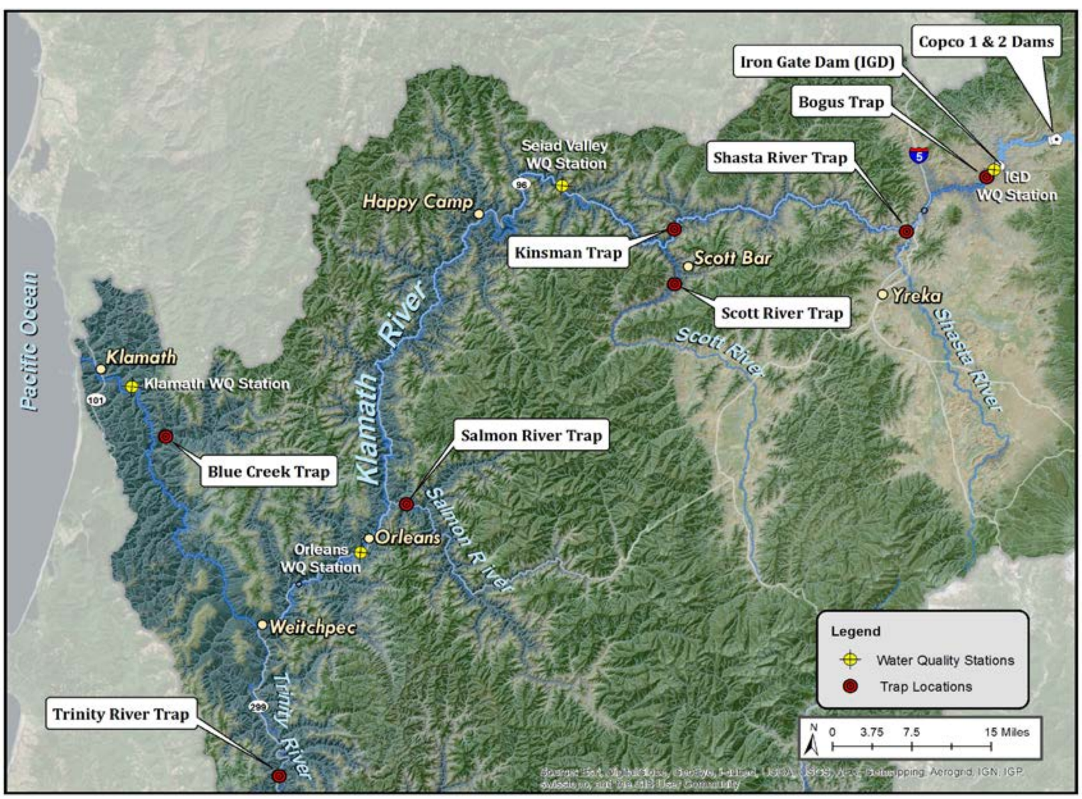
Table 4-2 Juvenile outmigration trap information and reporting data for Klamath River and Tributary Traps.

Reach	Trap Location	Trap Type	Acquiring Entity	Reporting Data
Upper Klamath River	Mainstem downstream from Bogus Creek[1] (RM 191.2)	Net frame	USFWS	Chinook (age-0) estimates Coho (age-0 and age-1+) catch Steelhead (age-0 and age-1+) catch
	Shasta River[2] (Confluence at RM 179.3)	RST*	CDFW	Chinook (age-0) estimates Coho (age-0 and age-1+) estimates Steelhead (age-0 and age-1+) estimates
	Mainstem at Kinsman Creek (RM 147.6)[1]	RST	USFWS	Chinook (age-0) estimates Coho (age-0 and age-1+) catch Steelhead (age-0 and age-1+) catch

Reach	Trap Location	Trap Type	Acquiring Entity	Reporting Data
	Scott River[2] (Confluence at RM 145.1)	RST	CDFW	Chinook (age-0) estimates Coho (age-0 and age-1+) estimates Steelhead (age-0 and age-1+) estimates
Middle Klamath River	Salmon River[3] (Confluence at RM 66.4)	RST	Karuk Tribe	Chinook (age-0+) catch Coho (age-0+) catch Steelhead (age-0+) catch
	Trinity River[4] (Confluence at RM 43.4)	RST	USFWS	Chinook (age-0+) catch Coho (age-0+) catch Steelhead (age-0+) catch
Lower Klamath River	Blue Creek[5] (Confluence at RM 16.0)	RST	Yurok Tribe	Chinook (age-0) estimates Coho (age-0 and age-1+) catch Steelhead (age-0 and age-1+) catch

**Rotary screw trap*
[1]Gough et al. 2015; 2Jetter et al. 2016; 3Karuk Tribe, unpublished data, 2017; 4Harris et al. 2016; 5Yurok Tribe, unpublished data, 2017

Figure 4-1 Screw trap and suspended sediment modeling stations on the Klamath River.



4.3.3 Suspended Sediment Concentration Analysis

Reclamation provided KRRC with the suspended sediment modeling output summarized in Reclamation's (2011) hydrology, hydraulics, and sediment report. KRRC replicated Reclamation's summary suspended sediment concentration graphs associated with sediment modeling for representative dry (2001), median (1976), and wet (1984) years at the four reporting stations: Iron Gate Dam, Seiad Valley, Orleans, and Klamath (see Figure 4-1 and Figure 4-2). Reservoir drawdowns are planned to begin January 1 of the dam removal year. Suspended sediment concentrations rise to an early to mid-February peak and then decline through the fall. Concentrations are generally highest for dry year scenario with other scenarios having lower relative suspended sediment concentration values (Table 4-3). Suspended sediment concentrations generally decrease in a downstream direction as inflows from clear water tributaries dilute suspended sediment concentrations in the Klamath River.

Figure 4-2 Modeled suspended sediment concentrations associated with reservoir drawdown and dam removal. Modeling output is presented for the Klamath River at Iron Gate, Seiad Valley, Orleans, and Klamath modeling stations. Graphs include dry year (2001, upper left), median year (1976, upper right), and wet year (1984, lower left).

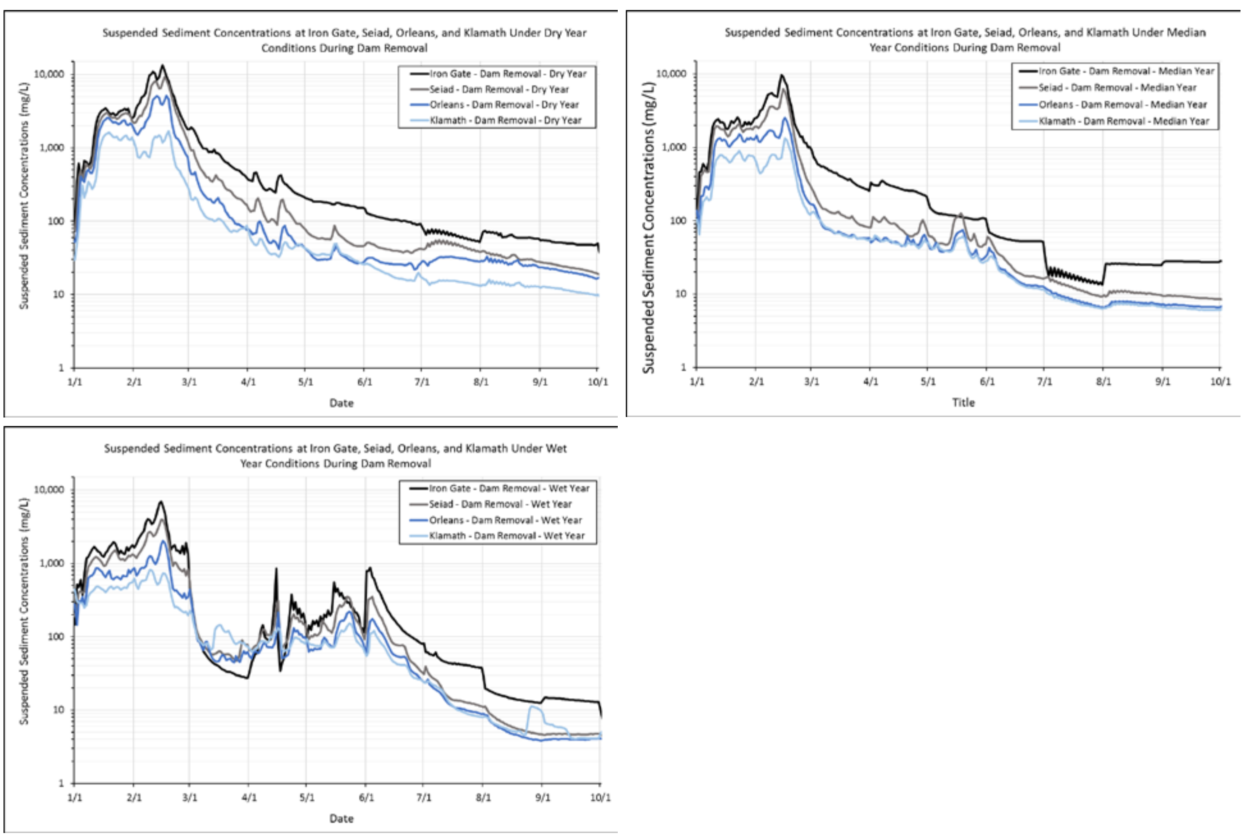


Table 4-3 Suspended sediment modeling output stations and summary results. Suspended sediment concentrations related to juvenile salmonid mortality are also included for reference. A 2-week exposure to 1,000 mg/L concentration is associated with predicted 0-20 percent mortality, and 2-week exposure to 3,000 mg/L is associated with 20-40 percent mortality.

Suspended Sediment Modeling Station	Approximate Location (river mile)	Wet Year / Dry Year Peak SSC (mg/L)	Wet Year / Dry Year Cumulative Days with SSC above 1,000 mg/L	Wet Year / Dry Year Cumulative Days with SSC above 3,000 mg/L
Iron Gate Dam	192.9	6,988 / 13,385	54 / 57	12 / 33
Seiad Valley	131.9	3,999 / 9,223	41 / 50	4 / 19
Orleans	59.0	2,046 / 5,157	11 / 45	0 / 11
Klamath	2.5	819 / 1,670	0 / 28	0 / 0

Juvenile Salmonid Suspended Sediment Exposure

The following sections present information on juvenile salmonid outmigration rates in the Klamath River and suspended sediment exposure effects.

Juvenile Salmonid Outmigration Travel Time

In order to better predict potential effects of elevated suspended sediment concentrations on outmigrating juvenile salmonids, KRRC reviewed past studies and analyzed Klamath River juvenile salmonid outmigration rates and timing. Past Klamath River studies found juvenile salmonid outmigration rates are influenced by tributary and Klamath River water temperatures, smolt growth rates, and other environmental cues.

Wallace (2004) reported coho salmon smolts in the Klamath River estuary peaked in May, the same month as peak outmigration from the tributaries (Stillwater Sciences 2010). Radio telemetry studies conducted on wild and hatchery coho salmon smolts in the Klamath River between 2006 and 2009 found a wide range of travel times for coho salmon smolts outmigrating from Iron Gate Dam to the gaging station near the Klamath River estuary (Beeman et al. 2012). The minimum and maximum travel time were 3.8 and 54.4 days, respectively, with median values over the 4-year study ranging between 15.1 and 25.9 days. However, the longest residence time for any single reach was from the Iron Gate Dam release site to the Shasta River as tagged fish remained near the release site until they were ready to begin the downstream migration to the Klamath estuary. Once fish passed the Shasta River, travel times in any individual reach were less than 2 days and coho salmon smolts usually took less than 1 week to fully migrate to Klamath estuary (Beeman et al. 2012). Courter (2008) assumed that all fish from a given cohort would migrate to the estuary in 2-weeks, and this assumption is also consistent with travel rates documented by Stutzer et al. (2006). Based on the literature review, a 2-week outmigration period is believed to be a conservative period for juvenile salmonid exposure to elevated suspended sediment concentrations in the Kamath River. We also anticipate that outmigrating salmonids will have access to, and will choose to use clean water locations such as clear water tributary confluences, off-channel ponds and tributaries, and spring seeps during their outmigration, reducing exposure times. Additionally, suspended sediment concentrations will be substantially diluted by tributary inputs including the Trinity River (RM 43.4).

Juvenile Salmonid Suspended Sediment Exposure Effects

Newcombe and Jensen (1996) created “look-up tables” to predict response severity to suspended sediment exposures of varying durations and concentrations. Predicted severity-of-ill effects scores or indices were developed from empirical data gathered from numerous dose-response studies. Based on review of these data, juvenile salmonids exposed to concentrations of approximately 1,100 mg/L for 2-weeks have a severity-of-ill-effects score of 10, and may experience mortality rates between 0 and 20 percent. Expected mortality rates increase to between 20-40 percent as suspended sediment concentrations approach 3,000 mg/L.

While these predicted severity scores are helpful for evaluating the potential effects to juvenile fish, there is considerable variability between the effects to different species under different conditions as documented in the numerous studies synthesized by Newcombe and Jensen (1996). For instance, the authors reviewed an unpublished study where coho fry that were exposed to suspended sediment at a concentration of 5,471 mg/L for 96 hours in water at 18.7ºC sustained a mortality rate of 10 percent, while similarly exposed steelhead experienced no mortality.

Servizi and Martens (1992) found that a stress response is dependent on a combination of factors including magnitude, frequency, and duration of exposure, as well as environmental factors such as particle size and water temperature. For example, effects to juvenile steelhead and coho salmon held in 18.7ºC water, may have exacerbated the effects of suspended sediment on coho since temperatures of 19ºC are considered suboptimal and juvenile coho salmon typically begin to seek cold water refugia at that threshold (Stenhouse et al. 2012). Likewise, Noggle (1978) found seasonal differences in salmonid tolerance to suspended sediment. In Noggle’s study, bioassays conducted in summer produced lethal concentrations and 50 percent mortality (LC50) of exposed fish at less than 1,500 mg/l, while bioassays in autumn produced LC50 values in excess of 30,000 mg/l. Servizi and Martens (1991) found that underyearling coho salmon survived higher concentrations of suspended sediment at 7ºC (22,700 mg/L) than at either 1ºC or 18ºC.

Based on literature reviewed in Newcombe and Jensen (1996), a 2-week exposure period to suspended sediment concentrations above 1,000 mg/L may result in up to 20 percent mortality of exposed fish, while a 2-week exposure to levels over 3,000 mg/L may result in 20-40 percent mortality of exposed fish. For comparison, parasite infection rates of outmigrating juvenile Chinook salmon from the upper Klamath River may be upwards of 60 percent in some years (Som et al. 2016).

Outmigration and Suspended Sediment Concentration Results

The following section presents a review of select screw trap data and suspended sediment concentration results. All outmigration and suspended sediment data are presented by Julian week (Table 4-4). Outmigration histograms represent weekly average number of outmigrants based on the sampled time period, generally 2008 to 2015. Salmon River outmigrant data are presented for two representative years rather than as multi-year averages. Juvenile outmigration variability plots presented in Appendix A, illustrate the plasticity of outmigration timing. Outmigration timing is influenced by flows, water temperature, and other environmental factors.

Table 4-4 Julian week correspondence with months of the year.

	Month											
Julian Week	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1-9												
9-17												
17-26												
26-35												
35-44												
44-52												

Upper Klamath River

Outmigration trap data for the Klamath River, Shasta River, and Scott River and suspended sediment concentrations for the Iron Gate Dam and Seiad Valley reporting stations are presented in the following section. Because the outmigration traps are located between Iron Gate Dam and the Seaid Valley reporting stations, juvenile salmonids entering the Klamath River closer to Iron Gate Dam will experience the highest concentrations while fish entering or moving downstream in the Klamath River closer to Seaid Valley will experience suspended sediment concentrations diluted by tributary and spring inputs. Inclusion of both reporting stations provide the range of modeled concentrations anticipated to affect the upper Klamath River reach.

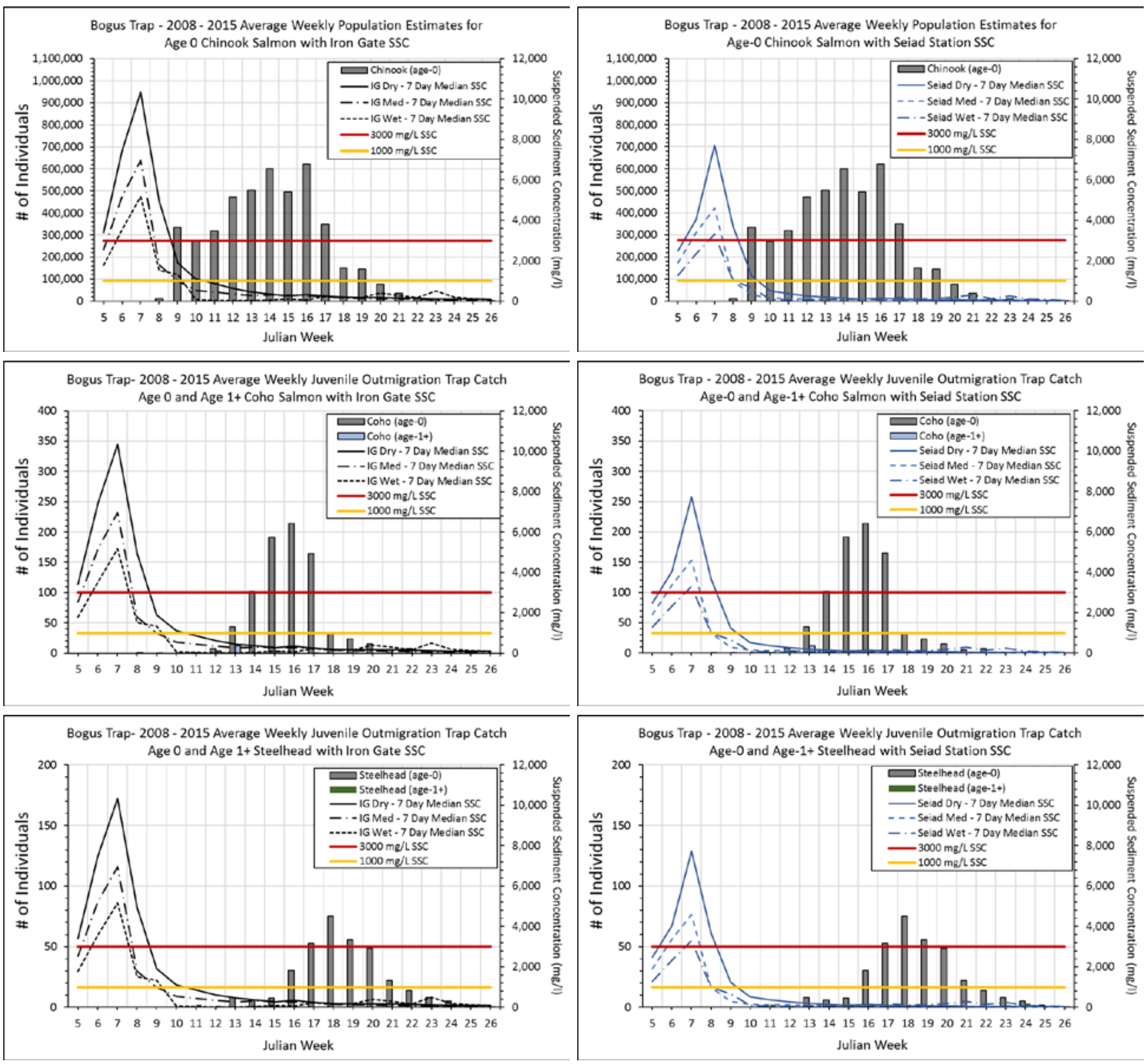
Graphs also include 1,000 mg/L and 3,000 mg/L mortality thresholds outlined in the previous report section. Fish outmigrating when the modeled suspended sediment concentrations exceed the mortality thresholds, may experience mortality likelihoods associated with the respective thresholds.

Klamath River – Bogus Trap Results

USFWS maintains the Bogus Creek trap located on the Klamath River downstream from Bogus Creek. The net frame trap samples outmigrants from Bogus Creek and the mainstem Klamath River. The Chinook salmon (age-0) outmigration window based on the sample period is from late February through June with an average peak in early to mid-April (Figure 4-3). On average, only the earliest outmigrants would experience suspended sediment concentrations above the 1,000 mg/L and 3,000 mg/L thresholds. Based on the reviewed trap data, most of the outmigrating juvenile Chinook salmon will move past the Bogus Creek trap location after the peak suspended sediment concentrations.

Trap catch results for outmigrating coho salmon and steelhead suggest these species tend to outmigrate from Bogus Creek and the mainstem Klamath River upstream of the Bogus trap later than Chinook salmon juveniles. Peak coho salmon and steelhead outmigrations are from early to mid-April, after suspended sediment concentrations have dropped below 1,000 mg/L.

Figure 4-3 Bogus trap on the Klamath River outmigration plots include Chinook salmon age-0 outmigration estimate (top), coho salmon age-0 and age-1+ trap catch (middle), and steelhead age-0 and age-1+ trap catch (bottom). The left column of plots includes the Iron Gate Dam suspended sediment concentrations, the right column includes the Seaid Valley concentrations. Outmigrating Chinook salmon appear to be the most vulnerable to peak suspended sediment concentrations. Coho and steelhead outmigrants are expected to outmigrate after peak suspended sediment concentrations.

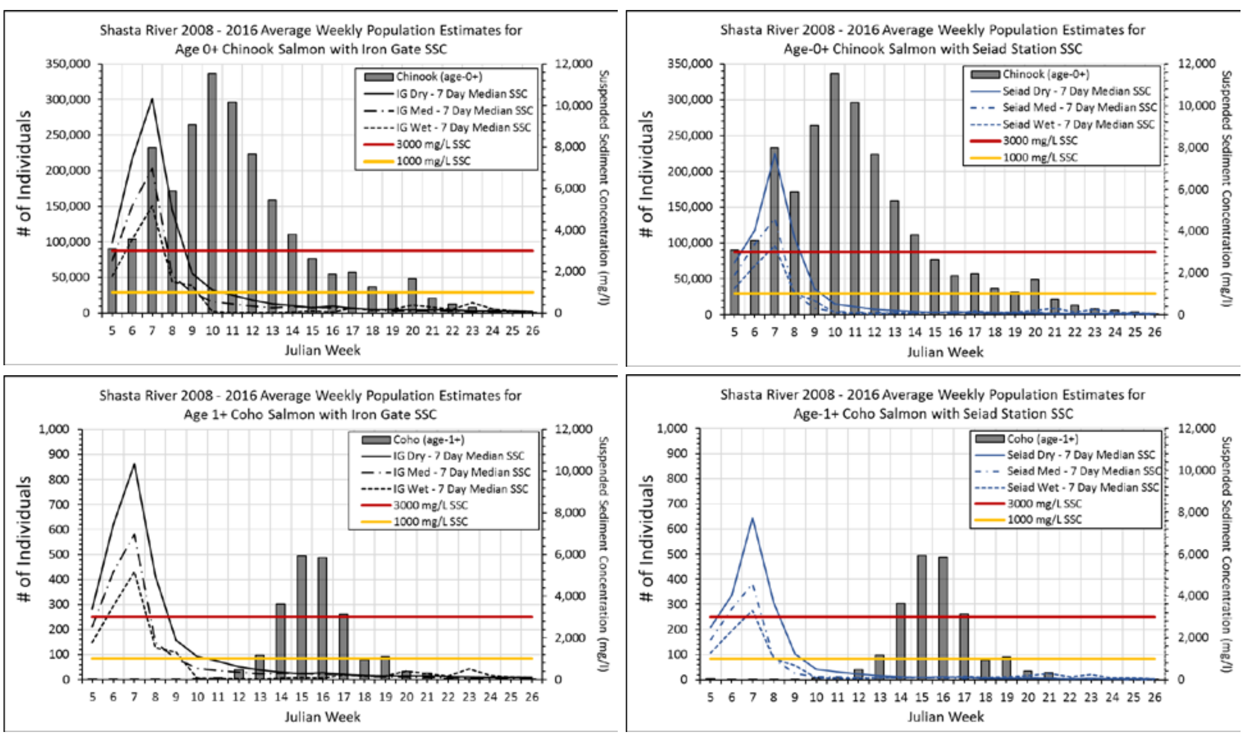


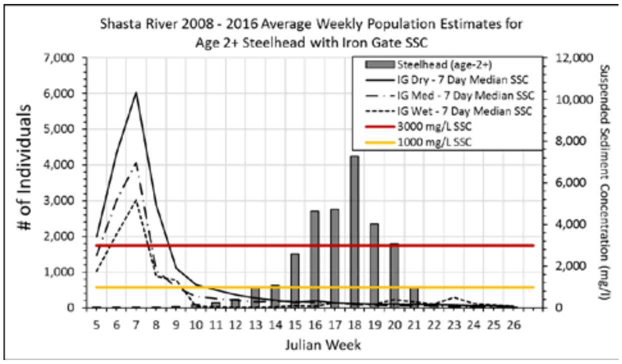
Shasta River Trap Results

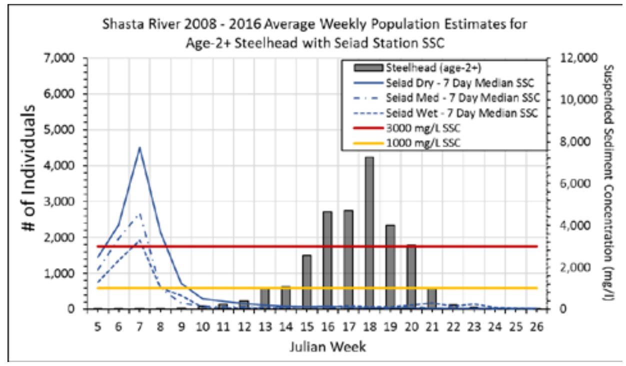
CDFW maintains the Shasta River rotary screw trap located near the Shasta River-Klamath River confluence. Chinook salmon (age-0+) outmigration from the Shasta River tends to occur earlier than in downstream tributaries and the mainstem Klamath River (Figure 4-4). On average, the outmigration begins in January and peaks in early March, overlapping with anticipated declining peak suspended sediment concentrations. Early Chinook salmon outmigrants entering the Klamath River would experience elevated sediment through mid-March. Results suggest the early portion of the Chinook salmon outmigration will be subjected to potentially lethal suspended sediment due to the concentration and exposure duration.

Population estimates for outmigrating coho salmon and steelhead suggest these species tend to outmigrate from the Shasta River later than Chinook salmon juveniles. Peak coho salmon and steelhead outmigrations are from mid to late April and are likely influenced by declining flows and rising water temperatures associated with onset of irrigation season. Coho salmon and steelhead outmigration patterns suggest that most fish outmigrate after suspended sediment concentrations have dropped below 1,000 mg/L.

Figure 4-4 Shasta River trap outmigration plots include Chinook salmon age-0+ outmigration estimate (top), coho salmon age-1+ outmigration estimate (middle), and steelhead age-2+ outmigration estimate (bottom). The left column of plots includes the Iron Gate Dam suspended sediment concentrations, the right column includes the Seaid Valley concentrations. Outmigrating Chinook salmon appear to be the most vulnerable to peak suspended sediment concentrations in the Klamath River. Coho salmon and steelhead outmigrants are expected to outmigrate after peak suspended sediment concentrations are below 1,000 mg/L.





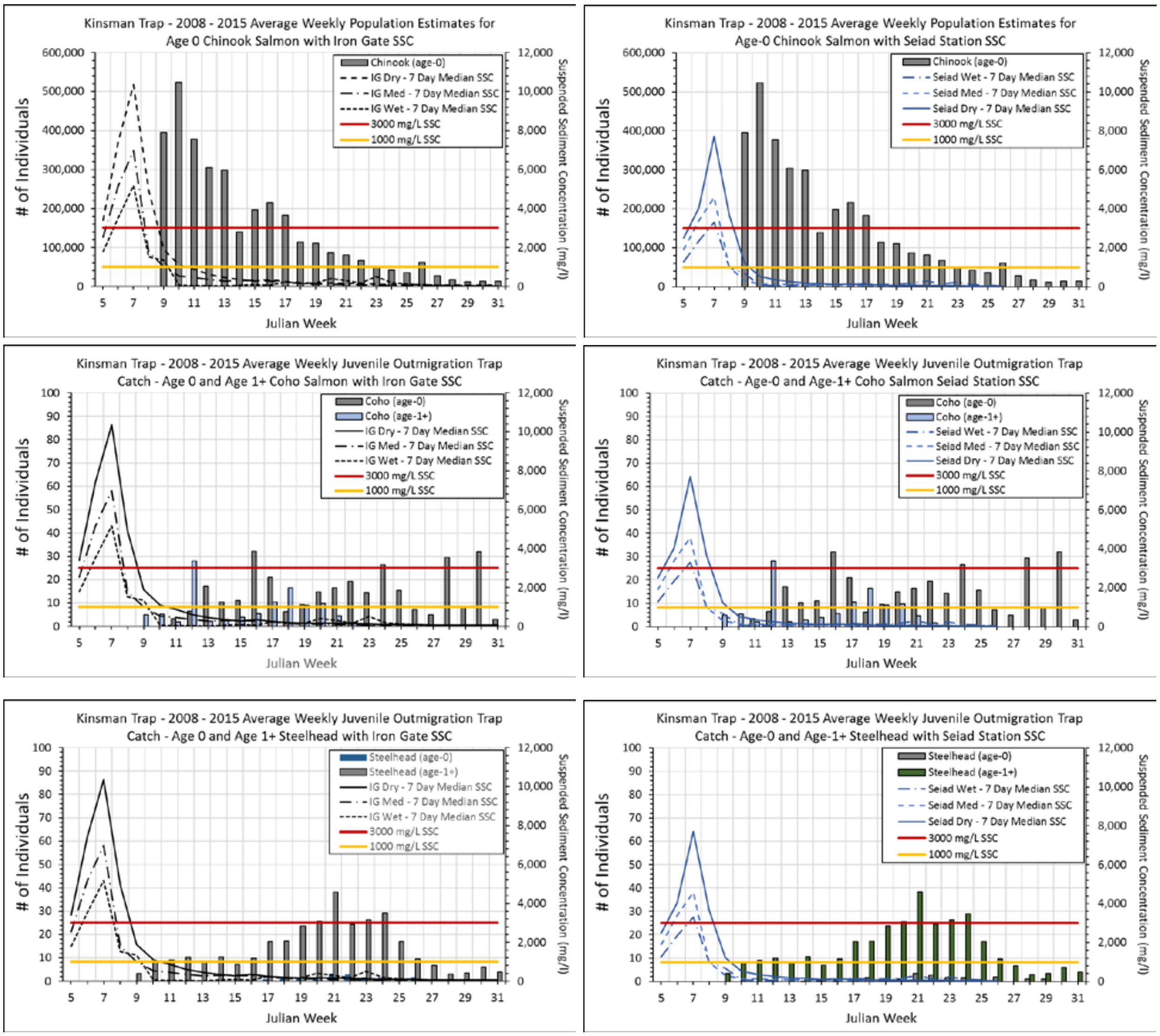


Klamath River – Kinsman Trap Results

USFWS maintains the Kinsman Creek trap located on the Klamath River just upstream of the Kinsman Creek-Klamath River confluence and approximately 2.5 miles upstream of the Scott River-Klamath River confluence. The timing and magnitude of juvenile Chinook salmon in the Kinsman trap suggest the influence of early outmigrants from the Shasta River. Over the period of record reviewed by KRRC, the Kinsman trap does not begin operation until the beginning of March and likely misses the early Shasta River outmigrants entering the Klamath River (Figure 4-5). Therefore, early outmigrating Chinook salmon in the Klamath River would be subjected to elevated suspended sediment concentrations. However, the peak of the Chinook salmon migration reaches the Kinsman trap location after peak sediment concentrations.

Trap catch results for outmigrating coho salmon and steelhead suggest these species tend to outmigrate from areas upstream of the Kinsman trap later than Chinook salmon juveniles. Coho salmon and steelhead outmigrate through the summer and mainly outmigrate after suspended sediment concentrations are projected to drop below 1,000 mg/L.

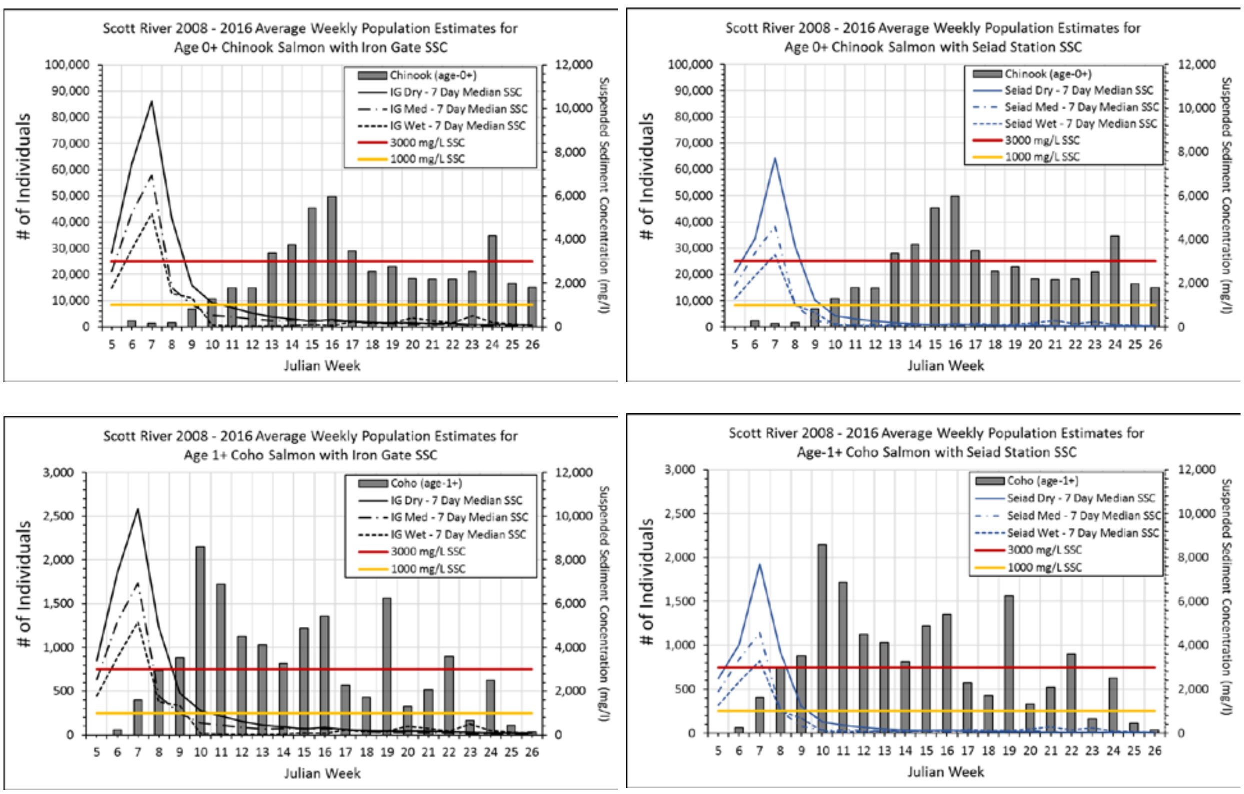
Figure 4-5 Kinsman trap on the Klamath River outmigration plots clockwise from upper left include Chinook salmon age-0 outmigration estimate (top), coho salmon age-0 and age-1+ trap catch (middle), and steelhead age-0 and age-1+ trap catch (bottom). The left column of plots includes the Iron Gate Dam suspended sediment concentrations; the right column includes the Seiad Valley concentrations. Outmigrating Chinook salmon appear to be the most vulnerable to peak suspended sediment concentrations. Most coho and steelhead outmigrants are expected to outmigrate after peak suspended sediment concentrations.

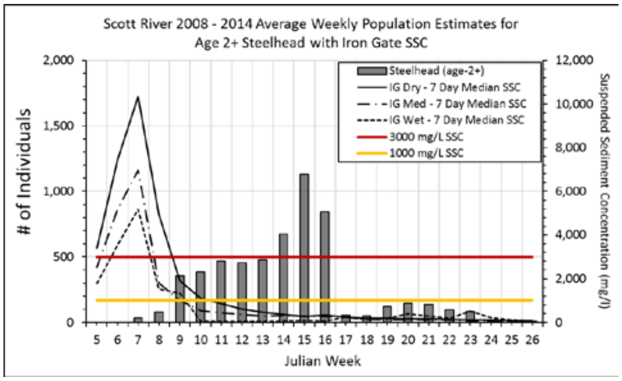


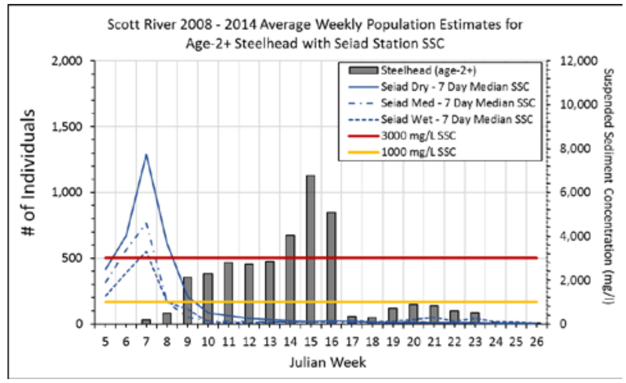
Scott River Trap Results

CDFW maintains the Scott River rotary screw trap located 4.75 miles upstream of the Scott River-Klamath River confluence. Chinook salmon (age-0+) outmigration from the Scott River occurs in mid-April (Figure 4-6) and is more similar to the mainstem Klamath River outmigrants than to the outmigration timing for the Shasta River. The Scott River Chinook salmon outmigration, on average, occurs over a longer period of time with lower abundance relative to the Shasta River Chinook outmigration. Few Chinook salmon outmigrate during the period of peak suspended sediment concentrations.

Figure 4-6 Scott River trap outmigration plots clockwise from upper left include Chinook salmon age-0+ outmigration estimate (top), coho salmon age-1+ outmigration estimate (middle), and steelhead age-2+ outmigration estimate (bottom). The left column of plots includes the Iron Gate Dam suspended sediment concentrations; the right column includes the Seaid Valley concentrations. Outmigrating coho salmon appear to be proportionally more vulnerable to peak suspended sediment concentrations, with approximately 25 percent of the average outmigrants subjected to concentrations above 1,000 mg/L.







Population estimate results for outmigrating coho salmon and steelhead suggest these species' outmigration periods overlap with outmigrating Scott River Chinook salmon more so than the level of species overlap in the Shasta River. Although at lower abundance levels relative to Scott River Chinook salmon, Scott River coho and steelhead juvenile outmigration amounts to several thousand fish. The earliest outmigrating fish (late February to early March) will likely be subjected to elevated suspended sediment concentrations as sediment levels taper from the peak. Coho and steelhead outmigration patterns suggest that most fish may outmigrate after suspended sediment concentrations have dropped below 1,000 mg/L.

Middle Klamath River

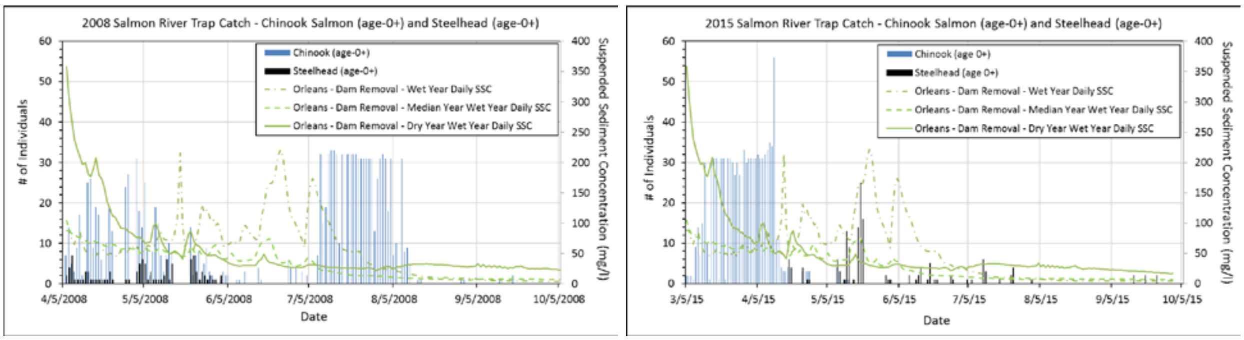
Data are provided for two traps in the middle Klamath River.

Salmon River Trap Results

The Karuk Tribe maintains a screw trap on the Salmon River at RM 0.96. The Salmon River joins the Klamath River at RM 66.4. Suspended sediment concentrations for the Orleans modeling station and Chinook (age-0+) and steelhead (age 0+) trap catch data for 2008 and 2015 are presented in Figure 4-7. The presented years 2008 and 2015 are representative of the outmigration timing for Chinook and steelhead on the Salmon River. The second grouping of Chinook salmon outmigrants from July through September in 2008 is characterized by larger juveniles compared to the earlier April to June outmigration period. The 2015 trap catch data suggest a dominant early juvenile Chinook salmon outmigration and few later outmigrants. There were low numbers of outmigrating juvenile steelhead in both years. Coho salmon outmigrants were not included in the analysis due to low trap catch numbers.

Anticipated suspended sediment concentrations at the Orleans station are below the 1,000 mg/L and 3,000 mg/L mortality thresholds and most Chinook salmon and steelhead juveniles migrate to the lower Salmon River when anticipated suspended sediment concentrations in the Klamath River are less than 500 mg/L. Based on the timing of juvenile Chinook salmon and steelhead entry into the Klamath River and the anticipated suspended sediment concentrations at entry, we do not expect outmigrating fish from the Salmon River to experience lethal conditions. We also anticipate outmigrants will reach the Klamath estuary in less than a week, minimizing their exposure to suspended sediment concentrations.

Figure 4-7 Salmon River trap catch outmigration plots for Chinook salmon (age-0+) and steelhead (age-0+) for 2008 (left) and 2015 (right). Anticipated suspended sediment concentrations from the Orleans station are also presented. Suspended sediment concentrations during the outmigration period are less than the mortality thresholds of 1,000 mg/L and 3,000 mg/L.

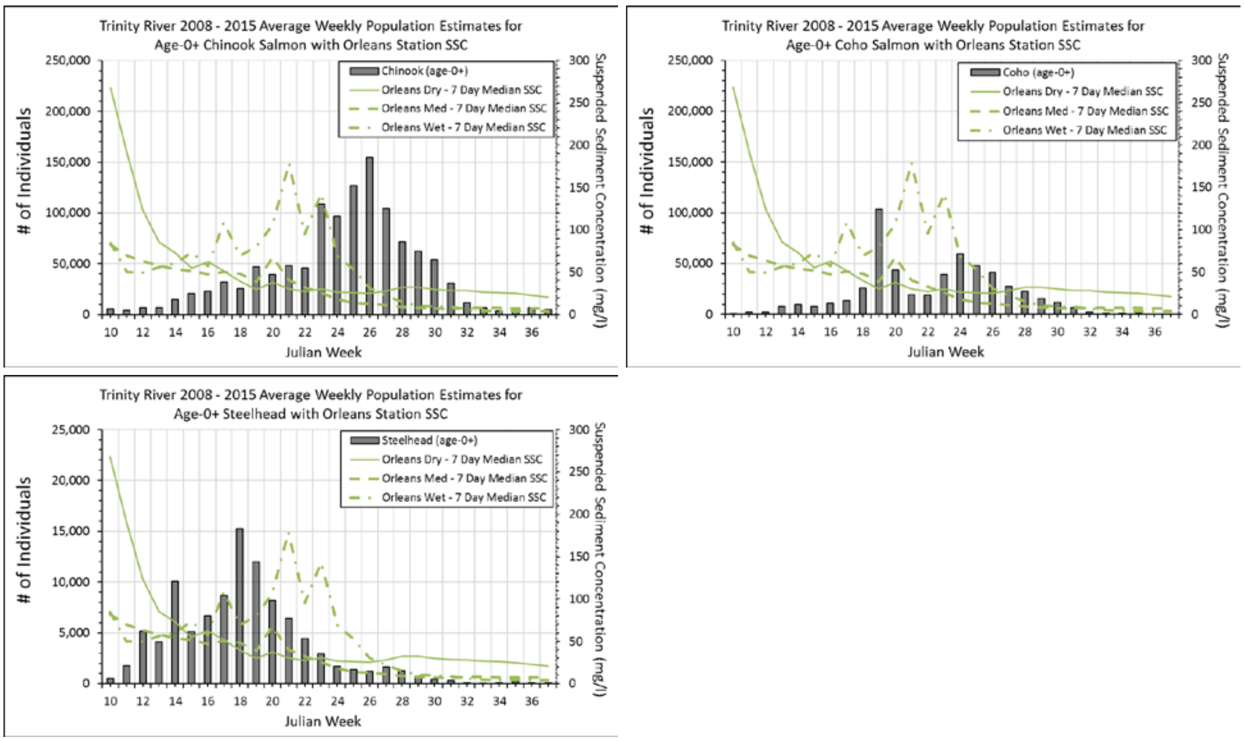


<u>Trinity River near Willow Creek Trap Results</u>

USFWS maintains a screw trap on the Trinity River at RM 21.1. The Trinity River joins the Klamath River at RM 43.4. Suspended sediment concentrations for the Orleans modeling station and Chinook salmon (age-0+), coho salmon (age-0+), and steelhead (age 0+) population estimates based on 2008 to 2015 screw trap data are presented in Figure 4-8. Steelhead peak outmigration is earlier than Chinook and coho salmon outmigration timing. The outmigration values include both hatchery and naturally-produced juveniles and age-0 smolts comprise the majority of the sampled outmigrants.

Anticipated suspended sediment concentrations at the Orleans station are below the 1,000 mg/L and 3,000 mg/L mortality thresholds and most fish migrate through the lower Trinity River when Klamath River suspended sediment concentrations are less than 300 mg/L. Based on outmigration timing to the Klamath River (assuming juvenile fish continue to outmigrate to the Klamath River after they bypass the Trinity River trap location) and the anticipated suspended sediment concentrations at entry, we do not expect outmigrating fish from the Trinity River to experience lethal conditions in the Klamath River. We also anticipate outmigrants will reach the Klamath estuary in less than a week, minimizing their exposure to elevated suspended sediment.

Figure 4-8 Trinity River trap outmigration plots for Chinook salmon age-0+ (upper left), coho salmon age-0+ (upper right), and steelhead age-0+ (lower left). Anticipated suspended sediment concentrations from the Orleans station are also presented. Suspended sediment concentrations during the outmigration period are less than the mortality thresholds of 1,000 mg/L and 3,000 mg/L.

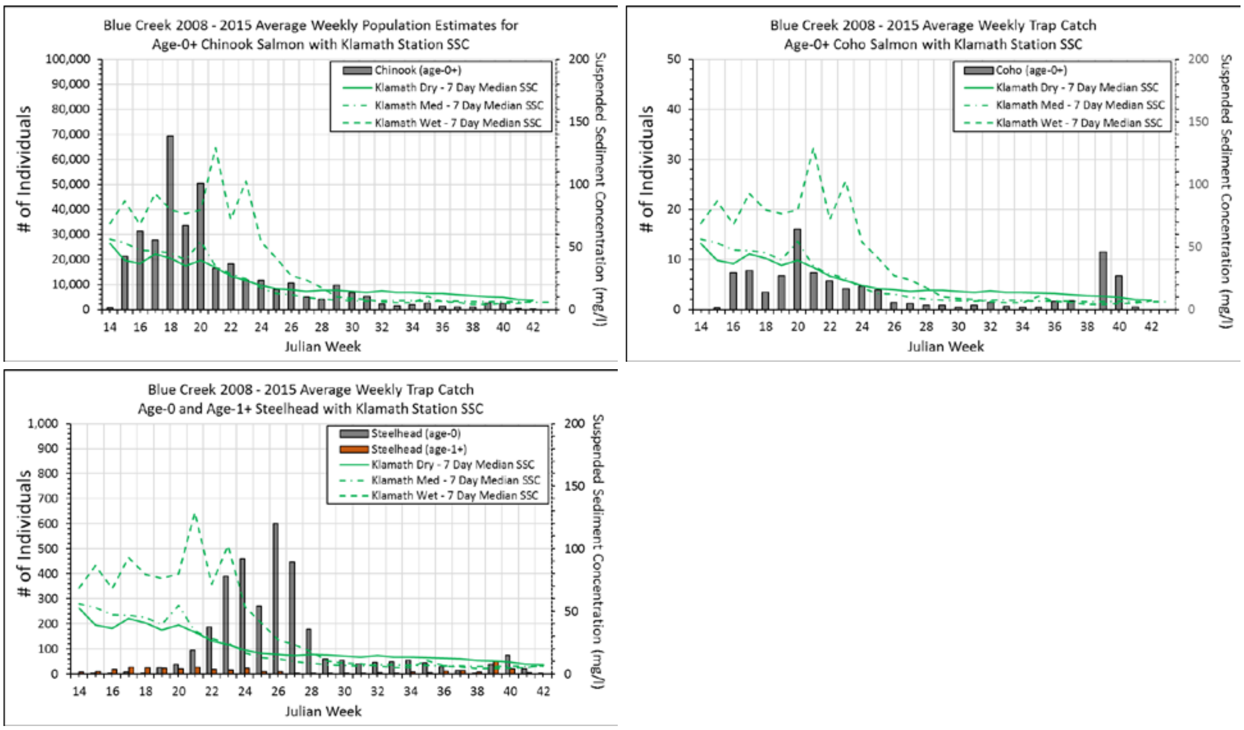


Lower Klamath River

The Yurok Tribe maintains a screw trap at RM 2.0 on Blue Creek, the largest tributary to the lower Klamath River. Blue Creek supports the largest anadromous fish populations in the sub-basin, and the tributary is considered to be a salmon stronghold by the Yurok Tribe (Antonetti and Partee 2013). Blue Creek joins the Klamath River at RM 16.0. Suspended sediment concentrations for the Klamath modeling station and population estimates for Chinook salmon (age-0+), and trap catch data for coho salmon (age-0+), and steelhead (age-0 and age-1+) for 2008 through 2015 are presented in Figure 4-9.

Anticipated suspended sediment concentrations at the Klamath station are below the 1,000 mg/L and 3,000 mg/L mortality thresholds. Outmigration timing for juvenile salmonids is generally during anticipated elevated suspended sediment concentrations less than 300 mg/L. We do not anticipate negative effects from suspended sediment concentrations on outmigrating juvenile salmonids in the Lower Klamath River based on low sediment concentrations and the close proximity of Blue Creek to the Klamath estuary.

Figure 4-9 Blue Creek trap outmigration plots include Chinook salmon age-0+ outmigration estimate (upper left), coho salmon age-0+ trap catch (upper right), and steelhead age-0 and age-1+ trap catch (lower left). Anticipated suspended sediment concentrations from the Klamath station are also presented. Suspended sediment concentrations during the outmigration period are less than the mortality thresholds of 1,000 mg/L and 3,000 mg/L.



Outmigration and Dissolved Oxygen

The release of organic-based sediments during reservoir drawdown is anticipated to affect dissolved oxygen levels in the Klamath River downstream from Iron Gate Dam (Stillwater Sciences 2011). The highest predicted oxygen demand levels will be associated with peak suspended sediment concentrations that are anticipated to occur during February of the drawdown year. Despite the relatively high predicted biological oxygen demand, dissolved oxygen concentrations downstream from Iron Gate Dam are anticipated to generally remain greater than 5 mg/L. Exceptions include predicted concentrations in February of the dam removal year for median (1976) and typical dry year (2001) hydrologic conditions, which exhibit minimum values of 3.5 mg/L and 1.3 mg/L, respectively.

For all water year types (wet, median, dry), the predicted dissolved oxygen minimum values would occur by approximately RM 188-190 (~3-5 miles downstream from Iron Gate Dam) and would return to at least 5 mg/L by approximately RM 175-177 (2-4 miles below the Shasta River confluence. The North Coast Basin Plan water quality objective for dissolved oxygen is expressed as percent saturation; at 90 percent saturation, the water quality objective for November through April, assuming average February (2009) water temperatures, would be 9.6-10.6 mg/l. Based on the spreadsheet model results, recovery to the North Coast Basin Plan water quality objective of 90 percent saturation would occur generally within the reach from Seiad Valley (RM 131.9) to the mainstem confluence with Clear Creek, or within a distance of 62-93 miles downstream from Iron Gate Dam, for all water years.

Dissolved oxygen monitoring during dam removal projects is complicated by the harsh in-stream conditions influenced by high suspended sediment concentrations. The U.S. Geological Survey monitored dissolved oxygen levels associated with the drawdown of Fall Creek Reservoir in the Willamette Basin. The Fall Creek monitoring included a water quality monitoring station downstream from the dam, and a second station at Jasper approximately 10 miles downstream from Fall Creek Dam. The Fall Creek Outflow station at the dam detected a decrease in dissolved oxygen concurrent with the sediment release, although the extent of the depletion was unknown due to equipment fouling (Schenk and Bragg 2014). Collected dissolved oxygen data suggested a decline from approximately 12.5 mg/L to between 6 mg/L and 7 mg/L during the first 5 hours following the drawdown. Dissolved oxygen levels trended upward over the course of the of the following 4 days until returning to background levels 6 days after the onset of drawdown (Schenk and Bragg 2014). Dissolved oxygen levels at the downstream Jasper station did not experience a large, rapid decrease in dissolved oxygen during the drawdown, suggesting the drawdown effects on dissolved oxygen were isolated to less than 10 miles of Fall Creek and the Middle Fork Willamette River.

Outmigration and Suspended Sediment Summary

Reservoir drawdown and dam removal sequencing was developed to minimize effects on Klamath River anadromous fish. A review of recent juvenile salmonid outmigration data collected from 2008 to 2015/2016, provides and updated understanding of juvenile salmonid outmigration timing on the Klamath River and select tributaries. Comparing outmigration timing and anticipated reservoir drawdown-influenced suspended sediment concentrations in the Klamath River is informative for predicting potential sediment effects to juvenile salmonids entering the Klamath River during the winter and early spring coincident with reservoir drawdowns. The data review suggests potential sediment effects to early outmigrating juvenile salmonids in the Shasta and Scott rivers. However, juvenile outmigration timing suggests a high degree of plasticity when fish outmigrate from tributaries to the Klamath River. Environmental conditions including stream flow, water temperature, food availability, and other biological and environmental cues influence outmigration timing. Initiating the reservoir drawdowns 2 weeks to a month earlier than planned, may reduce the exposure of early outmigrants to peak suspended sediment concentrations. The adaptive monitoring and salvage plan included in AR-2 is also intended to reduce sediment effects on outmigrating salmonids.

4.3.4 Juvenile Salmonid Suspended Sediment Avoidance Behavior Review

The following section provides a summary of reviewed literature pertaining to juvenile salmonid avoidance behaviors in response to elevated suspended sediment. The high levels of suspended sediment in the Klamath River during reservoir drawdown are anticipated to be problematic for outmigrating juvenile salmonids during peak concentrations. However, as concentrations decline over time and with distance from

Iron Gate Dam, juvenile salmonids are expected to employ behavioral adaptations to reduce exposure effects.

Avoidance Behavior

The reservoir drawdown period will be marked by poor water quality caused by high suspended sediment concentrations. Juvenile salmonids inhabiting the Klamath River are expected to employ coping strategies to survive poor conditions. Juveniles may use clear water tributary junctions, clear water off-channel ponds and tributaries, spring seeps, or increase their use of the benthic zone (Bash et al. 2001; Kjelland et al. 2015), or the upper portion of the water column (Servizi and Martens 1992). We expect juvenile fish to actively seek these areas as they move downstream from natal tributaries into the Klamath River. Factors affecting the ability of juvenile salmonids to find clear water areas include the frequency and output of clear water sources, the magnitude of suspended sediment in the Klamath River, and the developmental stage of juvenile fish (Sedell et al. 1990). Younger fish are generally more susceptible to high suspended sediment concentrations than older fish.

For juvenile salmonids rearing in the mainstem Klamath River at the time of reservoir drawdown, gradually increasing suspended sediment levels may promote more rapid downstream movement of juvenile fish as they seek cleaner water (Berg and Northcote 1985). Redding and Schreck (1987) found juvenile coho and steelhead exposed to 4,000 mg/L exhibited a physiological stress response, but tested fish were able to compensate for the high suspended sediment concentrations within a few days. Fish exposed to 2,000 - 4,000 mg/L of sediment exhibited physiological changes indicative of sublethal stress, but the tested sediment levels also caused modified feeding behavior and lowered the disease resistance of tested fish (Redding and Schreck 1987). Interestingly, physiological responses were moderate compared to cortisol levels in fish severely stressed by confinement and handling (Redding and Schreck 1983 cited in Redding and Schreck 1987), suggesting that minimizing handling in favor of allowing juvenile fish to make choices on their outmigration may result in lower juvenile salmonid mortality.

Exposure to Organics-based Suspended Sediment

Salmonid suspended sediment studies generally evaluate the effects of mineralized sediment on salmonids. Sockeye smolts were less susceptible to high levels of Frasier River sediments than they were to lower levels of angular ash particles associated with the Mount St. Helens eruption (Newcomb and Flagg cited in Servizi and Martens 1987). Compared to gill abrasion effects caused my mineralized sediment, organic-based suspended sediment may cause problematic effects related to low dissolved oxygen levels (Sorenson et al. 1977 cited in Bash et al. 2001), but organic sediments may be less abrasive compared to suspended mineralized sediments.

4.3.5 SWRCB Information Request Response Summary

Juvenile salmonids exhibit outmigration timing plasticity that reflects their response to instream conditions influenced by stream flow, water temperature, food availability, and other biological and environmental cues.

We would anticipate that juveniles will delay entry into the Klamath River when they experience adverse conditions, and fish will choose to outmigrate in response to tributary condition decline and mainstem river condition improvement. Based on the reviewed outmigration data, juveniles outmigrate from tributaries over several weeks from late winter through summer, with juvenile Chinook salmon being the earliest outmigrants from upper Klamath River tributaries. If juvenile fish remain in upper Klamath River tributaries through early to mid-March, they will experience substantially lower suspended sediment concentrations upon entry into the Klamath River. The mid-March time period precedes the start of irrigation season (beginning of April) in the Shasta River, when tributary conditions begin to decline due to reduced instream flows and rising water temperatures (Jetter et al. 2016).

Our data review suggests juvenile salmonids are capable of outmigrating from Iron Gate Dam to the Klamath estuary in less than 2 weeks. Clear water sources in the form of tributary confluences, off-channel ponds, and spring seeps will serve as moderate to high water quality stepping stones in an otherwise harsh aquatic environment. As juveniles migrate downstream, not only will they encounter pockets of improved water quality, but suspended sediment concentrations will also decline with tributary inputs. Water quality conditions downstream of the Trinity River confluence are anticipated to be near background levels as the Trinity River and other tributaries dilute suspended sediment concentrations. We would also expect fish exposed to high suspended sediment concentrations to outmigrate more rapidly, further reducing the exposure duration.

If suspended sediment concentrations remain elevated above 1,000 mg/L for any 2-week period during the outmigration, there may be up to 20 percent mortality of exposed fish. However, this conclusion should be considered in light of documented evidence of juvenile coho and steelhead survival at suspended sediment concentrations exceeding 2,000 mg/L (Redding et al. 1997). Likewise, it is unlikely fish will be continuously exposed to high suspended sediment concentrations over 14 days as they will have access to clear water refuges and will experience improving water quality conditions as they move downstream.

Based on juvenile salmonid outmigration data, anticipated suspended sediment concentrations during reservoir drawdown, and expected juvenile salmonid avoidance behaviors, an adaptive strategy that includes monitoring and salvaging juvenile fish as a last resort, is a prudent approach to reducing sediment effects on juvenile salmonids.

Beginning the reservoir drawdowns 2-4 weeks earlier than the Detailed Plan's proposed schedule would reduce the number of early outmigrating Chinook salmon and coho salmon from the Shasta and Scott rivers that would be exposed to high suspended sediment concentrations. However, an earlier start to reservoir drawdown would also potentially affect late migrating coho salmon that spawn in Klamath River tributaries through late December. Additional discussion with fisheries agencies is warranted to determine the appropriateness of beginning drawdown earlier than currently planned.

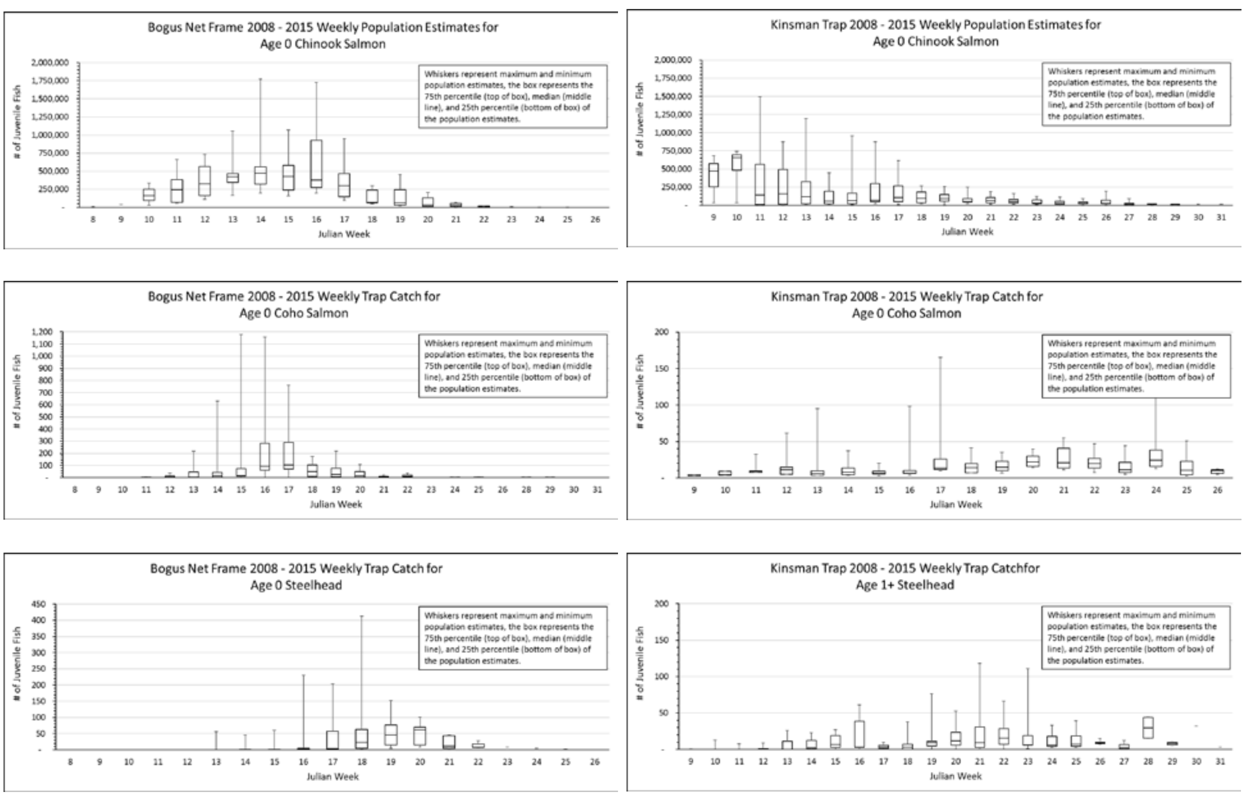
4.4 Juvenile Salmonid Outmigration Variability Plots

4.4.1 Introduction

Appendix A includes outmigration variability plots for trap data from the Klamath River and select tributaries. The plots provide an indication of the variability of outmigration timing by species and trap location. Outmigration variability is related to flow, water temperature, food resources, and other biological and environmental cues.

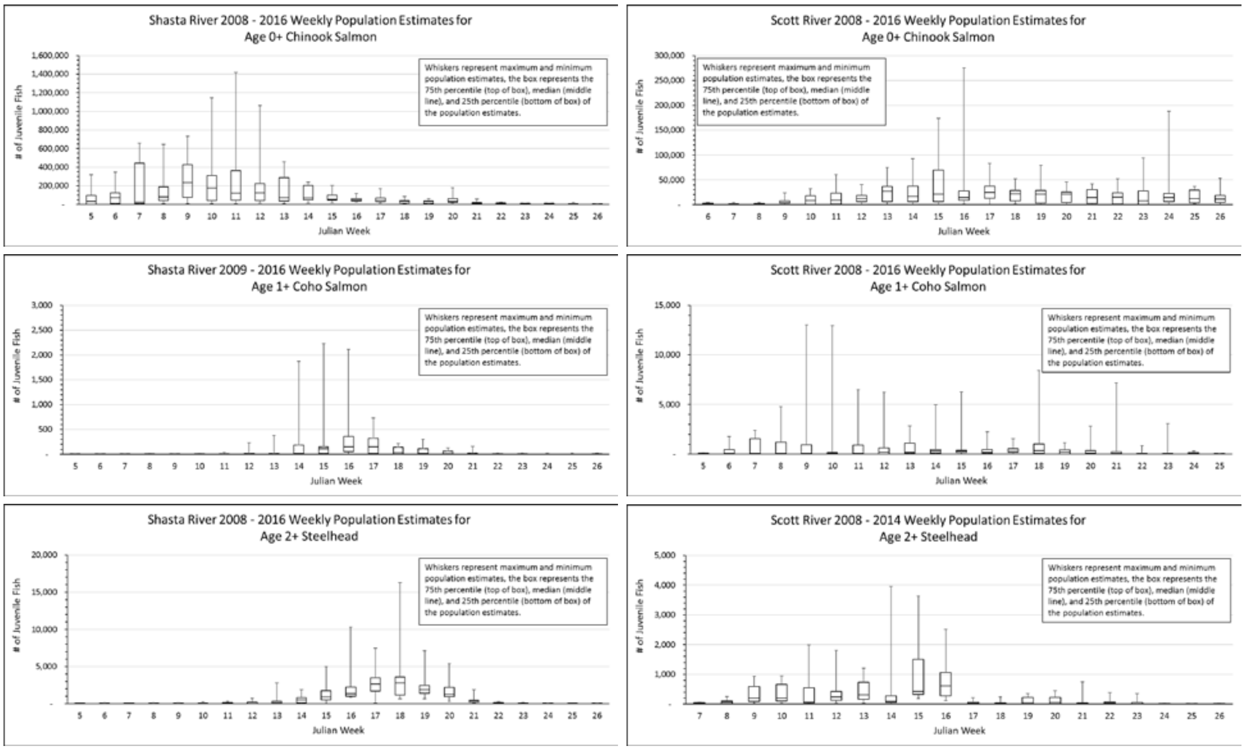
4.4.2 Upper Klamath River – Bogus Net Frame and Kinsman Trap Results

Figure 4-10 Chinook salmon, coho salmon, and steelhead weekly population estimates and trap catch results for the Bogus net frame and Kinsman rotary screw trap on the Klamath River.



4.4.3 Upper Klamath River – Shasta River and Scott River Trap Results

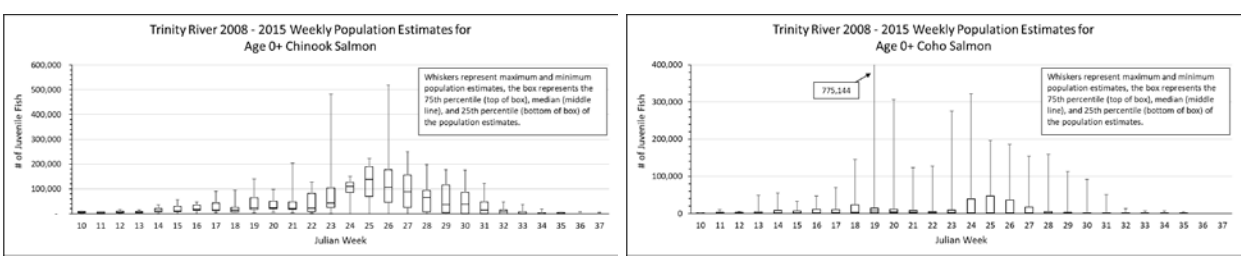
Figure 4-11 Chinook salmon, coho salmon and steelhead weekly population estimates for the Shasta River and Scott River traps.

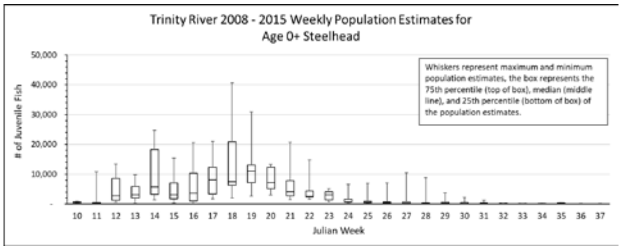


4.4.4 Middle Klamath River – Salmon River and Trinity River Trap Results

Trap variability calculations were not completed for the Salmon River trap catch.

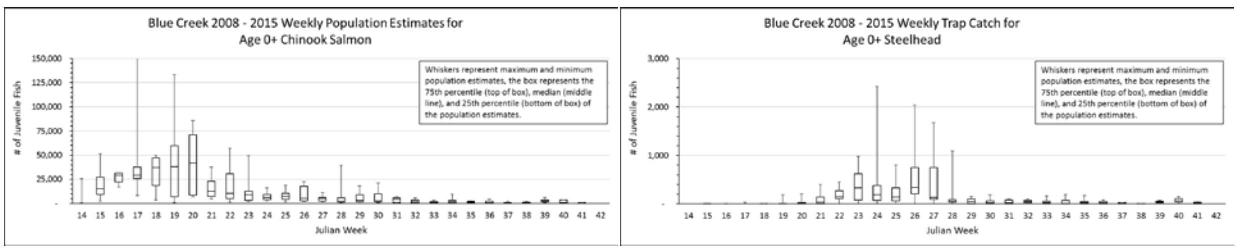
Figure 4-12 Chinook salmon, coho salmon and steelhead weekly population estimates for the Trinity River trap.





4.4.5 Lower Klamath River – Blue Creek Trap Results

Figure 4-13 Chinook salmon and steelhead weekly population estimates for the Blue Creek trap.



4.5 AR-2 Summary

The Klamath River dam decommissioning project is anticipated to have significant short-term effects, but long-term benefits, for fall Chinook salmon, coho salmon, winter steelhead, and Pacific lamprey. The 2012 EIS/R AR-2 measure included installing 17 screw traps on 13 tributaries to capture outmigrating juvenile fish in an effort to protect juvenile fish from entering the Klamath River during the dam decommissioning project. Captured fish would be transported and released downstream of the Trinity River confluence where water quality conditions during the dam decommissioning are expected to be improved by tributary dilution. ATWG input highlighted several concerns associated with the 2012 AR-2 plan including trapping feasibility and cost, life safety during winter flow conditions, handling mortality, and potential insufficient juvenile imprinting, followed by elevated stray rates associated with future adult returns. The ATWG concluded that the basis of these concerns could result in the proposed AR-2 mitigation effort being ineffective at reducing the project's impacts and potentially introducing additional risks to outmigrating juvenile salmonids. Therefore, KRRC determined that revised actions in the form of an updated AR-2 are warranted.

The updated AR-2 plan includes three primary actions; salvaging mainstem overwintering juvenile salmonids prior to reservoir drawdown; maintaining tributary-mainstem connectivity to ensure volitional fish passage between tributaries and the Klamath River; and developing a water quality monitoring network, trigger thresholds, and plan for salvaging and relocating juvenile fish from tributary confluence areas to cool water tributaries or nearby off-channel ponds. The three-pronged approach proposed by KRRC is anticipated to mitigate the short-term effects to outmigrating juvenile salmonids.

Chapter 5: AR-3 Fall Pulse Flows

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5. AR-3 FALL PULSE FLOWS

The objective of AR-3 is to address reservoir drawdown and dam removal effects on anadromous fish that migrate and spawn in the mainstem Klamath River and its tributaries. The original 2012 EIS/R AR-3 plan focused on increasing fall flows to encourage outmigration of post-spawned green sturgeon from the lower Klamath River and estuary to the Pacific Ocean, and increase fall Chinook salmon, coho salmon, and steelhead spawning in tributaries downstream from Iron Gate Dam. Fall pulse flows were anticipated to reduce the effects of elevated suspended sediment concentrations on anadromous fish inhabiting the Klamath River.

A review of current information regarding Klamath River fisheries and dam decommissioning effects suggests that the use of fall pulse flows would likely be ineffective in reducing the effects of suspended sediment on migrating and spawning salmon, steelhead, and green sturgeon. The uncertainty of storage water availability on the mainstem Klamath River prior to reservoir drawdown, and the natural (unregulated) hydrology of most Klamath River tributaries make implementation and success of this measure unpredictable. The measure may therefore be either infeasible or unnecessary to implement depending on the meteorological conditions prior to dam decommissioning. Therefore, fall pulse flows will not be implemented to offset the suspended sediment effects related to the dam decommissioning.

5.1 Summary of the 2012 EIS/R AR-3, Dam Removal Benefits and Effects, and Recent Fisheries Literature

The following sections review the components of the 2012 EIS/R AR-3 measure, anticipated dam removal effects and benefits on AR-3 species, and recent fisheries literature relative to juvenile salmonid outmigration.

5.1.1 AR-3 Affected Species

Species identified in AR-3 include:

- Coho salmon *(Oncorhynchus kisutch)* – Southern Oregon/Northern California Coastal (SONCC) evolutionary significant unit (ESU): Federally Threatened; California Threatened; Tribal Trust Species
- Chinook salmon *(O. tshawytscha)* – Upper Klamath-Trinity Rivers ESU - Fall Run: California Species of Special Concern; Tribal Trust Species
- Steelhead *(O. mykiss)* – Klamath Mountains Province distinct population segment (DPS) – Summer Run: California Species of Special Concern; Tribal Trust Species
- Steelhead *(O. mykiss)* – Klamath Mountains Province DPS – Winter Run: Tribal Trust Species
- Green sturgeon *(Acipenser medirostris)* - Northern DPS: Tribal Trust Species

5.1.2 Anticipated Dam Decommissioning Effects on AR-3 Species

Short-term effects of dam removal (from both suspended sediment and bedload movement) were predicted to result in high mortality of fall Chinook salmon and coho salmon embryos and pre-emergent alevin within redds that are constructed in the mainstem Klamath River downstream from Iron Gate Dam in the fall prior to reservoir drawdown (USBR and CDFG 2012). Approximately 2,100 fall Chinook salmon redds and approximately 13 SONCC coho salmon redds were predicted to be affected during reservoir drawdown. Migrating steelhead within the mainstem Klamath River after December 31 prior to reservoir drawdown are also anticipated to be directly affected by suspended sediment related to reservoir drawdown. Additionally, any adult green sturgeon remaining in the lower Klamath River and estuary could be exposed to elevated suspended sediment concentrations which could result in major stress to affected fish, although the effects of the dam decommissioning project are expected to be the same as under existing conditions (USBR and CDFG 2012). Table 5-1 includes the likely and worst-case effects to adult anadromous fish species downstream from Iron Gate Dam.

Table 5-1 2012 EIS/R anticipated effects summary for migratory adult salmonids and green sturgeon

Species	Life Stage	Likely Effects	Worst Effects
Coho Salmon	Adult Spawning	Loss of 13 redds (0.7-26%)[1]	Loss of 13 redds (0.7-26%)[1]
Chinook Salmon - Fall	Adult Spawning	Loss of 2,100 redds (8%)[1]	Loss of 2,100 redds (8%)[1]
Steelhead - Summer	Migrating Adults	No anticipated mortality	Loss of 0-130 adults (0-9%)
Steelhead - Winter	Migrating Adults	Loss of up to 1,008 adults (14%)[1]	Loss of up to 1,988 adults (28%)
Green Sturgeon	Holding Adults	Sublethal effects	Sublethal effects

Source: USBR and CDFG 2012
[1] Range of potential year class loss based on the average number of redds associated with the evaluated population(s).

The following sections include descriptions of species-specific effects adapted from the 2012 EIS/R (USBR and CDFG 2012; Vol. I, pp. 3.3-129 to 3.3-168).

Coho Salmon

The wide distribution and use of tributaries by both juvenile and adult coho salmon will likely protect the population from the worst effects of the dam decommissioning. However, direct mortality is anticipated for redds and smolts from the upper Klamath River, mid-Klamath River, Shasta River, and Scott River population units. No mortality is anticipated for the Salmon River, Trinity River, and Lower Klamath River populations under the most likely or worst-case scenarios. Based on substantial reduction in the abundance of a year class in the short-term, the effect of the dam decommissioning was found to be significant for the coho salmon from the Upper Klamath River, Mid-Klamath River, Shasta River, and Scott River population units.

Based on spawning surveys conducted from 2001 to 2005 (Magneson and Gough 2006), 6 to 13 redds could be affected during reservoir drawdown. The anticipated loss of redds from the Upper Klamath River coho salmon population unit was based on the peak count of redds surveyed in all years (13 redds counted in 2001). Mainstem Upper Klamath River coho redd surveys completed between 2001 and 2016 (not completed in 6 years) yielded 6 redds on average and no redds in 2009. A total of only 38 mainstem redds were documented between 2001-2005, with two-thirds of those redds being found within 12 miles of the dam (NOAA 2010). Many of the redds anticipated to be affected by the dam decommissioning are thought to be from returning hatchery fish (NOAA 2010). Based on the range of escapement estimates in Ackerman et al. (2006), 13 redds could represent anywhere from 0.7 to 26 percent of the naturally returning spawners in the upper Klamath River Population Unit, and likely much less than 1 percent of the natural and hatchery returns combined (Magneson and Gough 2006; USFWS, unpublished data 2017).

Chinook Salmon – Fall Run

Fall Chinook salmon use the mainstem Klamath River for spawning, rearing, and as a migratory corridor. Direct mortality is predicted for fall Chinook salmon redds and some smolts. The effect of suspended sediment concentrations on juvenile fall Chinook salmon from the dam decommissioning is expected to be relatively minor because of variable life histories, the large majority of age-0 juveniles that remain in tributaries until later in the spring and summer, and because many of the fry that out-migrate to the mainstem come from tributaries in the mid-or lower Klamath River, where suspended sediment concentrations resulting from the dam decommissioning are expected to be lower due to dilution from tributaries.

Suspended sediment is predicted to result in 100 percent mortality of fall Chinook salmon eggs and fry spawned in the mainstem Klamath River during the fall prior to reservoir drawdown. Much of the overall effect on fall run Chinook salmon will depend on the relative proportion of mainstem spawners during the fall prior to reservoir drawdown. Based on redd surveys using a mark and re-sight methodology from 1999 through 2009 (Magneson and Wright 2010), an average of 2,100 redds from hatchery and naturally returning adults are constructed in the mainstem Klamath River and represents approximately 8 percent of total, basin-wide escapement (USBR and CDFG 2012).

Steelhead – Summer and Winter

High suspended sediment concentrations resulting from the dam decommissioning are anticipated to affect winter steelhead migrating during the winter and spring of reservoir drawdown, particularly for the portion of the population that spawns in tributaries upstream of the Trinity River. For that portion of the population, effects are anticipated on adults, run-backs, half-pounders, any juveniles rearing in the mainstem, and out-migrating smolts. However, the broad spatial distribution of steelhead in the Klamath Basin and their flexible life history suggests that some steelhead will avoid the most serious effects of the dam decommissioning by remaining in tributaries for extended rearing, rearing farther downstream where suspended sediment concentrations should be lower due to dilution, and/or moving out of the mainstem into tributaries and off-channel habitats during winter to avoid periods of high suspended sediment concentrations.

Additionally, the life history variability observed in steelhead means that, although numerous year classes will be affected, not all individuals in any given year class will be exposed to project effects. Some portion of the progeny of those adults that spawn successfully would also rear in tributaries long enough to not only avoid the highest suspended sediment concentrations, but may also not return to spawn for up to 2 years, when suspended sediment resulting from the dam decommissioning should be greatly reduced. The high incidence of repeat spawning among summer steelhead, ranging from 40 to 64 percent (Hopelain 1998) should also increase that population's resilience to dam decommissioning effects. Dam decommissioning modeling results suggests the loss of up to 1,988 winter steelhead redds and up to 130 summer steelhead redds.

Green Sturgeon

Under the 2012 EIS/R most-likely-to-occur scenario and worst-case scenario, the dam decommissioning project was anticipated to have no effect relative to existing conditions on adult green sturgeon (USBR and CDFG 2012; Vol. I, p. 3.3-164). Because green sturgeon are distributed downstream of Ishi Pishi Falls (river mile [RM 66]) in the lower Klamath River (McCovey 2008), and generally do not enter the lower Klamath River until April, green sturgeon are likely to experience lower dam decommissioning-related suspended sediment concentrations. Tributary inputs between Iron Gate Dam and Ishi Pishi Falls will dilute suspended sediment concentrations, and green sturgeon entering the system later in spring will be subjected to near background water quality conditions as dam decommissioning effects diminish into summer. Green sturgeon also emigrate from the Klamath River in the fall (Benson et al. 2007) and are not expected to experience high suspended sediment concentrations associated with the early stages of dam decommissioning.

Green sturgeon in the Klamath River spawn on average of every four years, although males occasionally spawn every two years (McCovey 2010), and therefore up to 75 percent of the mature adult population (as well as 100 percent of sub-adults) are likely to be in the ocean during the spring and summer of reservoir drawdown and avoid effects associated with dam decommissioning. Green sturgeon are long-lived (>40 years) and are able to spawn multiple times (Klimley et al. 2007), so effects on two year classes may have little influence on the population as a whole (USBR and CDFG 2012).

5.1.3 2012 EIS/R AR-3 Actions

The 2012 EIS/R AR-3 plan (Vol. I, pp. 3.3-245 and 3.3-246) described the potential for augmented fall flows in the mainstem Klamath River downstream from Iron Gate Dam to encourage the outmigration of post-spawned green sturgeon from the lower Klamath River and to potentially increase the proportion of fall Chinook salmon, coho salmon, and steelhead spawning in tributaries. Green sturgeon outmigration from the Klamath River and increased tributary spawning by anadromous salmonids would reduce the number of fish exposed to elevated suspended sediment concentrations in the Klamath River as a result of the dam decommissioning project.

The 2012 EIS/R AR-3 plan suggested that water releases from the Klamath River Hydroelectric Reach reservoirs should mimic the natural hydrograph during a wet year prior to the dam deconstruction project, and flows should be consistent with previous recommendations intended to recover endangered and threatened fishes in the Klamath River (National Research Council 2004). During a dry year, water balancing would need to be considered to meet the needs of other basin programs and ecological goals. The 2012 EIS/R plan also stated that increasing fall flows would likely be most successful if elevated mainstem flows coincided with elevated tributary flows. Synchronized mainstem and tributary flows would create a large enough pulse of water to encourage upstream mainstem migration and unhindered access into tributary streams.

The plan also specified that spawning surveys could be conducted prior to reservoir drawdown to monitor AR-3 effectiveness.

5.1.4 KRRC Review of AR-3 for Feasibility and Appropriateness

The KRRC assessed the feasibility and appropriateness of AR-3 through multiple planning meetings held with the ATWG between May and August 2017. During these meetings, new information on Klamath River fisheries was presented and information on other dam removal projects conducted in the western United States was reviewed to understand how the aquatic ecosystem might respond to the dam decommissioning project. Major concerns voiced by the ATWG regarding the 2012 AR-3 included:

- Uncertainty of water availability during fall prior to reservoir drawdown.
- Tributary flows influencing tributary spawning.
- Water needs during reservoir drawdown for sediment evacuation.
- Adult coho salmon locations at the time of the reservoir drawdowns.
- Green sturgeon outmigration timing.

The following sections provide additional information regarding AR-3 feasibility and appropriateness, based on fisheries literature and ATWG input.

Uncertainty of Water Availability Prior to Reservoir Drawdown

The ATWG voiced concerns that the extra water needed to create the fall pulse flows prior to reservoir drawdown may not be available depending on the water year, water rights, and other basin program needs. Given these concerns, water availability creates a project uncertainty and executing the measure may not be possible. The ATWG concluded that the current operation plans in place for USBR’s Klamath Project have been analyzed under a biological opinion (NOAA and USFWS 2013) and are sufficient to describe water releases throughout the year to meet biological goals in the basin.

Tributary Flows Influencing Tributary Spawning

ATWG stated that the proportion of tributary spawning by coho salmon and Chinook salmon is dictated by flows in natal tributaries and not by flow conditions in the mainstem Klamath River. Since many of the primary spawning tributaries are unregulated, fall flows will be determined by the meteorological conditions that occur during the fall prior to reservoir drawdown and thus cannot be predetermined. The ATWG thought that while some water leasing options could be pursued in the Shasta River, water leasing in other tributaries is unlikely based on a lack of existing water leasing agreements and therefore, tributary flows may have minimal influence on the number of spawning fish in the Klamath River. The ATWG also stated that efforts to use pulse flows in the past have been unsuccessful in moving large numbers of fish into the river or into tributary streams.

In summary, KRRC and ATWG concluded that the prescribed fall pulse flows would have little or no effect on tributary streamflow and therefore is not anticipated to result in any additional tributary spawning during a dry year, and therefore could not be relied upon as a measure.

Water Needs During Reservoir Drawdown

ATWG expressed concerns that using available water volume for fall pulse flows could increase or extend the deleterious effects of elevated suspended sediment concentrations to other aquatic organisms in the Hydroelectric Reach and downstream from Iron Gate Dam. By using available water prior to reservoir drawdown, the ATWG expressed concern that less reservoir sediments would be evacuated in the first year, causing prolonged sediment effects beyond dam decommissioning.

KRRC and ATWG concluded that using available storage water in the fall prior to reservoir drawdown could potentially worsen or extend the deleterious effects of elevated suspended sediment concentrations on Klamath River focal species and stored water would be better used to evacuate as much sediment as possible during dam decommissioning.

Adult Coho Salmon Locations at Time of Reservoir Drawdown

KRRC and ATWG concluded that since coho salmon primarily spawn in Klamath River tributaries, adult coho salmon will largely be unaffected by poor water quality conditions associated with reservoir drawdown in the mainstem Klamath River. Coho salmon peak spawning typically occurs in November and December after fall freshets contribute to tributary flows (USBR and CDFG 2012). Additionally, the low numbers of coho salmon that spawn in the mainstem Klamath River are mostly of hatchery origin (NOAA 2014).

KRRC and ATWG concluded that the dam decommissioning effects to adult coho salmon will be minimal as the majority of coho salmon spawning takes place in tributaries, and that the implementation of fall pulse flows would not likely result in any further tributary spawning by natural origin coho salmon.

Green Sturgeon Outmigration Timing

ATWG stated that while green sturgeon outmigration timing from the lower Klamath River and estuary is correlated to increasing streamflow and decreasing water temperatures, these conditions would likely occur naturally prior to reservoir drawdown and additional releases of water are unnecessary to promote outmigration. Benson et al. (2007) stated that outmigration of any holding green sturgeon occurred during the first significant rainfall, usually in November and December. A green sturgeon tagging program in the lower Klamath River, has found no green sturgeon in either the Klamath River or Trinity River after mid-December (Barry McCovey, Yurok Tribe, personal communication, 2017).

KRRC and ATWG concluded that streamflow will naturally increase with fall rains, and no additional flow augmentation will be necessary to ensure that green sturgeon will outmigrate from the lower Klamath River and estuary prior to dam decommissioning.

2012 EIS/R Baseline Population Estimates and Project Effects Uncertainty

Effects to adult fish outlined in the 2012 EIS/R (Vol. II, Appendix E) included approximations and assumptions that were based on limited data on Klamath River anadromous salmonids and green sturgeon; incorporated a conservative analysis of fish avoidance behavior to the anticipated water quality conditions; and in part included a worst-case scenario analysis of dam decommissioning effects on adult Chinook and coho salmon, and green sturgeon.

Project Effects Uncertainty

Studies suggest that high suspended sediment concentrations (Newcombe and Jensen 1996; Chapman et al. 2014; Kjelland et al. 2015) and low dissolved oxygen concentrations (Bjorn and Reiser 1991; Washington Department of Ecology [WDOE] 2002; Carter 2005) affect adult salmonid behavior. Adult salmonid behavioral changes to high suspended sediment concentrations include avoidance of turbid waters in homing adult anadromous salmonids. Physiological effects of high turbidity include physiological stress and respiratory impairment, damage to gills, reduced tolerance to disease and toxicants, reduced survival, and direct mortality (Newcombe and Jensen 1996). Concentration and duration of elevated suspended sediment, as well as other factors including water temperature, disease, and river flow, influence the effect of suspended sediment on salmonids.

Very little information is available on the effects of suspended sediment on sturgeon, and most life stages of sturgeon are more resilient to poor water quality than salmonids (USBR and CDFG 2012).

Adult steelhead and Pacific lamprey entering the Klamath River during reservoir drawdown and dam removal would encounter poor water conditions and would be expected to avoid poor water quality by either entering tributary streams or using habitats less affected by high suspended sediment concentrations (e.g., tributary confluences or off-channel areas). For instance, in 2012 during dam deconstruction on the Elwha River, a high proportion (44 percent) of Chinook salmon redds were documented in two clear water tributaries (Indian Creek and Little River), while surveys conducted following dam removal activities (2014-2016) resulted in over 95 percent of Chinook redds constructed in the mainstem river. The high proportion of tributary spawning by fall Chinook salmon in 2012 suggests that these streams provided refugia from the effects of dam removal (McHenry et al. 2017). There is increasing evidence that fish will modify their behavior to avoid areas of high suspended sediment concentrations immediately following dam removal, thereby reducing the impact of reduced water quality on their populations. This is consistent with ecological and evolutionary theories that would predict that fish would evolve behaviors to avoid episodic events resulting is poor water quality, such as landslides, fires, and other naturally occurring processes.

The 2012 EIS/R effects determination assumed that fish would not exhibit behavioral responses to poor water quality, and instead would experience high mortality by voluntarily remaining in areas that had lethal concentrations of suspended sediment for extended periods of time.

5.2 AR-3 Summary

The 2012 EIS/R AR-3 included fall pulse flows to promote adult Chinook salmon and coho salmon migration into tributary streams for spawning, and to encourage the outmigration of green sturgeon from the lower Klamath River and estuary in advance of the dam decommissioning project. These migratory behaviors in response to the fall pulse flows were anticipated to reduce the effects of high suspended sediment concentrations on anadromous species in the mainstem Klamath River. KRRC and ATWG concluded that fall pulse flows would be difficult to execute due to unknown water availability and water needs of other water users in the basin. Additionally, higher mainstem flows would not necessarily improve tributary flow conditions unless higher tributary flows occurred concurrently with the mainstem pulse flows, or if water leasing could be undertaken on key tributaries. Chinook salmon, coho salmon, and green sturgeon have also evolved with the variable hydrology of the Klamath River and are likely to migrate into tributaries (Chinook and coho salmon) or to the Pacific Ocean (green sturgeon) with the onset of fall rain and increased flows which will precede the dam decommissioning project. Finally, implementing the fall pulse flows could also diminish available storage that could be used to maximize reservoir sediment flushing during reservoir drawdown.

In summary, KRRC proposes to follow USBR's existing operational plans outlined in the 2013 Biological Opinion (NOAA and USFWS 2013) and will not implement the 2012 EIS/R AR-3 plan

Chapter 6: AR-4 Iron Gate Hatchery Management

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6. AR-4 IRON GATE HATCHERY MANAGEMENT

The objective of AR-4 is to address reservoir drawdown and dam removal effects on hatchery-produced Chinook salmon and coho salmon smolts that would be released from Iron Gate Hatchery during the spring of the reservoir drawdown year during periods of high suspended sediment concentration which are potentially lethal to outmigrating juvenile salmonids. The original 2012 EIS/R AR-4 plan focused on delaying the release timing for hatchery produced smolts, or trucking hatchery smolts to downstream reaches of the Klamath River less affected by suspended sediment concentrations.

The KRRC recommends Iron Gate Hatchery-reared yearling coho salmon scheduled to be released in the spring of the drawdown year could be held at Iron Gate Hatchery or at another facility (depending on Iron Gate Hatchery's operational capacity) until water quality conditions in the mainstem Klamath River improve to sublethal levels. Based on the current Iron Gate Hatchery release schedules and suspended sediment predictions in the Klamath River following dam decommissioning, yearling coho salmon releases could be delayed approximately 2 weeks to avoid lethal water quality conditions. Water quality monitoring stations established prior to reservoir drawdown would be used to determine when conditions in the mainstem Klamath River are suitable for the release of hatchery-reared coho salmon.

6.1 Summary of the 2012 EIS/R AR-4, Dam Removal Benefits and Effects, and Recent Fisheries Literature

The following sections review the components of the 2012 EIS/R AR-4 measure, anticipated dam removal effects and benefits on AR-4 species, and recent fisheries literature relative to juvenile salmonid outmigration. This information is presented in support of the existing AR-4 measure.

6.1.1 AR-4 Affected Species

Species identified in AR-4 include:

- Coho salmon *(Oncorhynchus kisutch)* – Southern Oregon/Northern California Coastal (SONCC) evolutionary significant unit (ESU): Federally Threatened; California Threatened; Tribal Trust Species
- Chinook salmon *(O. tshawytscha)* – Upper Klamath-Trinity Rivers ESU - Fall Run: California Species of Special Concern; Tribal Trust Species

6.1.2 Anticipated Dam Decommissioning Effects on AR-4 Species

Short-term effects of dam removal were expected to result in mostly sublethal, and in some cases lethal, impacts to a portion of the juvenile Chinook salmon, coho salmon, steelhead, and Pacific lamprey that are outmigrating from tributary streams to the Klamath River during late winter and early spring of 2020 (USBR and CDFG 2012). Deleterious short-term effects are expected to be caused by high SSC levels and low dissolved oxygen concentrations in the Klamath River from Iron Gate Dam downstream to Orleans. Hatchery-produced Chinook and coho salmon smolts that are released from the Iron Gate Hatchery into this reach could suffer from high mortality if they are released during periods of high SSC levels as a result of the dam decommissioning. Iron Gate Hatchery current production goals include 75,000 yearling coho salmon, 900,000 yearling Chinook salmon, and 5,100,000 Chinook salmon smolts (CDFW and PacifiCorp 2014). Table 6-1 includes the production goals and typical release schedules for Iron Gate Hatchery. Table 6-2 includes the actual production for 2001 to 2017 (K. Pomeroy, CDFW, personal communication, 2017).

Table 6-1 Current Iron Gate Hatchery production goals and release schedules

Species	Release Type	Production Goal	Release Schedule
Coho Salmon	Yearling	75,000	March-April
Chinook Salmon - Fall	Yearling	900,000	November
Chinook Salmon - Fall	Smolt	5,100,000	May-June

Table 6-2 Iron Gate Hatchery actual annual production totals for 2001 to 2017

Release Year	Chinook	Coho	Steelhead	Total
2001	5,849,147	46,254	31,898	5,929,300
2002	5,880,294	67,933	141,362	6,091,591
2003	5,595,997	74,271	192,771	5,865,042
2004	5,777,904	109,374	148,991	6,038,273
2005	6,212,640	74,716	195,698	6,485,059
2006	7,046,755	89,482	83,034	7,221,277
2007	6,348,474	118,487	21,208	6,490,176
2008	6,394,875	53,950	18,461	6,469,294
2009	4,749,470	118,340	29,683	4,899,502
2010	5,380,185	121,000	22,500	5,525,695
2011	4,882,247	22,236	21,034	4,927,528
2012	6,180,447	155,840	51,948	6,390,247
2013	5,091,396	39,402	-	5,132,811
2014	5,422,994	79,585	-	5,504,593

Release Year	Chinook	Coho	Steelhead	Total
2015	943,489	89,500	-	1,035,004
2016	4,612,598	27,568	-	4,642,182
2017	410,686	17,102	-	429,805
Total	86,779,598	1,305,040	958,588	89,077,379
Max	7,046,755	155,840	195,698	7,221,277
Ave	5,104,682	76,767	79,882	5,239,846
Min	410,686	17,102	18,461	429,805

6.1.3 2012 EIS/R AR-4 Actions

The 2012 EIS/R AR-4 plan (Vol. I, p. 3.3-246) included two potential actions that could be implemented to reduce the impacts of high SSC levels on hatchery Chinook and coho salmon smolts as a result of dam decommissioning. The first action is to delay the coho salmon yearling release until later in the spring (e.g., early to mid-May) in order to avoid peak SSC levels associated with the dam decommissioning. Avoiding the peak SSC levels is anticipated to reduce smolt mortality.

An alternative action to the delayed smolt release approach included allowing sub-yearling and yearling smolts to imprint at the hatchery and then truck them to Klamath River release locations downstream of the Trinity River where tributary flows are anticipated to reduce SSC levels to near background. The timing of the releases would be consistent with normal hatchery release schedules.

The 2012 EIS/R AR-4 plan suggested that the implementation of this measure is contingent on the hatchery remaining open and having a suitable water supply during dam decommissioning.

6.1.4 KRRC Review of AR-4 for Feasibility and Appropriateness

The KRRC assessed the feasibility and appropriateness of AR-4 through multiple planning meetings held with the ATWG between May and August 2017. During these meetings, new information on Klamath River fisheries and hatchery management was presented and information on other dam removal projects conducted in the western United States was reviewed to understand how the aquatic ecosystem might respond as discussed above. Major concerns voiced thus far by the ATWG regarding the 2012 AR-4 included:

- Iron Gate Hatchery water supply uncertainty during and after dam decommissioning.
- Potential mortality associated with hauling and releasing juvenile salmonids.
- Potential Chinook and coho salmon juvenile imprinting and adult straying issues.

The following sections provide additional information regarding AR-4 feasibility and appropriateness, based on fisheries literature and ATWG input.

Iron Gate Hatchery Water Supply Uncertainty

The ATWG voiced concerns that the current water supply for the Iron Gate Hatchery is located at varying depths in Iron Gate Reservoir and will no longer be operational following dam decommissioning. Additionally, high SSC levels in the Klamath River during reservoir drawdown will require an alternative water source(s) or filtration of river water for use in the hatchery, as the water quality will not be sufficient for hatchery operation. The ATWG to currently reviewing potential alternative water sources or water treatment solutions that would allow for continued Iron Gate Hatchery operation during and after the dam decommissioning.

Potential Mortality Associated with Hauling and Releasing Juvenile Salmonids

The ATWG expressed concerns that long trucking distances could result in stress and handling mortality of transported fish. The ATWG was concerned that truck or equipment malfunction could also result in smolt losses during transport. Transporting juvenile salmonids causes stress in smolts (Barton et al. 1980; Specker and Schreck 1980; Matthews et al. 1986), which may reduce survival when fish are released (Kenaston et al. 2001).

The ATWG concluded that transporting hatchery Chinook and coho salmon smolts long distances downstream from Iron Gate Hatchery could lead to high mortality rates.

Potential Chinook and Coho Salmon Juvenile Imprinting and Adult Straying Issues

ATWG expressed concerns regarding how handling and transport of juvenile salmonids may affect imprinting processes resulting in future straying of returning adults. Juvenile imprinting is influenced by natal stream water chemistry and the juvenile fish's physiological state during rearing and outmigration (Keefer and Caudill 2014). Juvenile fish with extended freshwater residency times, or long-distance migrations, almost certainly experience multiple imprinting events that contribute to homing success of adult spawners. Transporting juvenile fish has been shown to disrupt this 'sequential imprinting' process, and several studies on coho salmon (Solazzi et al. 1991) and Atlantic salmon (Gunnerød et al. 1988; Heggberget et al. 1991) have shown that adult homing success is inversely related to transport distance from rearing sites (Keefer and Caudill 2014).

Therefore, the release of juvenile fish downstream of the Trinity River could compromise the imprinting process for relocated juvenile fish. Insufficient imprinting to natal streams or the loss of spatially distinct imprinting events during outmigration could potentially increase adult straying rates during future returns and result in the loss of genetic integrity in distinct populations. Future, elevated stray rates could result in a more homogenous distribution of fish returning to the lower Klamath River and also hinder the natural recolonization of areas upstream of Iron Gate Dam.

The ATWG concluded that releasing hatchery-reared fish downstream of the Trinity River could jeopardize future hatchery returns to the upper Klamath River and could increase straying rates that could negatively affect wild populations.

6.2 AR-4 Summary

The 2012 EIS/R AR-4 included two strategies for addressing short-term dam decommissioning effects to hatchery-produced Chinook and coho salmon smolts. The two strategies included either delaying the release of Chinook salmon smolts and coho salmon yearlings, or the transport of these fish from Iron Gate Hatchery to the Lower Klamath River where the fish would be released into reaches less affected by poor water quality associated with the dam decommissioning. Delaying the release of yearling coho salmon is not expected to require a substantial change in the typical hatchery release schedule and may only require a two-week delay in the release schedule. The ATWG raised concerns about potential juvenile stress and mortality associated with the trucking option, and increased stray rates of returning adults due to insufficient juvenile imprinting. In summary, the KRRC recommends the delayed release of yearling coho salmon from Iron Gate Hatchery

Chapter 7: AR-5 Pacific Lamprey Ammocoetes

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7. AR-5 PACIFIC LAMPREY AMMOCOETES

The objective of AR-5 is to monitor the distribution and abundance of Pacific lamprey ammocoetes downstream of Iron Gate Dam. The original 2012 EIS/R AR-5 measure involved capturing and relocating Pacific lamprey ammocoetes from the Klamath River starting at, and extending 2 miles downstream from Iron Gate Dam (RM 192.9). Relocating lamprey ammocoetes from this reach was expected to offset some of the potential effects of high suspended sediment concentrations and low dissolved oxygen levels during reservoir drawdown.

Based on existing lamprey ammocoete presence information, dam removal effects to Pacific lamprey ammocoetes in the 2-mile reach downstream from Iron Gate Dam (RM 192.9) are expected to be minimal, and the KRRC recommends no protective action is necessary for Pacific lamprey ammocoetes.

7.1 Summary of the 2012 EIS/R AR-5, Dam Removal Benefits and Effects, and Recent Fisheries Literature

The following sections review the components of the 2012 EIS/R AR-5 measure, anticipated dam removal effects and benefits on Pacific lamprey ammocoetes, and recent fisheries literature relative to Pacific lamprey ammocoetes.

7.1.1 AR-5 Affected Species

Species identified in AR-5 include:

- Pacific lamprey *(Entosphenus tridentatus):* California Species of Special Concern; Oregon Sensitive Species, Tribal Trust Species

7.1.2 Anticipated Dam Decommissioning Effects on AR-5 Species

The short-term effects of dam removal (high suspended sediment concentrations and low dissolved oxygen) are anticipated to result in high rates of ammocoete mortality, although the resilience of ammocoetes to extended periods of high suspended sediment concentrations and low dissolved oxygen are unknown (Goodman and Reid 2012). The 2012 EIS/R (Reclamation and CDFG 2012; Vol. II, Appendix E, pp. E52-E56) analysis applied the effects of suspended sediment on salmonids to predict effects on Pacific lamprey ammocoetes, with the assumption that effects on Pacific lamprey ammocoetes are equivalent to or less severe than on salmonids. This likely overestimates any effects to lamprey ammocoetes since their preferred rearing strategy is to burrow in fine sediments mixed with organic matter. In general, most life stages of

Pacific lamprey appear to be more resilient to poor water quality conditions (such as suspended sediment) than salmonids (Zaroban et al. 1999). Table 7-1 includes the anticipated effects to Pacific lamprey ammocoetes presented in the 2012 EIS/R (Reclamation and CDFG 2012).

Table 7-1 2012 EIS/R anticipated effects summary for Pacific lamprey ammocoetes

Species	Life Stage	Likely Effects	Worst Effects
Pacific Lamprey	Ammocoete Rearing	High mortality (52%)[1]	High mortality (71%)[1]
Source: USBR and CDFG 2012			

Dam decommissioning would have short-term effects on Pacific lamprey ammocoetes related to suspended sediment concentrations, bedload sediment transport and deposition, and impaired water quality (particularly low dissolved oxygen levels). Overall, because multiple year classes of Pacific lamprey rear in the mainstem Klamath River at any given time, and since adults will migrate upstream over the entire year, including January of the reservoir drawdown year when effects from the dam decommissioning will be most pronounced, effects on Pacific lamprey adults and ammocoetes are anticipated to be substantial. However, because of their wide spatial distribution and varied life history, most of the population (which spans nearly the entire northern Pacific Rim), would not be affected by the dam decommissioning. In addition, Pacific lamprey are considered to have low fidelity to their natal streams (FERC 2006), and may not enter the mainstem Klamath River if environmental conditions are unfavorable during the reservoir drawdown period. Migration into the Trinity River and other lower Klamath River tributaries may also increase during reservoir drawdown because of poor water quality in the upper Klamath River. Low site fidelity and a prevalence of tributary ammocoetes also increases the potential for Pacific lamprey recolonization of mainstem habitats following dam decommissioning.

The 2-mile reach of the Klamath River downstream from Iron Gate Dam (RM 192.9) was the focus of lamprey relocation efforts in the 2012 EIS/R (Reclamation and CDFG 2012). At the time of the 2012 EIS/R, lamprey ammocoete presence downstream from Iron Gate Dam was unknown. Recent surveys have found very low numbers or absence of lamprey ammocoetes in the Klamath River between Iron Gate Dam and the Scott River (approximately 47 river miles; Goodman and Hetrick 2017). Referenced as a “dead zone” containing few ammocoetes this reach is presumably affected by flow management, poor water quality, lack of sandy fines, and high deposition rates of organic material (Goodman and Reid 2015). Kostow (2002) also found Pacific lamprey ammocoete distributions can be patchy, perhaps due to environmental conditions, and Petersen (2006) related tribal eelers’ belief that the effects of the dams on anadromous fish returns may affect marine-derived nutrients that sustain ammocoetes.

Tribal elders and eelers with the Yurok and Karuk Tribes were interviewed as part of a traditional ecological knowledge (TEK) project investigating the importance of Pacific lamprey to the lower Klamath River tribes (Petersen 2006). Eelers noted the dramatic reduction in Pacific lamprey since European-American settlement and specifically over the last 50 years. The construction of Iron Gate Dam, mining, forest fire suppression, commercial logging, other forestry practices including herbicide application, road building, rotenone treatments (see Jackson et al. 1996 for similar treatments in the Columbia Basin), periodic high magnitude floods, and changing ocean conditions were frequently identified as reasons for Pacific lamprey declines in the basin (Petersen 2006). Of these impacts, loss of the natural flow regime on the Klamath River was highlighted as having the most detrimental effect on Pacific lamprey spawning and ammocoete rearing habitats. Dewatering of channel margin ammocoete rearing habitats downstream from Iron Gate Dam caused by hydropower ramping were also suspected in the decline of Pacific lamprey (Petersen 2006).

Dam decommissioning will address some of the limiting factors that are believed to currently affect Pacific lamprey across their geographic region and in the Klamath River basin. Increasing connectivity across the river network and restoring connectivity between the Klamath River and tributaries in the Hydroelectric Reach will provide access to more Pacific lamprey spawning and rearing habitats (Schultz et al. 2014). Restoring more natural flow and temperature regimes, and transport of fine sediments downstream of Iron Gate Dam, will improve ammocoete rearing habitat conditions. Ammocoete rearing habitats are believed to be important for maintaining recruitment to the population as these areas provide pheromone-based migratory cues for spawning adults (Stone et al. 2002; Li et al. 2003) and may preserve lamprey population persistence (Jolley et al. 2016).

7.1.3 2012 EIS/R AR-5 Actions

The 2012 EIS/R AR-5 plan directed the capture and relocation of Pacific lamprey ammocoetes from preferred habitats in the reach of the Klamath River starting at, and extending 2 miles downstream from Iron Gate Dam. Relocating lamprey ammocoetes from this reach was expected to offset some of the potential effects of high suspended sediment concentrations and low dissolved oxygen levels during reservoir drawdown.

The 2012 EIS/R AR-5 measure included the following tasks.

- Identify preferred habitat areas where dissolved oxygen levels would be particularly low, including pools, alcoves, backwaters, and channel margins that experience low water velocities and sand and silt deposition from the reach within 2 miles downstream from Iron Gate Dam.
- Conduct reconnaissance level surveys to assess if enough ammocoetes are present in this reach to warrant protection.
- The salvage operation, if implemented, would be conducted utilizing a specialized backpack electrofishing unit to capture ammocoetes. Captured individuals would be transported to suitable locations (with current low occurrences of lamprey) within tributaries upstream or upstream of Keno Dam.

7.1.4 KRRC Review of AR-5 for Feasibility and Appropriateness

The KRRC assessed the feasibility and appropriateness of AR-5 through multiple planning meetings held with the ATWG between May and August 2017. During these meetings, current information on Klamath River fisheries was presented and information on other dam removal projects conducted in the western United

States were reviewed to understand how the aquatic ecosystem might respond as discuss above. Major concerns voiced by the ATWG regarding the 2012 AR-5 included:

- Pacific lamprey ammocoete absence in the prescribed 2012 EIS/R salvage reach.
- Potential effects of relocated Pacific lamprey ammocoetes on endemic lamprey species.
- Effects to the Pacific lamprey metapopulation.

The following sections provide additional information regarding AR-5 feasibility and appropriateness based on supplemental information provided in the 2012 EIS/R, current fisheries research literature, and input from the ATWG.

Pacific Lamprey Ammocoetes Absence from Salvage Reach

Previous sampling efforts conducted by the Karuk Tribe and USFWS in the proposed salvage reach (2 miles downstream from Iron Gate Dam) found very few or no ammocoetes in sampled habitats (Goodman and Hetrick 2017; T. Soto, Karuk Tribe, personal communication, 2017). At 37 sites sampled in the Klamath River, ammocoetes were detected at an expected catch per unit effort at all locations except those within proximity to Iron Gate Dam (Goodman and Hetrick 2017). Goodman and Reid (2015) documented the 47-mile reach of the Klamath River from Iron Gate Dam to the Scott River as a "dead zone" containing few ammocoetes, presumably due to flow management, poor water quality, lack of sandy fines, and high deposition rates of organic material. Since river conditions and river management have not changed since these ammocoete survey were completed, Pacific lamprey ammocoete habitation in the 2-mile reach downstream of Iron Gate Dam is unlikely. The ATWG concluded further allocation of resources to sample ammocoetes from this reach is not warranted.

Effects of Relocated Pacific Lamprey Ammocoetes on Endemic Lamprey Ammocoetes

Currently, five other resident species of lamprey occur in the Klamath Basin. Although Pacific lamprey likely historically occupied the Upper Klamath Basin (Goodman and Reid 2015) and tribal knowledge relates that Pacific lamprey occupied habitats beyond the upstream limit of steelhead occupation (Petersen 2006), there are uncertainties regarding the historical overlap of Pacific lamprey and endemic lamprey species (ODFW 2008). The ATWG suggested that it would be difficult or impossible to differentiate larval lamprey ammocoetes of a variety of species during a field relocation effort. With this consideration, the ATWG expressed concerns regarding the potential effects of relocating non-target ammocoetes to areas upstream of Keno Dam or into Klamath River tributaries as the original 2012 EIS/R AR-5 specified. Potential effects on endemic lamprey species could include competition for habitat and food, and disease transmission from relocated lamprey ammocoetes to existing populations. ODFW's 2008 draft of *A Plan for the Reintroduction of Anadromous Fish in the Upper Klamath Basin* sought a passive reintroduction strategy for Pacific lamprey. ODFW's current strategy is likely to follow a similar passive reintroduction process (T. Wise, ODFW, personal communication, 2017). The ATWG concluded that relocating salvaged lamprey ammocoetes from the mainstem Klamath River could pose significant risks to other endemic lamprey species.

Pacific Lamprey Metapopulation

Recent genetic analysis of Pacific lamprey suggests no significant population structure exists across populations or regions, indicating a high degree of historical gene flow even across expansive distances of the northern Pacific Rim (Goodman and Reid 2012). Klamath Basin Pacific lampreys are part of a more geographically-widespread interbreeding population that exhibits little basin-specific site fidelity (Goodman and Hetrick 2017). Because the metapopulation is now believed to extend potentially across the species' range, the percentage of the metapopulation's adult and larval Pacific lamprey that will be affected by the dam decommissioning will be insignificant. The ATWG concluded that the potential loss of Pacific lamprey ammocoetes during dam decommissioning would be a temporary impact to the population and ammocoete mortality would constitute a minimal impact to the metapopulation.

7.2 AR-5 Summary

The Klamath River from Iron Gate Dam downstream to the Scott River (47 miles) is referred to as a "dead zone" for Pacific lamprey ammocoetes. Past sampling efforts have detected few or no ammocoetes in this reach. Based on these sampling efforts and concerns regarding Pacific lamprey ammocoete relocation, no protective actions are planned to address project effects to Pacific lamprey ammocoetes. Like other reviewed species, Pacific lamprey are expected to benefit from the dam decommissioning project over the long-term. Benefits to Pacific lamprey include restoring access to historical habitat upstream of Iron Gate Dam, fine sediment transport and local fining of channel bed sediments downstream of Iron Gate Dam, and improved water quality conditions.

Chapter 8: AR-6 Suckers

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8. AR-6 SUCKERS

The objective of AR-6 is to address reservoir drawdown and dam removal effects on Lost River and shortnose suckers inhabiting the Hydroelectric Reach reservoirs by salvaging suckers from the reservoirs and relocating the salvaged suckers to waterbodies outside of the affected area. The original 2012 EIS/R AR-6 measure focused on trapping and hauling Lost River, shortnose, and Klamath smallscale suckers. Lost River and shortnose suckers would be released into Upper Klamath Lake, and Klamath small smallscale suckers released into Spencer Creek, a tributary to the Klamath River in the Hydroelectric Reach. Based on a review of the information provided herein, the KRRC concluded that an updated AR-6 is necessary to address anticipated short-term effects of the dam decommissioning project. The updated AR-6 measure includes a step-wise adaptive process for sampling, salvaging, and releasing Lost River and shortnose suckers into waterbodies that will not be affected by dam decommissioning effects.

8.1 Proposed Updated AR-6

Based on a review of the original 2012 EIS/R AR-6 measure presented in Section 8.2, input from the ATWG, and recent Lost River and shortnose suckers literature, the KRRC concluded that an updated AR-6 is necessary to offset the anticipated short-term effects of dam decommissioning on Lost River and shortnose suckers. The updated AR-6 includes sampling, and salvaging and releasing suckers into designated waterbodies that are isolated from sucker recovery populations in Upper Klamath Lake. The updated AR-6 has two actions.

- **Action 1:** Lost River and shortnose suckers will be sampled in the Klamath River and in Hydroelectric Reach reservoirs in 2018 and 2019. River sampling will be completed in spring of 2019 and reservoir sampling will be completed in fall of 2018. The purpose of sampling is to document the abundance and genetics of Lost River and shortnose suckers in the Hydroelectric Reach. Captured fish will be marked with a passive integrated transponder (PIT) tag, fin clipped for genetic material, measured, and released. Recaptured fish will be used to estimate the sucker population abundance. Fin clips will be used to determine the genetics of the sampled fish. USFWS is currently developing genetic markers for Lost River and shortnose suckers.
- **Action 2:** Adult Lost River and shortnose suckers in reservoirs downstream from Keno Dam would be captured and relocated to isolated water bodies in the Klamath Basin. The proposed relocation of rescued suckers to isolated waterbodies is to ensure hybridized suckers do not mix with sucker populations designated as recovery populations in Upper Klamath Lake. An estimated 14 days will be required for sampling, and 14 days will be required for salvage and release efforts. We anticipate salvaging and translocating 100 Lost River and 100 shortnose suckers from each of the three Klamath River reservoirs (600 fish total). The number of translocated fish will not exceed 3,000 fish, which is the capacity of the currently identified recipient waterbody (Tule Lake). The salvage effort will likely translocate less than 10 percent of the sucker populations in the respective reservoirs.

The proposed actions are intended to reduce Project effects on Lost River and shortnose suckers inhabiting the Hydroelectric Reach reservoirs. The following sections provide additional detail on the proposed actions.

8.1.1 Action 1: Reservoir and River Sampling

Lost River and shortnose suckers will be sampled in the Hydroelectric Reach reservoirs and the Klamath River in 2018 and 2019. Sampling in both the reservoirs and the Klamath River is anticipated to improve the number of fish encounters since suckers may not spawn every year (Buettner 2000) and the current population demographics are unknown.

River sampling will be completed in spring of 2019 and reservoir sampling will be completed in fall of 2018. The intent of the sampling is to document the abundance and genetics of Lost River and shortnose suckers in the Hydroelectric Reach. Sampling will include placing trammel nets in the reservoirs (reservoir sampling) and in Klamath River segments upstream of the reservoirs (river sampling) to determine the abundance and genetics of suckers in the Hydroelectric Reach. Electrofishing or other means of trapping suckers may also be employed if trammel netting is ineffective. Captured fish will be marked with a PIT tag (Burdick 2013), fin clipped for genetic material, measured, and released. Recaptured fish will be used to estimate the size of sucker populations, and fin clips will be used to determine the genetics of the sampled fish. Summary reports will be prepared following each sampling effort and the ATWG will meet to review the sampling data and determine if additional sampling is necessary. Collected data will be stored in a database managed by USFWS or USGS.

Primers will need to be developed from the genetic markers that USFWS's Abernathy Fish Technology Center identifies for Lost River and shortnose suckers. Genetic analysis of the sampled suckers will be used to inform managers on the genetics of Lost River and shortnose sucker populations in the Hydroelectric Reach. Genetic information will in part be used to determine appropriate salvaged suckers' release locations.

8.1.2 Action 2: Sucker Salvage and Relocation

Adult Lost River and shortnose suckers in reservoirs downstream from Keno Dam would be captured and relocated to isolated water bodies in the Klamath Basin using similar methods as outlined for the sampling. The proposed relocation of rescued suckers to isolated waterbodies is to ensure hybridized suckers do not mix with sucker populations designated as recovery populations in Upper Klamath Lake. An estimated 14 days will be required for sampling, and 14 days will be required for salvage and release efforts. We anticipate salvaging and translocating 100 Lost River and 100 shortnose suckers from each of the three Klamath River reservoirs (600 fish total). The number of translocated fish will not exceed 3,000 fish, which is the capacity of the currently identified recipient waterbody (Tule Lake). The salvage effort will likely translocate less than 10 percent of the sucker populations in the respective reservoirs.

In summary, the updated AR-6 includes two actions to sample and then salvage and relocate Lost River and shortnose suckers from the Hydroelectric Reservoirs to Tule Lake.

8.2 Summary of the 2012 EIS/R AR-6, Dam Removal Benefits and Effects, and Recent Fisheries Literature

The following sections review the components of the 2012 EIS/R AR-6 measure, anticipated dam removal effects on Lost River and shortnose suckers, and current sucker literature.

8.2.1 AR-6 Affected Species

Species identified in AR-6 include:

- Lost River sucker *(Deltistes luxatus)*: Federally Endangered; California Endangered and Fully Protected; Oregon Endangered; Tribal Trust Species
- Shortnose sucker *(Chasmistes brevirostris):* Federally Endangered; California Endangered and Fully Protected; Oregon Endangered; Tribal Trust Species
- Klamath smallscale sucker *(Catostomus rimiculus)*

8.2.2 Anticipated Dam Decommissioning Effects on AR-6 Species

The dam decommissioning project will result in the loss of Lost River and shortnose sucker reservoir populations as the lake-type habitat these sucker species inhabit will be restored to free-flowing riverine conditions. Although sucker populations in the Hydroelectric Reach reservoirs are generally unknown (Buettner et al. 2006), past sampling efforts have documented larval and adult suckers in Topsy Reservoir (J.C. Boyle Dam; Desjardins and Markle 2000), Copco Reservoir (Copco 1 Dam; Beak Consultants 1987; Desjardins and Markle 2000), and Iron Gate Reservoir (Desjardins and Markle 2000). More recent anecdotal evidence suggests a sucker spawning run occurred upstream of Topsy Reservoir in April 2017 (B. Tinniswood, ODFW, personal communication, 2017). Table 8-1 includes the likely and worst-case effects to Lost River and shortnose suckers in the Hydroelectric Reach reservoirs.

Table 8-1 2012 EIS/R anticipated effects summary for Lost River and shortnose suckers

Species	Life Stage	Likely Effects	Worst Effects
Lost River & Shortnose Suckers	All	Loss of reservoir populations	Loss of reservoir populations
Source: USBR and CDFG 2012			

The following section includes a description of species-specific effects adapted from the 2012 EIS/R (Reclamation and CDFG 2012; Vol. I, pp. 3.3-166 to 3.3-168) and other literature.

Lost River Suckers and Shortnose Suckers

Lost River and shortnose suckers are endemic to the Upper Klamath Basin (Moyle 2002). The Lost River sucker historically occurred in Upper Klamath Lake (Williams et al. 1985) and its tributaries, and the Lost River watershed, Tule Lake, Lower Klamath Lake, and Sheepy Lake (Moyle 1976). Shortnose suckers historically occurred throughout Upper Klamath Lake and its tributaries (Williams et al. 1985; Miller and Smith 1981). The present distribution of both species includes Upper Klamath Lake and its tributaries (Buettner and Scoppettone 1990), Clear Lake Reservoir and its tributaries (USFWS 1993), Tule Lake, Lost River up to Anderson-Rose Dam (USFWS 1993), and the Klamath River downstream to Copco Reservoir and probably to Iron Gate Reservoir (USFWS 1993). Shortnose sucker occur in Gerber Reservoir and its tributaries, but Lost River sucker do not.

The dam decommissioning project will eliminate existing reservoir habitat used by Lost River and shortnose suckers. The Lost River and shortnose suckers that have been observed in the Hydroelectric Reach reservoirs are believed to be fish that originated in Upper Klamath Lake and moved down through Lake Euwana and the Hydroelectric Reach (Buettner and Scoppettone 1991; Markle et al. 1999; Desjardins and Markle 2000). The populations are not thought to represent a viable, self-supporting populations (Buettner et al. 2006; USFWS 2012), and no longer interact with Upper Klamath Lake populations. The Hydroelectric Reach habitat is not designated critical habitat for either species, and Hydroelectric Reach populations are not part of the species' recovery units (USFWS 2012).

8.2.3 2012 EIS/R AR-6 Actions

The 2012 EIS/R AR-6 plan (Vol. I, pp. 3.3-247 to 3.3-248) directed a multi-step process that included a telemetry study to determine sucker locations in the Hydroelectric Reach reservoirs, followed by salvaging Lost River and shortnose suckers during the reservoir drawdowns, and releasing the salvaged suckers into Upper Klamath Lake. If deemed feasible prior to dam decommissioning, Klamath smallscale suckers were to be collected in a 2-mile reach downstream from J.C. Boyle Dam and transported for release into Spencer Creek immediately downstream of the Spencer Creek hook-up road (upper limits for sucker in Spencer Creek; Reclamation and CDFG 2012).

8.2.4 KRRC Review of AR-6 for Feasibility and Appropriateness

The KRRC assessed the feasibility and appropriateness of AR-6 through multiple planning meetings held with the ATWG between May and August 2017. During these meetings, current information on Klamath River fisheries was presented and information on other dam removal projects conducted in the western United States were reviewed to understand how the aquatic ecosystem might respond as discussed above. Major concerns voiced by the ATWG regarding the 2012 AR-6 included:

- Genetic integrity of salvaged suckers and effects on recipient populations.
- Relocation site availability.
- Klamath small scale sucker salvage.

- Designated critical habitat and sink populations.
- Telemetry study feasibility and benefit.
- 2012 EIS/R baseline population estimates and effects uncertainty.

The following sections provide additional information regarding AR-6 feasibility and appropriateness based on fisheries literature and ATWG input.

Genetic Integrity of Salvaged Suckers and Effects on Recipient Populations

Klamath reservoir sucker populations have not been formally studied since the late 1990s (see Beak Consultants 1987; 1988; Desjardins and Markle 2000). Current population sizes, age class distribution, and genetic composition of Lost River and shortnose suckers are unknown, although genetic introgression between Lost River and shortnose suckers and Klamath smallscale suckers is suspected (Beak Consultants 1987; Markle et al. 1999). USFWS is concerned that relocating hybridized Lost River and shortnose suckers into Upper Klamath Lake could compromise the genetic integrity of recovery unit populations in Upper Klamath Lake. As Klamath smallscale suckers are very rare in Upper Klamath Lake (one has been found in Upper Klamath Lake; Markle et al. 1999), hybridized Lost River-Klamath smallscale suckers or shortnose-Klamath smallscale suckers in Upper Klamath Lake would create a novel sucker hybrid not known to exist in designated critical habitat (i.e., Klamath Basin upstream from Keno Dam). However, Markle et al. (1999) found more genetic similarity between Lost River suckers and Klamath smallscale suckers, and shortnose suckers and Klamath largescale suckers, although there also geographic-related differences among individuals within the respective species (e.g., Lost River suckers from Lost River and the Upper Klamath subbasins had meristic differences). Markle et al. (1999) concluded that Klamath Basin suckers are part of a species complex, or syngameon, defined as groups of interbreeding species that maintain their ecological, morphological, genetic, and evolutionary integrity in spite of hybridization (Templeton 1989 *cited in* Markle et al. 1999). In these hybrid species complexes, species integrity may be maintained by selection.

Based on the unknown genetic composition of suckers in the Hydroelectric Reach, it was concluded that relocating salvaged suckers to Upper Klamath Lake could threaten recovery populations and alternative release locations are necessary.

Relocation Site Availability

Salvaged sucker relocation sites must be isolated from Lost River and shortnose sucker populations inhabiting critical habitat or recovery areas in order to maintain the genetic integrity and health of recovery populations. Although it is unlikely that Lost River and shortnose suckers would have disease and parasite loads different from suckers in Upper Klamath Lake, such concerns further require the separation of salvage fish from recovery populations in the Upper Klamath Basin.

Tule Lake is the most likely relocation site for salvaged suckers. Tule Lake is an agricultural sump that is maintained by agricultural return flow. USFWS currently uses Tule Lake as a relocation site for Lost River and shortnose suckers salvaged from other areas in the basin, and the lake currently has the capacity for an additional 2,000 to 3,000 relocated suckers (J. Rasmussen, USFWS, personal communication, 2017).

Management of Tule Lake is complicated by multiple user groups and the periodic need to draw down the reservoir for sediment maintenance. USFWS is currently investigating other potential sucker relocation sites in the Upper Klamath Basin.

We recommend that salvaged suckers be relocated to Tule Lake or another isolated waterbody until Hydroelectric Reach sucker genetics are better understood.

Klamath Smallscale Sucker Salvage

Klamath smallscale sucker is a riverine sucker species that historically inhabited the Klamath River below the Keno reef, and the adjacent Rogue River basin (Markle et al. 1999). The species is not known to inhabit Upper Klamath Lake or Upper Klamath Basin tributaries. Klamath smallscale sucker salvage would require sorting and releasing Klamath smallscale suckers at different locations than Lost River and shortnose suckers since the listed suckers are lake-type suckers (Buettner and Scoppettone 1991). ODFW also expressed concern with releasing salvaged Klamath smallscale suckers into Spencer Creek due to competition with the existing Spencer Creek sucker population (T. Wise, ODFW, personal communication, 2017). Although included in the original AR-6, Klamath smallscale sucker is not a federal or state listed species, and is not recognized as a tribal trust species. Therefore, we recommend Klamath smallscale sucker be removed from consideration in the updated AR-6 plan.

Designated Critical Habitat and Sink Populations

Hydroelectric Reach reservoirs and Klamath River downstream from Keno Dam were not designated as critical habitat by USFWS (2012). The sucker populations inhabiting the Klamath reservoirs are part of the Upper Klamath Lake Recovery Unit, however, they are sink populations that will likely never be viable and therefore are not actively managed for recovery (USFWS 2012). From a federal regulatory perspective, recovery of Lost River and shortnose suckers does not require preservation of the Hydroelectric Reach reservoirs or the sucker populations within.

Telemetry Study

Based on research in Upper Klamath Lake and past studies in the Klamath River reservoirs, USFWS and the U.S. Geological Survey (USGS) are in support of a multi-stage sampling and salvage effort that would use passive integrated transponder (PIT) tag technology to mark suckers. Lost River and shortnose suckers would be netted during a two-year sampling effort (2017 and 2018) and marked to estimate population sizes and demographics for suckers in the Hydroelectric Reach reservoirs. Sampling would occur in the reservoirs in the fall and in reaches of the Klamath River upstream of the reservoirs in the spring. Fall sampling would focus on shallow areas in the reservoirs and spring sampling would target sucker spawning migrations as fish leave the reservoirs and enter river reaches for spawning (Janney et al. 2009; Hewitt et al. 2014). Genetic material collected during the sampling phase would be used to develop genetic profiles of reservoir suckers and inform the sucker relocation effort. Suckers would be relocated during salvage efforts in the spring and fall of 2019. Based on this information, we have concluded the proposed PIT tag study will be more informative and less costly to implement relative to the originally proposed telemetry study.

2012 EIS/R Baseline Population Estimates

Desjardins and Markle (2000) provided the most comprehensive population estimates for suckers in the Hydroelectric Reach reservoirs. The number of adult shortnose suckers was estimated to be highest in Copco Reservoir (n=165), followed by J.C. Boyle (n=50), and then Iron Gate (n=22). Larger and older individuals dominated Copco and Iron Gate reservoirs and little size structure was detected. J. C. Boyle tended to have smaller adult shortnose suckers and many size classes were present. It appeared that recruitment of young-of-the-year suckers only occurred in J.C. Boyle with downstream reservoirs recruiting older individuals, perhaps those that had earlier recruited to J.C. Boyle Reservoir.

No new baseline population data have been produced for suckers inhabiting the Hydroelectric Reach reservoirs. However, anecdotal evidence (B. Tinniswood, ODFW, personal communication, 2017) suggests more suckers may inhabit the reservoirs than previously anticipated (e.g., Buettner and Scoppettone 1991; Beak Consultants 1987). USFWS's Abernathy Fish Technology Center, Longview, Washington, is also currently undertaking a genetic analysis of Lost River, shortnose, and other basin sucker species to identify genetic markers that may be used to differentiate suckers in the future. The Abernathy lab is anticipated to produce a report on sucker genetics by summer of 2018.

8.3 AR-6 Summary

The Klamath River dam decommissioning project is anticipated to have significant short-term effects on Lost River and shortnose suckers in the Hydroelectric Reach. Because the reservoirs will be restored to free-flowing historical conditions and the special-status suckers are lake-type suckers, individuals of these species that remain in the Hydroelectric Reach following dam removal are not expected to survive. The 2012 EIS/R AR-6 measure included a telemetry study to assess potential sucker locations in the Hydroelectric Reach, followed by a sucker salvage effort to remove fish from the reservoirs and transport them to Upper Klamath Lake for release. Several concerns were identified with the 2012 AR-6 plan, including the genetic integrity of Hydroelectric Reach suckers, relocation site availability, the need to salvage Klamath smallscale suckers, and the feasibility and benefit of the proposed telemetry study. We concluded that the basis of these concerns could result in the originally proposed AR-6 measure negatively affecting the recovery of Lost River and shortnose sucker populations in Upper Klamath Lake. Therefore, it was determined that additional actions in the form of an updated AR-6 are warranted.

The updated AR-6 plan, prepared by the KRRC and supported by the ATWG, includes two primary actions including reservoir and river sampling, and sucker salvage and release into appropriate waterbodies selected by fisheries managers. The proposed actions are anticipated to maximize the survival of Lost River and shortnose suckers currently inhabiting the Hydroelectric Reach. The number of translocated fish will not exceed 3,000 fish, which is the capacity of the currently identified recipient waterbody (Tule Lake). The salvage effort will likely translocate less than 10 percent of the sucker populations in the respective reservoirs.

Chapter 9: AR-7 Freshwater Mussels

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9. AR-7 FRESHWATER MUSSELS

The objective of AR-7 is to address reservoir drawdown and dam removal effects on freshwater mussels located in the Klamath River in the Hydroelectric Reach and downstream from Iron Gate Dam (RM 192.9). The 2012 EIS/R AR-7 measure focused conducting a freshwater mussel relocation pilot study followed by the salvage and relocation of freshwater mussels prior to reservoir drawdown. Salvaged mussels were to be held in a temporary location for later placement following reservoir drawdown, and placed in locations that would not be affected by the reservoir drawdown. Based on a review of the provided information herein, the KRRC and the ATWG concluded that a moderate scale freshwater mussel relocation effort is warranted. The updated AR-7 includes a freshwater mussel reconnaissance in 2018 followed by a limited freshwater mussel salvage in 2019 prior to reservoir drawdown. Freshwater mussels will be salvaged from the 8-mile long Iron Gate Dam (RM 192.9) to Cottonwood Creek (RM 184.9) reach, and translocated to the Klamath River between the upstream extent of J.C. Boyle Reservoir (RM 233.0) and Keno Dam (RM 238.2).

9.1 Proposed Updated AR-7

Based on a review of the original 2012 EIS/R AR-7 measure presented in Section 9.2, input from the ATWG, and current freshwater mussels literature, the KRRC concluded that an updated AR-7 is necessary to offset the anticipated short-term effects of dam decommissioning on freshwater mussels. The updated AR-7 includes a reconnaissance, salvage, and relocation of freshwater mussels from the 8-mile reach between Iron Gate Dam and the Cottonwood Creek confluence with the Klamath River. The monitoring and adaptive management plan has two specific actions.

- **Action 1:** A reconnaissance will be completed in 2018 to assess the distribution and density of freshwater mussels in the 8-mile long bedload deposition reach from Iron Gate Dam (RM 192.9) downstream to the Cottonwood Creek confluence (RM 184.9). The reconnaissance will confirm mussel beds identified in the 2007-2010 surveys and estimate abundance at a subset of the mussel beds in the reach.
- **Action 2:** Based on the reconnaissance, a portion of the freshwater mussels located between Iron Gate Dam and Cottonwood Creek will be salvaged and relocated to reduce dam decommissioning effects to the mussel community. Approximately 15,000 to 20,000 mussels are planned for translocation to appropriate habitats in the Klamath River between the upstream extent of J.C. Boyle Reservoir (RM 233.0) and Keno Dam (RM 238.2). The proposed number of translocated mussels is likely less than 10 percent of freshwater mussels in the mainstem Klamath River in the Hydroelectric Reach and downstream from Iron Gate Dam.

The proposed actions are intended to reduce Project effects on freshwater mussels located downstream from Iron Gate Dam. The following sections provide additional detail on the proposed actions.

9.1.1 Action 1: Freshwater Mussel Reconnaissance

The KRRC will prepare a reconnaissance plan to assess freshwater mussels in the Iron Gate Dam to Cottonwood Creek reach in 2018. Habitat conditions will also be evaluated from the upstream extent of J.C. Boyle Reservoir (RM 233.0) upstream to Keno Dam (RM 238.2) to determine the habitat capacity for translocated mussels. An existing freshwater mussel data set (base data for Davis et al. 2013), compiled by the Karuk Tribe, USFWS, and other collaborators from 2007 to 2010 for the Klamath River downstream from Iron Gate Dam, will be reviewed and used to plan the reconnaissance. The reconnaissance will confirm mussel beds identified in the 2007-2010 surveys and estimate abundance at a subset of the mussel beds locations. Habitat metrics in the potential translocation reach will be evaluated to maximize translocation success. The freshwater mussel reconnaissance and translocation reach habitat assessment are anticipated to take 5 days

9.1.2 Action 2: Freshwater Mussel Salvage and Relocation

The KRRC will coordinate and implement a freshwater mussel salvage plan with freshwater mussel specialists. Based on the reconnaissance, a portion of the freshwater mussels located between Iron Gate Dam and Cottonwood Creek will be salvaged and relocated to reduce dam decommissioning effects to the freshwater mussel community. The freshwater mussel salvage and translocation effort is anticipated to require 10 days. The percentage of the existing mussel beds that will be salvaged and translocated is predicated on the available habitat in the Klamath River from the upstream extent of J.C. Boyle Reservoir to Keno Dam, and the abundance of mussels between Iron Gate Dam and Cottonwood Creek. Approximately 15,000 to 20,000 mussels are planned for translocation. The proposed number of translocated mussels is likely less than 10 percent of freshwater mussels in the mainstem Klamath River in the Hydroelectric Reach and downstream from Iron Gate Dam.

9.2 Summary of the 2012 EIS/R AR-7, Dam Removal Benefits and Effects, and Recent Fisheries Literature

The following sections review the components of the 2012 EIS/R AR-7 measure, anticipated dam removal effects and benefits on freshwater mussels, and current freshwater mussel literature.

9.2.1 AR-7 Affected Species

Species identified in AR-7 include:

- Oregon floater *(Anodonta oregonensis)*
- California floater *(A. californiensis)*
- Western ridged mussel *(Gonidea angulata)*
- Western pearlshell mussel *(Margaritifera falcata)*

9.2.2 Anticipated Dam Decommissioning Effects on AR-7 Species

Short-term effects of dam removal (prolonged exposure to high suspended sediment levels and bedload movement) are predicted to be deleterious to freshwater mussels in the Hydroelectric Reach and in the lower Klamath River downstream from Iron Gate Dam (Reclamation and CDFG 2012). Substantial freshwater mussel population reductions are expected due to sediment effects and possibly low dissolved oxygen levels. The change in hydrological properties following dam removal may also disrupt the current distribution of freshwater mussels downstream from Iron Gate Dam (Davis et al. 2013). Table 9-1 includes the likely and worst-case effects on freshwater mussel species in the Klamath River.

Table 9-1 2012 EIS/R anticipated effects summary for freshwater mussels

Species	Life Stage	Likely Effects	Worst Effects
California Floater Oregon Floater Western Ridged Western Pearlshell	All	Substantial reduction in populations	Substantial reduction in populations
Source: USBR and CDFG 2012			

The following sections include descriptions of anticipated effects to freshwater mussels adapted from the 2012 EIS/R (Reclamation and CDFG 2012; Vol. 1, pp. 3.3-173 to 3.3-175) and augmented with information from other freshwater mussel studies.

Freshwater Mussels

Past studies evaluated Klamath River Basin freshwater mussel age structure, growth rates, and size distribution (*G. angulata*; Tennant 2010); population distribution and habitat use (Krall 2010; Davis et al. 2013; May and Pryor 2015); and habitat associations (Westover 2010; Davis et al. 2013). Klamath River mussels are long lived (from 10 to more than 100 years, depending on species) and may not reach sexual maturity until 4 years of age or more. *Anodonta* species are found primarily downstream from Iron Gate Dam, and likely benefit from the stable hydrology and fine sediment deposits attributed to hydroregulation below the dam (Davis et al. 2013). *G. angulata* is the most abundant freshwater mussel in the Klamath River and the species is widely distributed between Iron Gate Dam and the Trinity River (Westover 2010; Davis et al. 2013). *M. falcata* is the least abundant freshwater mussel found in the Klamath River and seems to be mostly found downstream from the confluence of the Salmon River (Westover 2010; Davis et al. 2013).

Freshwater mussel tolerance of high suspended sediment, low dissolved oxygen, and bedload deposition are not well understood. Vannote and Minshall (1982) evaluated freshwater mussels in an aggrading river system in Idaho and concluded that *G. angulata* appear to be better adapted for aggrading rivers based on siphon positions, shell morphology, and foot placement in the underlying substrate. *M. falcata* seemed to be less adapted for aggrading rivers due to a less developed siphon for filtering water. *M. falcata* also rarely burrow into substrate more than 25-40 percent of the valve length which may increase the mussel's susceptibility to scour (Vannote and Minshall 1982). *G. angulata* migrate vertically in the channel bed and are capable of maintaining position near the channel bed surface (Vannote and Minshall 1982). *M. falcata* are not known to migrate and are therefore more susceptible to sediment burial. *Anodonta* species are likewise susceptible to sediment scour and burial due to their thinner shells. Mussels that are dislodged from their normal vertical position and fall onto their sides may not regain the normal position and may perish (Vannote and Minshall 1982).

Mussels play important roles in aquatic ecosystems. Mussels influence water quality, nutrient cycling, and habitat and are also known as "ecosystem engineers" that actively modify their environment (Xerces Society 2009; Lopes-Lima et al. 2016; Lummer et al. 2016). They filter fine sediment and organic particles, create byproducts that are food items for macroinvertebrates, and comprise the greatest proportion of animal biomass in some waterbodies (Xerces Society 2009). In the Klamath River Basin, freshwater mussels filter and sequester toxins including toxigenic algae microsystins (Kann et al. 2010) and mercury (Bettaso and Goodman 2010). Filtration of waterborne toxins may result in bioaccumulation in freshwater mussels leading to human consumption risks (Bettaso and Goodman 2010; Kann et al. 2010).

The dam decommissioning project is anticipated to result in high suspended sediment levels and bedload deposition in the 8 miles of the Klamath River between Iron Gate Dam and Cottonwood Creek. Extremely poor water quality due to high suspended sediment concentrations is expected in the first 2 miles of the Klamath River downstream from Iron Gate Dam (Reclamation and CDFG 2012). Fine sediment effects on freshwater mussels include gill clogging, possible growth reduction, and impairment to mussel larval stages (Lummer et al. 2016). Due to both the anticipated deleterious high suspended sediment concentrations and low dissolved oxygen levels, freshwater mussels downstream from Iron Gate Dam may experience substantial mortality with the most significant impacts anticipated to mussels located immediately downstream from Iron Gate Dam.

Over the long-term, freshwater mussels are expected to benefit from the dam decommissioning through the conversion of Hydroelectric Reach reservoirs to gravel bed rivers which will restore freshwater mussel habitat, reduce water quality and water temperature impairments related to the reservoirs, and restore access for anadromous and resident host fish species that will distribute freshwater mussel larvae throughout the Klamath River upstream from Iron Gate Dam. However, due to the long time freshwater mussels take to reach sexual maturity, the recolonization and/or growth of existing freshwater mussel populations upstream of Iron Gate Dam may be slow and may not be readily noticeable for some time.

9.2.3 2012 EIS/R AR-7 Actions

The 2012 EIS/R AR-1 plan (Vol. I, pp. 3.3-248 to 3.3-249) directed the salvage of freshwater mussels from the Hydroelectric Reach and downstream from Iron Gate Dam. Salvaged mussels were to be relocated to suitable instream habitat unaffected by high suspended sediment concentrations, or could be placed in temporary facilities and returned to the Klamath River following the dam decommissioning project. A salvage and relocation pilot study was also suggested to assess salvage feasibility and relocated mussel survival. Based on the pilot study results, a detailed salvage and relocation plan was to be developed.

9.2.4 KRRC Review of AR-7 for Feasibility and Appropriateness

The KRRC assessed the feasibility and appropriateness of AR-7 through multiple planning meetings held with the ATWG between May and August 2017. During these meetings, current information on Klamath River fisheries was presented and information on other dam removal projects conducted in the western United States was reviewed to understand how the aquatic ecosystem might respond, as discussed above. Concerns voiced by the ATWG regarding the 2012 AR-7 included:

- Unfamiliarity with successful freshwater mussel relocation efforts.
- Disease transmission concerns.

The following sections provide additional information regarding AR-7 feasibility and appropriateness, based on fisheries literature and ATWG input.

Unfamiliarity with Successful Freshwater Mussel Relocation Efforts

The ATWG was unfamiliar with successful freshwater mussel translocation efforts. Anecdotal information discussed during the ATWG planning meeting (Yreka, CA, May 23, 2017) alluded to low translocation success for the Elwha Dam Removal Project and highway construction projects. Additional information was acquired by the KRRC on the Elwha Dam Removal Project freshwater mussel (*M. falcata*) translocation. Freshwater mussels were translocated to two sites and remained in one site prior to the dam removal project (P. Crain, U.S. Park Service, personal communication, 2017). The relocated freshwater mussels had high survival following the translocation and prior to the dam removals. Subsequent events that impacted the translocated mussels resulted in high mussel mortality. The events included raccoon predation due to shallow habitat at the first translocation site, and excessive sediment deposition at a side channel translocation site. The third monitored site was an artificial outfall channel from the water treatment facility that went dry due to inadvertent project operations. Mussels that remained in the Elwha River downstream from Elwha Dam are suspected to have experienced high mortality due to excessive sediment deposition following dam removal, followed by channel scour during the post-dam sediment sorting process.

Freshwater mussel translocation project monitoring results are not well represented in the fisheries literature. Unpublished freshwater mussel translocation monitoring manuscripts were reviewed to better understand the range of potential translocation success. Fernandez (2013) described the translocation success of 265 individual *M. falcata* in coastal southwest Washington. Between 55 percent and 95 percent of the transplanted *M. falcata* were accounted for in the translocation sites between one and three years following the translocation.

Seventeen percent of *G. angulata* translocated to a site downstream of a channel reconstruction project on the Upper Truckee River, were relocated three years after the translocation effort.

A review of translocation projects found mean mortality of relocated mussels was 49 percent based on an average recovery rate of 43 percent (Cope and Waller 1995). Cope and Waller (1995) found that survival of relocated mussels was generally poor and the factors influencing the survival of relocated mussels were poorly understood. For mussel relocation to be successful, more consideration must be given to habitat characterization at both the source and translocation sites. Olden et al. (2010) and Germano et al. (2015) offer considerations for successful freshwater organism and wildlife translocation efforts, respectively Luzier and Miller (2009) offer suggestions and considerations for freshwater mussel translocations.

Disease Transmission Concerns

The role of freshwater mussels in freshwater disease transmission is not well understood. Freshwater mussels are known to provide habitat for polychaete works, one of the hosts in the life *C. shasta*. Polychaetes have been infrequently collected from freshwater mussel shells in the Hydroelectric Reach of the Klamath River (PacifiCorp 2004). Mussels may serve as a vector for other fish pathogens like *Flavobacterium columnare* and *Ichthyophthirius multifiliis* that are endemic to the Klamath River Basin (K. Kwak, CDFW, personal communication 2017).

Freshwater mussels inhabit the Klamath River upstream from Iron Gate Dam (Byron and Tupen 2017) and in tributaries upstream (Byron and Tupen 2017) and downstream from Iron Gate Dam (Davis et al. 2013; Howard et al. 2015; May and Pryor 2015), disease transmission may be less of a concern.

9.3 AR-7 Summary

The Klamath River dam decommissioning project is anticipated to have significant short-term effects, but long-term benefits for freshwater mussels. The 2012 EIS/R AR-7 mitigation plan included a freshwater mussel salvage and relocation pilot study followed by an informed salvage and relocation plan prior to the dam decommissioning. The updated AR-7 measure includes completing a reconnaissance of existing freshwater mussels from Iron Gate Dam to Cottonwood Creek and potential relocation habitat between the upstream extent of J.C. Boyle Reservoir and Keno Dam. Freshwater mussels will be salvaged and relocated in 2019 prior to the reservoir drawdown. Approximately 15,000 to 20,000 mussels are planned for translocation. The proposed number of translocated mussels is likely less than 10 percent of freshwater mussels in the mainstem Klamath River in the Hydroelectric Reach and downstream from Iron Gate Dam.

Chapter 10: References

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