3.3 Aquatic Resources

This section describes existing conditions of aquatic resources in the Klamath Basin; analyzes potential impacts that the Proposed Project would have on these aquatic resources and the recovery of listed fish species; and includes measures to avoid or mitigate any significant adverse impacts to fish, aquatic mammals, freshwater mussels, and aquatic macroinvertebrates. Commercial fisheries are discussed in Section 5.3.1 *Regional Economic Impacts*, and potential impacts to recreational fisheries opportunities are in discussed Section 3.20 *Recreation*. The tribal significance of fisheries and potential impacts are discussed in Section 3.12 *Historical Resources and Tribal Cultural Resources*. Floating and attached algae are addressed in Section 3.4 *Phytoplankton and Periphyton*, and wetlands and riparian vegetation and wildlife species (including amphibians and reptiles) are addressed in Section 3.5 *Terrestrial Resources*.

The objectives of the Proposed Project include advancing the long-term restoration of the natural fish populations in the Klamath Basin through water quality improvements, habitat expansion, and a reduction in existing disease rates among salmonids (Section 2.1 *Project Objectives*). Many comments were received by the State Water Board during the public scoping process relating to aquatic resources (see Appendix A), and several of the comment topics were controversial. Some commenters expressed concern that the Proposed Project will not, or is not likely to, meet the stated objectives, or that the costs of implementation (financial and otherwise) are too great to justify the potential for gain. Numerous commenters asserted that hundreds of miles of habitat would become available to salmonids should the dams be removed, and many commenters asserted evidence of historical salmon migrations to Upper Klamath Lake. In contrast, a number of comments identified potential fish passage obstructions located within the portion of the mainstem Klamath River that is currently inundated by the Lower Klamath Project reservoirs. Many comments further stated the belief that coho salmon were not historically found in the Klamath Basin, while others stated that coho salmon were not found in the mid- or upper Klamath Basin due to natural passage barriers. Numerous comments described the fishery benefits that could result from dam removal, including increased habitat access and reduced fish disease, while other comments described the fishery benefits that could result from leaving the dams in place and using fish ladders to support passage and hatchery operations to offset habitat losses. Many public comments contended that the Lower Klamath Project dams are responsible for the reduction in salmon populations in the Klamath Basin, while a roughly equal number of comments indicated that other factors are responsible for the observed population declines, including predation by sea lions, tribal harvest, and fishing pressure from foreign fishing fleets. Comments were also received regarding the relationship between marine mammals, such as Southern Resident Killer Whales and sea lions, and the Chinook salmon fishery in the Klamath watershed, including comments that dam removal could benefit the mammals by increasing abundance of their prey. Additional summary of the aquatic resource comments received during the public scoping process, as well as the individual comments, are presented in Appendix A.

3.3.1 Area of Analysis

The Area of Analysis for aquatic resources considers the range of environments that could be affected by the Proposed Project. The Area of Analysis includes most portions of the Klamath Basin, excluding the Lost River watershed, and most of the Trinity River.

Although the Area of Analysis for aquatic resources includes much of the Upper Klamath Basin in Oregon, these areas are included only to the extent to which they affect California aquatic resources. As the lower 1/4 to 1/2 mile of the Trinity River could be used as a refuge by Klamath River fish attempting to avoid exposure to sediment pulses associated with dam removal, this portion of the Trinity River is also considered in the analysis as part of the Klamath Basin, the Area of Analysis includes the Klamath River Estuary and the nearshore portions of the Pacific Ocean.

This aquatic resources analysis includes an assessment of potential impacts within and across five study reaches of the Klamath River separated by changes in basin physiography (e.g., Upper and Lower Klamath basins), the presence of Lower Klamath Project facilities, and the degree of marine influence (Figure 3.3-1). The five study reaches within the Area of Analysis for aquatic resources are as follows:

1. Upper Klamath River and Connected Waterbodies
    a. Tributaries to Upper Klamath Lake (Sprague, Wood, and Williamson rivers)
    b. Upper Klamath Lake and Agency Lake
    c. Keno Impoundment/Lake Ewauna
    d. Upper Klamath River upstream of the influence of J.C. Boyle Reservoir to Keno Dam
    e. Tule Lake and Lost River between Anderson Rose Dam and Tule Lake
2. Upper Klamath River − Hydroelectric Reach
    a. J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate reservoirs
    b. J.C. Boyle Bypass and Peaking reaches
    c. Copco No. 2 Bypass Channel
    d. Tributaries to the Upper Klamath River (e.g., Jenny, Spencer, Shovel, and Fall creeks)
3. Middle and Lower Klamath River
    a. Middle Klamath River from Iron Gate Dam downstream to the confluence with Trinity River
    b. Major tributaries to the Middle Klamath River (e.g., Shasta, Scott, and Salmon Rivers)
    c. Minor tributaries to the Middle Klamath River (e.g., Bogus, Beaver, Humbug, and Cottonwood creeks)
    d. Lower Klamath River from the confluence with the Trinity River to the estuary
    e. Lower portion of the Trinity River
4. Klamath River Estuary
5. Pacific Ocean Nearshore Environment
    a. California portion of the Klamath River Management Zone (KMZ, Oregon-California state line south to Horse Mountain [40° 05’ 00” N. latitude])

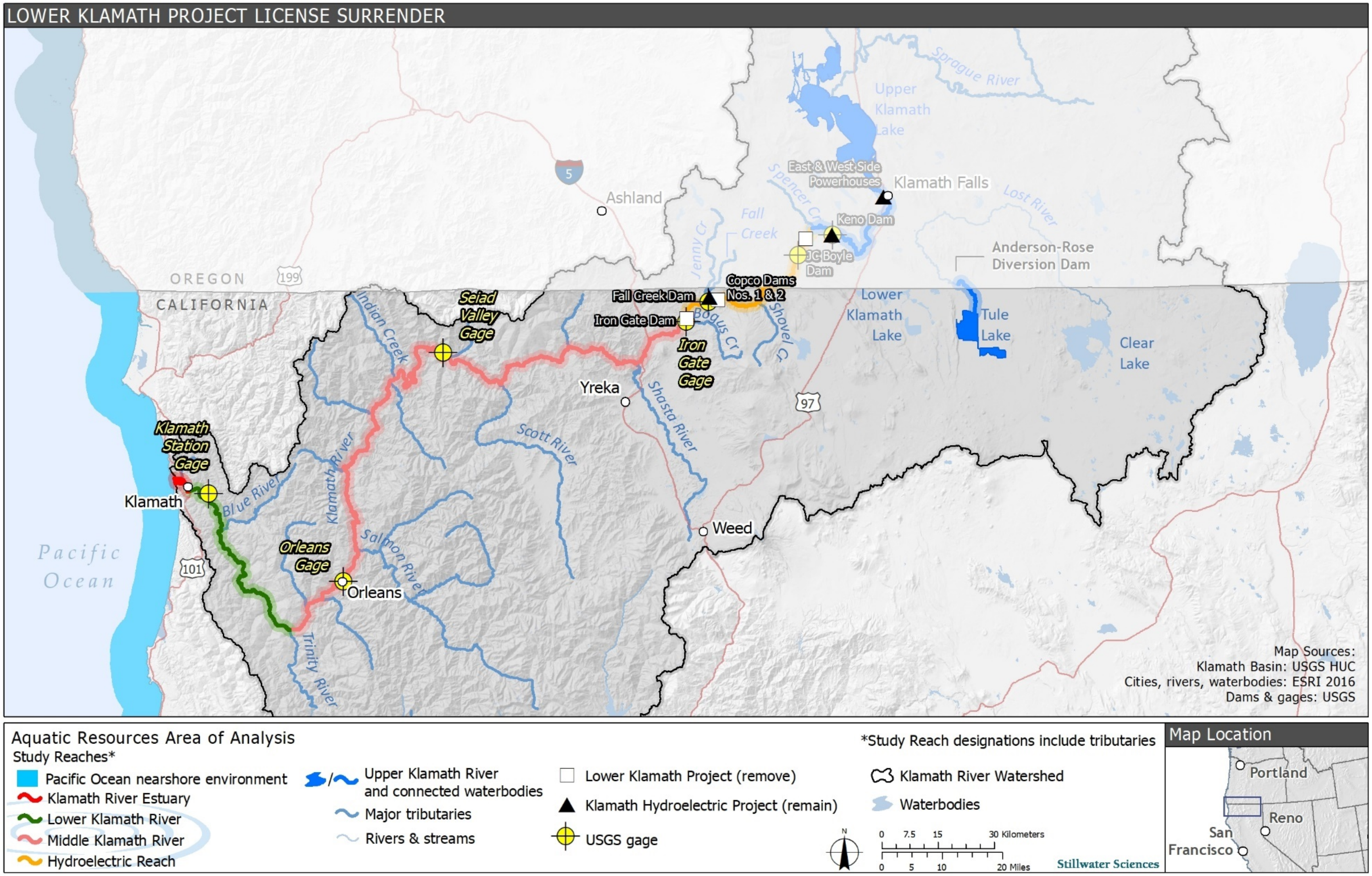


Figure 3.3-1. Study Reaches within the Area of Analysis for Aquatic Resources.

3.3.2 Environmental Setting

This section describes existing conditions in the Area of Analysis for aquatic resources, including discussion of aquatic species (Section 3.3.2.1 *Aquatic Species*); physical habitat in the waterbodies (Section 3.3.2.2 *Physical Habitat Descriptions*); and important factors affecting aquatic resources that the Proposed Project would influence, if implemented (Section 3.3.2.3 *Habitat Attributes Expected to be Affected by the Proposed Project*).

Each aquatic species description includes a brief summary of the current and historical distribution, life-history patterns, and habitat requirements. The narrative is subdivided into anadromous fish, resident riverine fish, non-native fish species, estuarine species, freshwater mollusks, benthic macroinvertebrates, and marine mammals.

The description of physical habitat contains a summary of water quality and other factors that may limit aquatic resource production in the waterbodies in the Area of Analysis, and it describes the species that occur in the California portion of these waterbodies. This section also describes designated critical habitat for species listed under the federal ESA and Essential Fish Habitat (EFH) managed under the Magnuson-Stevens Fishery Conservation and Management Act occurring within the California portion of the aquatic resources Area of Analysis.

Section 3.3.2.3 *Habitat Attributes Expected to be Affected by the Proposed Project* provides a more detailed description of existing conditions for factors that potentially could have a major influence on aquatic resources. These factors form the basis for Section 3.3.5 *[Aquatic Resources] Potential Impacts and Mitigation*.

3.3.2.1 Aquatic Species

Numerous aquatic species use the California portion of the Klamath Basin during some or all of their lives. The large number of species prohibits an individual evaluation of each species. Instead, the assessment of potential impacts and/or benefits of the Proposed Project within California on aquatic species is based on an analysis of target species that possess a legal status or importance for tribal, commercial, or recreational fisheries, and for which there are sufficient data to support the analysis. Appendix J: *Special-status Plant, Fish, and Wildlife Scoping Lists* Table J-1 includes a summary of all special-status aquatic fish documented in the Project vicinity. Special status species included in the analysis are summarized in Table 3.3-1, and all the target species (including others without special status) selected for analysis are discussed below.

Table 3.3-1. Special-status Aquatic Species Documented in the Vicinity of the Proposed Project and Included in Aquatic Resources Analysis.

Common Name *Scientific Name*	**Status[a] Federal/ State/Forest Service, Bureau of Land Management**	**Query Sources**	**Distribution**	**Habitat Association**
Fish				
Shortnose sucker *Chasmistes brevirostris*	FE/SE, SFP/-- Designated critical habitat	CNDDB USFWS	Resident fish observed in the Upper Klamath Basin. In California, they are found in the Klamath River downstream to Copco No. 1 Reservoir and Iron Gate Reservoir.	Warm slow-moving waters or lakes. Spawning occurs along shorelines of lakes or tributaries.
Lost River sucker *Deltistes luxatus*	FE/SE, SFP Designated critical habitat within Area of Analysis	CNDDB USFWS	Resident fish observed in the Upper Klamath Basin. In California, they are found in the Klamath River downstream to Copco No. 1 Reservoir and Iron Gate Reservoir.	Warm slow-moving waters or lakes. Spawning occurs along shorelines of lakes or tributaries.
Coho salmon, southern Oregon/northern California coasts ESU *Oncorhynchus kisutch*	FT/ST/-- Designated critical habitat within Area of Analysis	USFWS	Within the Area of Analysis anadromous fish occurring downstream in the mainstem Klamath River and tributaries downstream of Iron Gate Dam	Streams; spawns in gravel riffles
Chinook salmon - upper Klamath and Trinity Rivers ESU *Oncorhynchus tshawytscha*	--/SSC/FSS	CNDDB	Within the Area of Analysis anadromous fish occurring downstream in the mainstem Klamath River and tributaries downstream of Iron Gate Dam	Streams; spawns in gravel riffles
Coastal cutthroat trout *Oncorhynchus clarki*	--/SSC/FSS	CNDDB	Within the Area of Analysis coastal cutthroat trout are distributed primarily within smaller tributaries to the lower 22 miles of the Klamath River mainstem above the estuary, but also within tributaries to the Trinity River.	Shaded streams with water temperatures below 64.4˚F and small gravel for spawning
Summer-run steelhead trout *Oncorhynchus mykiss irideus*	--/SSC/--	CNDDB	Within the Area of Analysis anadromous fish distributed throughout the Klamath River and in its tributaries, downstream from Iron Gate Dam	Streams; spawns in gravel riffles
Longfin smelt *Spirinchus thaleichthys*	FC/ST, SSC/--	CNDDB	Within the Area of Analysis anadromous fish found in Klamath River Estuary	Adults in large bays, estuaries, and nearshore coastal areas; migrate into freshwater rivers to spawn; salinities of 15–30 ppt

Common Name ***Scientific Name***	**Status[a] Federal/ State/Forest Service, Bureau of Land Management**	**Query Sources**	**Distribution**	**Habitat Association**
Eulachon *Thaleichthys pacificus*	FT/--/-- Designated critical habitat within Area of Analysis	CNDDB	Within the Area of Analysis anadromous fish found in Klamath River Estuary	Adults in large bays, estuaries, and nearshore coastal areas; migrate into freshwater rivers to spawn.
Aquatic Mollusks				
Montane peaclam *Pisidium ultramontanum*	–/–/FSS	CNDDB	Within the Area of Analysis, they have been found in Upper and Lower Klamath Basin	Mollusk found in spring-influenced streams, lakes, and pools and strongly associated with sands or small clean gravels
Mammals				
Killer whale *Orcinus orca* Southern Resident DPS	FE/– Critical habitat (Designated)	NMFS	Pacific Ocean	Coastal habitats of temperate waters, including bays

[a] Status codes:

Federal
- FE = Listed as endangered under the federal Endangered Species Act
- FT = Listed as threatened under the federal Endangered Species Act
- FPE = Federally proposed as endangered
- FPT = Federally proposed as threatened
- FC = Federal candidate species
- FD = Federally delisted
- PD = Federally proposed for delisting
- BGEPA = Federally protected under the Bald and Golden Eagle Protection Act
- FSS = Forest Service Sensitive species
- BLMS = Bureau of Land Management Sensitive Species

State
- SE = Listed as Endangered under the California Endangered Species Act
- ST = Listed as Threatened under the California Endangered Species Act
- SCE = State Candidate Endangered
- SD = State Delisted
- SSC = CDFW Species of Special Concern
- SFP = CDFW Fully Protected species
- BOFS = Considered a sensitive species by the California Board of Forestry under the California Forest Practice Rules (14 CCR §895.1)

Fish

Numerous fish species use the California portion of the Klamath Basin during some portion or all of their lives. Native fishes found in riverine environments, some of which are listed under the federal or state ESAs, include salmonids, lamprey, sturgeon, suckers, minnows, dace, sculpin; and in the estuary, anchovy, gunnel, pipefish, eulachon, smelt, stickleback, and gobies occur. Species that have been introduced into the Klamath Basin include non-native yellow perch (*Perca flavescens*), largemouth bass (*Micropterus salmoides*), spotted bass (*Micropterus punctulatus*), sunfish (*Lepomis spp*), and catfish (*Siluriformes spp*).

Anadromous Fish Species

The Klamath Basin provides habitat for many species of anadromous fish – fish that migrate between salt and fresh water. Many Klamath River anadromous fish are salmonids, but there are also green sturgeon (*Acipenser medirostris*), Pacific lamprey (*Entosphenus tridentatus*), American shad (*Alosa sapidissima*) (discussed under *Non-native Fish Species* below), and eulachon (*Thaleichthys pacificus*) (discussed under *Estuarine Species* below). Additionally, CDFW operates the Iron Gate Hatchery directly downstream of Iron Gate Dam for salmonid production, as described in more detail in Section 3.3.2.3 *Habitat Attributes Expected to be Affected by the Proposed Project – Fish Hatcheries*.

Anadromous fish species within the Klamath Basin have nearly all declined compared to their historical abundance (Table 3.3-2). Although historical data are not available for green sturgeon, the population appears to be more stable than other fish species. Based on reports of green sturgeon captures in the Yurok Tribal Chinook salmon gill-net fishery, Van Eenennaam et al. (2006) conditionally suggests that the Klamath River green sturgeon population appears strong and stable but cautions against conclusions based on short time frames relative to the green sturgeon's long-life span.

Table 3.3-2. Historical and Recent Status of Klamath River Anadromous Fish.

Species	Historical Run Estimate[1]	Recent Run Size Estimate	Source
Pacific Lamprey			
Basin Wide	N/A	4,750–13,000[2]	Goodman and Reid 2012
Shasta River	N/A	250–1,000[2]	Goodman and Reid 2012
Scott River	N/A	250–1,000[2]	Goodman and Reid 2012
Salmon River	N/A	1,000–2,500[2]	Goodman and Reid 2012
Trinity River	N/A	2,000–5,000[2]	Goodman and Reid 2012
Steelhead			
Basin Wide	400,000[3]	Summer – 110,000[4] Winter – 20,000[4]	Historical (Leidy and Leidy 1984) Recent (Busby et al. 1994)
Scott River	N/A	146–419[5]	CDFW 2013
Trinity River (wild spawners)	N/A	2,454–9,205[6]	CDFW 2016a
Trinity River Hatchery[5]	N/A	4,460–46,379[6]	CDFW 2016a

Species	Historical Run Estimate[1]	Recent Run Size Estimate	Source
Iron Gate Hatchery	N/A	<100–631	CA HSRG 2012 CDFW 2018c
Coho Salmon			
Basin Wide	15,400–20,000	973 to 14,650[8]	Historical (Moyle et al. 1995) Recent (Ackerman et al. 2006)
Iron Gate Hatchery (spawners)	N/A	70–1,734[9]	CDFW 2015a
Bogus Creek (spawners)	N/A	6–409[5]	CDFW 2015a
Shasta River (spawners)	N/A	9–373[5]	CDFW 2015a
Scott River	N/A	63–1,622[5]	CDFW 2013
Trinity River (wild spawners)	N/A	645–4,457[6]	CDFW 2016a
Trinity River Hatchery[7]	N/A	3,805-18,454[6]	CDFW 2016a
Fall-Run Chinook Salmon			
Basin Wide	500,000	27,369–316,754[6,10]	Historical (Moyle 2002) Recent (CDFW 2017)
Bogus Creek (spawners)	N/A	2,353–12,930[6]	CDFW 2017
Salmon River (spawners)	N/A	1,432–5,493[6]	CDFW 2017
Scott River (spawners)	N/A	1,515–12,470[6]	CDFW 2017
Shasta River[9] (spawners)	20,000–80,000	1,348–29,544[6]	Historical (Moyle 2002) Recent (CDFW 2017)
Trinity River (wild spawners)	N/A	5,834–47,944[6]	CDFW 2016a, CDFW 2017
Trinity River Hatchery	N/A	4,531–32,875[6]	CDFW 2016a, CDFW 2017
Iron Gate Hatchery (spawners)	N/A	8,176–40,015[6]	CDFW 2017

Species	Historical Run Estimate[1]	Recent Run Size Estimate	Source
Spring-Run Chinook Salmon			
Basin Wide (Run size)	100,000	11,930–35,082[10,11]	Historical (Moyle 2002) Recent (CDFW 2015b)
Salmon River (spawners)	N/A	90–1,593[11]	CDFW 2015b
Trinity River (wild spawners)	N/A	5,382–22,727[11]	CDFW 2015b
Trinity River Hatchery (spawners)	N/A	2,578–6,990[11]	CDFW 2015b
Green Sturgeon			
Basin-wide	Unknown	Unknown[12]	Adams et al. 2007
Coastal cutthroat			
Basin-wide	Unknown	Unknown, but likely stable to increasing[13]	Moyle et al. 2017

N/A: Not available.
1 "Historical" is considered pre-1900's, unless otherwise noted.
2 Based on data from 2009–2012
3 Estimate from 1960. Anadromous fish numbers were already in decline in the early 1900s (Snyder 1931)
4 Based on data from 1977–1991
5 Based on data from 2007–2012
6 Based on data from 2006–2015
7 Trinity River Hatchery steelhead includes hatchery returns and hatchery origin fish that spawn in the wild
8 Based on data from 1999–2005
9 Based on data from 2004–2012
10 Run size includes hatchery returns
11 Based on data from 2005–2015
12 Klamath River has the largest spawning population in the ESU, but while harvest numbers are available, no populations estimates have been made.
13 Coastal cutthroat are present in lower Klamath tributaries, but no population numbers are available.

Anadromous Salmonids

Anadromous salmonids in the Klamath River include fall-run[76] and spring-run Chinook salmon (*Oncorhynchus tshawytscha*); coho salmon (*Oncorhynchus kisutch*); fall-, winter-, and summer-run steelhead (*Oncorhynchus mykiss*); and coastal cutthroat trout (*Oncorhynchus clarki clarki)*. Anadromous salmonids share similar life-history traits, but the timing of their upstream migrations, timing of outmigration[77], habitat preferences, and distributions differ. All anadromous salmonids spawn in gravel or cobble substrates that are relatively free of fine sediment with suitable surface and subsurface flow to carry oxygen to the eggs and carry metabolic waste away from the eggs. Once suitable spawning habitat is found, the adult female digs one or more nests (called redds) and deposits up to 3,000 eggs per redd (depending on species). The larger the female, the greater the number of eggs she produces. Her mate, or mates, will simultaneously

76 Run is a migration of salmon up a river from the sea.
77 Outmigration is the migration of juvenile salmonids from rivers downstream to the estuary and ocean.

fertilize the eggs and fend off other males and egg-eating predators. The female continues digging upstream of the nest, which forms a distinctive pit just upstream from and a protective mound of gravel and cobble over the eggs. The female will continue the mound-building process and defend her nest location. Most anadromous male and female salmonids die after completing spawning, although steelhead and coastal cutthroat may survive spawning, re-enter the ocean, and return to spawn the following year(s).

The salmonid eggs hatch several weeks or months after spawning, depending on species and water temperature. The resulting yolk-sac fry, also referred to as alevins, reside in the gravel for several more weeks and feed off their yolk sac until it is depleted. Egg-to-emergence survival is related to fine sediment infiltration, water temperature, and the fitness of the eggs. The fry that survive to emerge from the redds seek slow shallow areas near shoreline or vegetative cover, feed on benthic macroinvertebrates, gradually moving into deeper and faster water as they grow. Anadromous salmonids are generally considered "juveniles" when they have grown to a fork length of approximately 55 millimeters (about 2.2 inches)[78].

Juveniles feed opportunistically on macroinvertebrates, crustaceans, and smaller fish, and grow on their way downstream. Downstream migration is increased during spring rain events. As discussed in detail in subsequent sections, survival of fry and juvenile life stages is related to disease, parasites, food availability, predation risk, water temperature, and habitat availability (e.g., refuge from high flows). Within the Klamath River juvenile salmonids seek refuge from high flows and turbidity during winter in off-channel features such as side-channels and ponds, and during summer locate thermal refuge within cool water at the confluence with tributaries (in addition to thermal relief during nighttime cooling). Juvenile salmonids may also rear for some time in the estuary feeding prior to entering the ocean. Before entering brackish or salt water, juveniles must undergo a physiological process called smoltification, which is the series of physiological changes allowing juveniles to adapt from living in fresh water to living in seawater. After entering the ocean, smolts range up and down the coast as they grow to adulthood.

Most adult salmonids return to spawn in the stream where they were born, although some straying to nearby waterbodies does occur. Different salmon species and populations (and even the same populations from year to year) have highly variable straying rates, with hatchery origin spawners straying at a higher rate (Lasko et al. 2014). Straying may be the result of a multitude of factors, including as a response to environmental conditions or disturbance events, or exploration of new habitats for suitability. Survival of adults in the marine environment is related to fishing pressure, food availability, and predation risk (e.g., marine mammals). When adults return to natal streams upstream migration success is related to availability of adequate instream flows, turbidity, water temperature (for spring- and summer-runs), disease and parasites, fishing pressure, and passage obstacles (both natural and man-made). Between 1998 and 2008, smolt-to-adult-return-ratios (SAR) for coho at Iron Gate Hatchery ranged from 0.04 percent to 2.66 percent with an average of 0.99 percent (CDFW 2014). From 1988 to 2003, the SAR for fall Chinook released from the Trinity River hatchery ranged from 0.12 percent to 3.19 percent with an average of 1.61 percent (California HSRG 2012).

[78] Fork length is the length of a fish measured from the tip of the snout to the end of the middle caudal fin rays.

For Trinity River Spring Chinook, Yearling releases have averaged just over twice the survival of smolt releases (0.54 percent vs. 1.11 percent). The range of SARs for smolts was from 0.004 percent in 1989 to 2.27 percent in 1999. The SAR range for yearlings was from 0.08 percent in 1990 to 3.30 percent in 1999.

Specific details of life history and distribution are described in the following sections for each anadromous salmonid species.

Chinook Salmon

Two Chinook salmon Evolutionarily Significant Units (ESUs) currently occur in the Klamath Basin downstream of Iron Gate Dam—the Southern Oregon and Northern California Coastal ESU, which includes all naturally spawned Chinook salmon in the Lower Klamath River downstream from its confluence with the Trinity River, and the Upper Klamath and Trinity Rivers ESU, which includes all naturally spawned populations of Chinook salmon in the Klamath and Trinity rivers upstream of the confluence of the two rivers. A status review in 1999 determined that neither ESU warranted listing under the federal ESA (NMFS 1999a). The Upper Klamath and Trinity Rivers ESU is listed as a CDFW Species of Special Concern and a USDA Forest Service Sensitive Species.

Another petition to list Chinook salmon in the Upper Klamath and Trinity Rivers ESU under the ESA was submitted to NMFS in January 2011 (CBD et al. 2011). In the petition, NMFS was asked to consider one of three alternatives for the listing of Chinook salmon in the Upper Klamath and Trinity River ESU: (1) list spring-run only as a separate ESU, (2) list spring-run as a distinct population segment (DPS) within the Upper Klamath and Trinity River Chinook Salmon ESU, or (3) list the entire Chinook salmon Upper Klamath and Trinity River ESU including both spring-run and fall-run populations. In April 2011, NMFS announced that the petition contained substantial scientific information warranting federal review as to whether Chinook salmon within the Upper Klamath and Trinity River ESU should be listed as threatened or endangered. As a result, NMFS formed a Biological Review Team (BRT) to assess the biological status of the species and determine if listing under the ESA is necessary. The BRT (Williams et al. 2011) found that recent spawner abundance estimates of both fall-run and spring-run Chinook salmon returning to spawn in natural areas are generally low compared to historical estimates of abundance; however, the majority of populations have not declined in spawner abundance over the past 30 years (i.e., from the late 1970s and early 1980s to 2016) except for the Scott and Shasta rivers where there have been modest declines (Williams et al. 2011). In addition, Williams et al. (2011) found that hatchery returns did not track escapement[79] to natural spawning areas and they concluded that there has been little change in the abundance levels, trends in abundance, or population growth rates since the review conducted by Myers et al. (1998). The BRT also noted that recent abundance levels of some populations are low, especially in the context of historical abundance estimates. This was most evident with two of the three spring-run population units that were evaluated (Salmon River and South Fork Trinity River). The BRT concluded that although current levels of abundance are low when compared to historical estimates of abundance, the current abundance levels did not constitute a major risk in terms of ESU extinction.

[79] Escapement is the portion of a salmon population that does not get caught by commercial or recreational fisheries and returns to their freshwater spawning habitat or hatchery of origin.

The BRT also concluded that spring-run Chinook salmon did not warrant designation as a separate ESU or DPS within the Upper Klamath and Trinity River ESU. This finding was based in part on genetic evidence that indicates that spring-run and fall-run life histories have evolved on multiple occasions across different coastal watersheds located north and south of the Klamath River. Kinziger et al. (2008) found that there are four genetically distinct and geographically separated groups of Chinook salmon populations in the Upper Klamath and Trinity River basins; and that spring-run and fall-run Chinook salmon life histories have evolved independently, but in parallel, within both the Salmon and Trinity rivers. In addition, spring-run and fall-run populations in the Salmon River were nearly genetically indistinguishable and spring-run and fall-run populations in the South Fork Trinity River were extremely similar to each other and to Trinity River hatchery stocks. Williams et al. (2011) concluded that spring-run and fall-run Chinook salmon within the Upper Klamath and Trinity River basins are genetically similar to each other and that the two runs are not substantially reproductively isolated from each other. In addition, ocean type (ocean entry in early spring within a few months of emergence) and stream type (ocean entry during spring of their second year of life) life history strategies are exhibited by both run types, further suggesting that spring-run Chinook salmon in the Upper Klamath and Trinity River basins do not represent an important component in the evolutionary legacy of the species.

However, recently published research by Prince et al. (2017) questions the basis of treating the fall-run and spring-run Chinook salmon in the Upper Klamath and Trinity River ESU as a single ESU, which was based on overall genetic structure that is primarily defined by geography. The genomic results of Price et al. indicate that premature migration observed in spring-run Chinook salmon is defined by a single genetic variation, questioning the basis of conventional ESU designations which assume that genetic structure is primarily defined by geography.

In response to new information from Prince et al. (2017), and the overall decline of spring-run Chinook salmon, in November 2017, the Karuk Tribe and the Salmon River Watershed Council submitted a petition to NMFS to list as threatened or endangered the Upper Klamath and Trinity Rivers ESU or, alternatively, create a new ESU to describe Klamath spring-run Chinook salmon and list the new ESU as threatened or endangered under the ESA. In February 2018, NMFS announced a 90-day finding on this petition (NMFS 2018a). NMFS found that the petition presents substantial scientific information indicating the petitioned actions may be warranted. NMFS will conduct a status review of the Chinook salmon in the Upper Klamath and Trinity rivers to determine if the petitioned actions are warranted. No final decision has been published to date.

Regardless of the status of a determination on whether spring-run and fall-run Chinook salmon comprise a single ESU, these two runs have different life history strategies (NRC 2004), and therefore are considered distinct in this analysis. A more detailed discussion of the two run types is described below.

Fall-Run Chinook Salmon

Fall-run Chinook salmon are currently distributed throughout the Klamath River downstream from Iron Gate Dam. Upstream adult migration through the estuary and Lower Klamath River peaks in early September and continues through late October (Moyle 2002, FERC 2007, Strange 2008) (Table 3.3-3). Spawning peaks in late October and early November, and fry begin emerging from early February through early April (Stillwater Sciences 2009a), although timing may vary somewhat depending on temperatures in different years and tributaries. Table 3.3-3 provides a generalized life history periodicity for fall-run Chinook salmon life stages, with additional timing provided in Appendix E.3.1.1.

Table 3.3-3. Life-history Timing of Fall-run Chinook Salmon in the Klamath River Basin Downstream of Iron Gate Dam. Peak activity is indicated in black.

Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
All Types												
Incubation												
Emergence												
Adult migration												
Spawning												
Type I												
Rearing												
Juvenile outmigration												
Type II												
Rearing												
Juvenile outmigration												
Type III												
Rearing												
Juvenile outmigration												

Fall-run Chinook salmon in the Klamath Basin exhibit three juvenile life-history types: Type I (ocean entry at age 0[80] in early spring within a few months of emergence), Type II (ocean entry at age 0 in fall or early winter), and Type III (ocean entry at age 1 in spring) (Sullivan 1989) (Table 3.3-3). Based on outmigrant trapping at Big Bar on the Klamath River from 1997 to 2000, 63 percent of natural Chinook salmon outmigrants are Type I, 37 percent are Type II, and less than 1 percent are Type III (Scheiff et al. 2001). Although trapping efforts are not equal among seasons, the results are consistent with scale analysis of adult returns by Sullivan (1989).

Critical stressors on fall-run Chinook salmon in the basin include water quality and quantity in the mainstem and within spawning tributaries. Downstream from Iron Gate Dam, the mainstem Klamath River undergoes seasonal changes in flows, water temperature, dissolved oxygen, and nutrients, as well occasional blooms of *Microcystis aeruginosa* (a blue-green algae species that is potentially toxic to fish, as discussed in detail below and in Section 3.4 *Phytoplankton and Periphyton*). During outmigration, juvenile Chinook salmon are vulnerable to contracting disease from pathogens, including the bacterium *Flavobacterium columnare*, and myxozoan parasites *Parvicapsula minibicornis* and *Ceratomyxa shasta*.

Spring-Run Chinook Salmon

Spring-run Chinook salmon in the Klamath Basin are distributed mostly in the Salmon and Trinity rivers and in the mainstem Klamath River downstream from these tributaries during migratory periods, although a few fish are occasionally observed in other areas

[80] A fish emerging in spring is designated as age 0 until January 1st of the following year, when it is designated as age 1 until January 1st of the next year, when it is designated age 2.

(Stillwater Sciences 2009a). Based on data from 2005 to 2014 (CDFW 2015b), the Salmon River contributions to the overall escapement of spring-run Chinook salmon ranged from 1 to 12 percent of the total escapement, and from 1 to 20 percent of the natural escapement. To date, no spring-run Chinook salmon spawning has been observed in the mainstem Klamath River (Shaw et al. 1997). As described above, the BRT (Williams et al. 2011) concluded that while current abundance is low compared with historical abundance (Table 3.3-2), the Chinook salmon population (which includes hatchery fish) appears to have been fairly stable for the past 30 years. However, the BRT noted, as did Myers et al. (1998), that the recent spawner abundance levels of two of the three spring-run population components (Salmon River and South Fork Trinity River) are very low compared to historical abundance (less than 2,000 fish and 1,000 fish, respectively). The BRT was concerned about the relatively few populations of spring-run Chinook salmon and the low numbers of spawners within those populations (Williams et al. 2011).

The BRT (Williams et al. 2011) found the decline in spring-run salmon especially troubling given that historically the spring-run population may have been equal to, if not larger than the fall-run (Barnhart 1994). Huntington (2006) reasoned that spring-run Chinook salmon likely accounted for the majority of the Upper Klamath Basin's actual salmon production under historical conditions. Spring-run Chinook salmon spawned in the tributaries of the Upper Klamath Basin (Moyle 2002, Hamilton et al. 2005, Hamilton et al. 2016) with large numbers of spring-run Chinook salmon spawning in the basin upstream of Klamath Lake in the Williamson, Sprague, and Wood rivers (Snyder 1931). Large runs of spring-run Chinook salmon also historically returned to the Shasta, Scott, and Salmon rivers (Moyle et al. 1995). The runs in the Upper Klamath Basin are thought to have been in substantial decline by the early 1900s and were eliminated by the completion of Copco No. 1 Dam in 1917 (Snyder 1931). The cause of the decline of the Klamath River spring-run Chinook salmon prior to Copco No. 1 Dam has been attributed to dams, overfishing, irrigation, and largely to commercial hydraulic mining operations (Coots 1962, Snyder 1931). These large-scale mining operations occurred primarily in the late 1800's, and along with overfishing, left spring-run Chinook salmon little chance to recover prior to dam construction in the early 1900's. Dams (e.g., Link River Dam, Iron Gate Dam, Lewiston Dam, etc.) have eliminated access to much of the historical spring-run spawning and rearing habitat and are partly responsible for the extirpation of at least seven spring-run populations from the Klamath-Trinity River system (Myers et al. 1998). For example, the construction of Dwinnell Dam on the Shasta River in 1926 was soon followed by the disappearance of the spring-run Chinook salmon run in that tributary (Moyle et al. 1995).

Wild spring-run Chinook salmon from the Salmon River appear to primarily express a Type II life history, based on scale analyses of adults returning from 1990 to 1994 in the Salmon River (Olson 1996), as well as otolith analyses of Salmon River fry and adults (Sartori 2006). A small number of fish employ the Type III life history, although it does not appear to be nearly as prevalent as the Type II.

Spring-run Chinook salmon upstream migration is observed during two-time periods—spring (April through June) and summer (July through August) (Strange 2008) (Table 3.3-4). Snyder (1931) also describes a run of Chinook salmon occurring in the Klamath River during July and August under historical water quality and temperature conditions. Adults spawn from mid-September to late-October in the Salmon River and from September through early November in the South Fork Trinity River (Stillwater Sciences

2009a). Emergence begins in March and continues until early June (West et al. 1990). Age-0 juveniles rearing in the Salmon River emigrate at various times of the year, with one of the peaks of outmigration occurring in April through May (Olson 1996), which would be considered Type I life history. Based on outmigrant trapping from April to November in 1991 at three locations in the South Fork Salmon River, Olson (1996) reported that the greatest peak in outmigration of age-0 juveniles (69 percent) was in mid-October, which would be considered Type II life history. Sullivan (1989) reported that outmigration of Type II age-0 juveniles can occur as late in the year as early-winter. On the South Fork Trinity River outmigration occurs in late-April and May with a peak in May (Dean 1994, 1995), although it is not possible to differentiate between spring- and fall-run juveniles and so the spring-run may have different run timing. Age-1 juveniles (Type III) have been found to outmigrate from the South Fork Trinity River during the following spring (Dean 1994, 1995). Table 3.3-4 provides a generalized life history periodicity for spring-run Chinook salmon life stages, with additional timing provided in Appendix E.3.1.2.

Table 3.3-4. Life-history Timing of Spring-run Chinook Salmon in the Klamath River Basin Downstream of Iron Gate Dam. Peak Activity is Indicated in Black.

Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
All Types												
Incubation												
Emergence												
Adult migration in mainstem												
Adult entrance into tributaries												
Spawning												
Type I												
Rearing												
Juvenile outmigration												
Type II												
Rearing												
Juvenile outmigration												
Type III												
Rearing												
Juvenile outmigration												

It is unclear how much time outmigrating age-0 juveniles spend in the Klamath River mainstem and estuary before entering the ocean. Sartori (2006) did identify a period of increased growth (an estimated mean of 24 days) just prior to reaching an estuarine environment based on otolith analyses of returning adults to the Salmon River, but this period was never clearly linked to mainstem residence. From March to May, there were fair numbers of age-1 juvenile outmigrants captured in the Klamath River Estuary (Wallace 2004). Approximately half were identified to be hatchery age-1 juvenile fall-run Chinook salmon, and the rest were identified to be of natural origin, based on tag expansions.

Stressors on spring-run Chinook salmon related to water quality and quantity are similar to those for fall-run Chinook salmon in the mainstem Klamath River. Although water quality tends to improve in the mainstem downstream from the confluence with the Salmon River (the upstream-most spawning tributary), degradation of water quality (especially temperature and dissolved oxygen) can create critically stressful conditions for spring-run Chinook salmon adults and juveniles for much of the summer (June through September). Production in the Salmon River is primarily controlled by high water temperatures that reduce adult holding and summer rearing habitat in the mainstem Salmon River, while increased fine sediment input within the watershed reduces spawning and rearing habitat quality in some locations (Elder et al. 2002).

Coho Salmon

Coho salmon within the Klamath Basin are included within the Southern Oregon/Northern California Coast (SONCC) coho salmon ESU, which is listed as federally threatened (NMFS 1997a). SONCC coho salmon designated critical habitat includes the Klamath River downstream of Iron Gate Dam, including the estuary (NMFS 1999b). This ESU includes all naturally spawning populations between Punta Gorda, California and Cape Blanco, Oregon, which encompasses the Trinity and Klamath basins (NMFS 1997a). In addition, coho salmon in the Klamath Basin have been listed by the California Fish and Game Commission as threatened under the California Endangered Species Act (CESA) (CDFG 2002a). The Pacific Fishery Management Council (PFMC) considers potential impacts from fishing when setting retention limits each year. The annual coho salmon exploitation rate (proportion of a population that is caught during a year) averaged approximately 5 percent from 2000 to 2013. California waters were open to coho salmon fishing prior to 1998, but currently, coho salmon fishing in California is restricted to tribal harvest under federal reserved fishing rights in the Klamath River. California’s statewide prohibition of coho salmon fishing maintains consistently low impacts from freshwater recreational fisheries on SONCC coho salmon (NMFS 2014).

Coho salmon are native to the Klamath Basin. Williams et al. (2006) described nine historical coho salmon populations within the Klamath Basin: the Upper Klamath River, Shasta River, Scott River, Salmon River, Middle Klamath River, Lower Klamath River, and three population units within the Trinity River watershed (Upper Trinity River, Lower Trinity River, and South Fork Trinity River). Note that the designation of these population units varies from the Area of Analysis study reach designations used in this EIR.

Although coho salmon are native to the Klamath River, documentation of coho salmon in the Klamath River is scarce prior to the early 1900’s due, in part, to the apparent difficulty of those providing written records in recognizing that there were different species of salmon inhabiting the rivers of the area (Snyder 1931). Snyder (1931) reported that coho salmon were said to migrate to the headwaters of the Klamath River to spawn, but that most people did not distinguish them from other salmon species. Available data suggests that coho salmon were in both mainstem and tributary reaches of the Klamath River upstream to and including Spencer Creek at RM 232.6 (NRC 2004, as cited in NMFS 2007a, Hamilton et al. 2005). While noting that the evidence of historic presence between Fall and Spencer creeks was not conclusive, the 2006 Administrative Law Judge trial-type hearing under Section 241 of the Energy Policy Act of 2005 (NMFS 2006a) determined that coho salmon were abundant at Fall Creek, and that suitable habitat in the Hydroelectric Reach included Spencer, Fall, Beaver, Deer, Shovel, Scotch and Jenny creeks, as well as the main stem of the Klamath River itself.

The final SONCC Coho Salmon Recovery Plan was published on September 9, 2014 (NMFS 2014). Estimated extinction risk is designated as high for the Lower and Upper Klamath River populations, and moderate for the Middle Klamath River population. Estimated extinction risks of the Shasta, Scott, and Salmon river populations are designated as high, moderate, and high, respectively. Extinction risks for the Lower and Upper Trinity River populations are designated as high and moderate, respectively, while the South Fork Trinity River population is designated as high. Williams et al. (2006) describes population units to support recovery planning for the listed SONCC ESU. Analysis of coho salmon in this EIR considers impacts and benefits for each of the nine population units in the Klamath Basin separately but makes a significance determination for all population units combined within the Klamath Basin to be consistent with the approach to assessing other aquatic species populations.

The 2016 five-year status review of SONCC coho salmon (NMFS 2016a) indicated that the ESU's extinction risk has increased since the last status review in 2011. Drought conditions had persisted in four of the prior five years and were ongoing. These conditions are unprecedented in the time since SONCC coho salmon have been listed and were found likely to have resulted in reduced juvenile survival and stressful rearing conditions in nearly all parts of the ESU's range. Those juveniles that survived the freshwater conditions were also found likely to have faced poor ocean conditions, the results of which would only be apparent after these year classes return as adults.

Coho salmon are currently widely distributed in the Klamath River downstream from Iron Gate Dam (RM 193.1), which blocks the upstream migration of coho salmon to historically available habitat in the upper watershed. To minimize and mitigate for adverse effects to coho salmon, PacifiCorp prepared a Habitat Conservation Plan (HCP) for its interim operations of the Klamath Hydroelectric Project (PacifiCorp 2012). This HCP underlines the conservation strategy and measures that PacifiCorp will undertake to address anticipated effects on SONCC coho salmon and their habitat in the Klamath Basin. Per the HCP, PacifiCorp provides funding for the California Klamath Restoration Fund/Coho Enhancement Fund as an Interim Measure (IM2). Between 2009 and 2014, NMFS and CDFW selected 24 projects to benefit coho salmon (PacifiCorp 2014). These projects have been conducted at the mouths of 72 tributaries as well as in Seiad Creek, Scott River, Denny Ditch, Shasta River, Huseman Ditch, McBravey Creek, Fort Goff Creek Stanshaw Creek and Lower Hoopaw Creek. PacifiCorp has developed a partnership with the National Fish and Wildlife Foundation (NFWF) to administer the fund, and this allows grant recipients to apply for additional funding from other grant programs. A Technical Review Team was formed in 2012 and meets annually to review existing projects funded under the Coho Enhancement Fund and to recommend possible adaptive management changes.

Coho salmon use the mainstem Klamath River for some or all of their life history stages (spawning, rearing and migration). However, the majority of returning adult coho salmon spawn in the tributaries to the mainstem (Magneson and Gough 2006, NMFS 2010a).

Adult coho salmon in the Klamath Basin migrate upstream from September through late December, with migration peaking in October and November (Table 3.3-5). Spawning occurs mainly in November and December, with fry emerging from the gravel in the spring, three to four months after spawning, depending on water temperature (Trihey and Associates 1996, NRC 2004) (Table 3.3.-5). Table 3.3-4 provides a generalized life history periodicity for spring-run Chinook salmon life stages, with additional timing provided in Appendix E.3.1.2.

Table 3.3-5. Life-history Timing of Coho Salmon in the Klamath River Basin Downstream of Iron Gate Dam. Peak Activity is Indicated in Black.

Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Incubation												
Emergence												
Rearing												
Juvenile redistribution												
Juvenile outmigration												
Adult migration												
Spawning												

Some fry and age-0 juveniles enter the mainstem in the spring and summer following emergence (Chesney et al. 2009). Large numbers of age-0 juveniles from tributaries in the mid-Klamath River move into the mainstem in the fall (October through November) (Soto et al. 2008, Hillemeier et al. 2009). Juvenile coho salmon have been observed to move into off-channel ponds, non-natal tributaries to the Klamath River, downstream portions of the Lower Klamath River, and the estuary for overwintering (Soto et al. 2008, Hillemeier et al. 2009). Some proportion of juveniles generally remain in their natal tributaries to rear.

Age-1 coho salmon migrate downstream from tributaries into the mainstem Klamath River as smolts from February through mid-June with a peak in April and May, which often coincides with the descending limb of the spring hydrograph (NRC 2004, Chesney and Yokel 2003, Scheiff et al. 2001). Once in the mainstem, smolts appear to move downstream rather quickly; 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.

The major activities identified as responsible for the decline of SONCC coho salmon and degradation of their habitat include logging, road building, grazing, mining, urbanization, stream channelization, dams, wetland loss, beaver trapping, artificial propagation, overfishing, water withdrawals, and unscreened diversions for irrigation (NMFS 1997a). In 2007, NMFS published a Klamath River Coho Salmon Recovery Plan to comply with the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006. This level of recovery planning is not as intensive or thorough as the recovery planning process required under the ESA (which to date had not been completed). The 2007 plan includes the following actions identified as high priority for recovery:

- Restore access for coho salmon to the Upper Klamath Basin by providing passage upstream of existing mainstem dams.
- Fully implement the Trinity River Restoration Program.
- Provide incentives for private landowners and water users to cooperate in (1) restoring access to tributary streams that are important for coho spawning and rearing, and (2) enhancing mainstem and tributary flows to improve instream habitat conditions.

- Continue to improve the protective measures already in place to address forestry practices and road building/maintenance activities that compromise the quality of coho salmon habitat.
- Implement restorative measures identified through fish disease research results to improve the health of Klamath River coho salmon populations.

Many of the actions identified in the 2007 plan have been, or are in the process of being, addressed: the Proposed Project in this EIR would address restoration of access for coho salmon; the Trinity River Restoration Program is currently being implemented; and, many private landowners and water users are restoring coho access and habitat to stream reaches and they are addressing forestry practices that could harm fish. Fish disease issues are being researched and addressed, most recently in 2013 when the NMFS and USFWS issued a joint Biological Opinion (2013 BiOp; NMFS, and USFWS 2013) for the USBR's Klamath Irrigation Project operations, as described in detail in Section 3.1.6 *Summary of Available Hydrology Information for the Proposed Project*. While the 2013 BiOp is for operations upstream of the Lower Klamath Project, the conditions of the 2013 BiOp form an important part of the existing condition for coho salmon downstream of Iron Gate Dam, and, as discussed below, are intended to reduce coho disease rates. In this joint BiOp, NMFS consulted on coho salmon, while USFWS consulted on listed suckers (discussed below under *Lost River and Shortnose Suckers*).

In the 2013 BiOp, NMFS concluded that the effect of proposed USBR Klamath Irrigation Project operations on flows would result in habitat reductions for coho salmon juveniles in the mainstem Klamath River. To offset these negative effects, the 2013 BiOp includes flow release requirements to reduce disease incidence for coho salmon in the Klamath River downstream of Iron Gate Dam. The formulaic approach to flow releases designed to benefit coho salmon, as described in the 2013 BiOp, prioritizes a volume of water set-aside in an Environmental Water Account (EWA) for releases in the spring, and minimum daily flow targets in April through June to meet Hardy et al. (2006) recommended ecological base flows (discussed further in Section 3.3.2.3 *Habitat Attributes Expected to be Affected by the Proposed Project*). The 2013 BiOp found that Klamath Irrigation Project operations were not likely to diminish habitat for coho salmon fry and juveniles in the Upper Klamath, Middle Klamath, Shasta, and Scott river populations to an extent that would reduce life history diversity.

In their 2013 BiOp analysis of the Klamath Irrigation Project operations, NMFS concluded that the proposed flow releases would result in coho salmon disease risks that are lower than observed period of record conditions, yet higher than under natural flow conditions (NMFS and USFWS 2013). Of all the adverse effects of the proposed Klamath Irrigation Project operations, NMFS concluded that risk of fish disease due to the myxozoan parasite *Ceratomyxa shasta* (*C. shasta*) is the most significant for coho salmon, since *C. shasta* is a key factor limiting salmon recovery in the Klamath River (e.g., Foott et al. 2009). The adaptive management element of the USBR's Klamath Irrigation Project proposed operations was intended to minimize disease risks to coho salmon during average to below average water years if EWA surplus volume is available. Lastly, NMFS concluded that the proposed minimum daily flows below Iron Gate Dam in April to June would limit the increase in disease risks posed to coho salmon from Klamath Irrigation Project operations. The Klamath Irrigation Project directs flow requirements in the Klamath River below Iron Gate Dam by releases from the Lower Klamath Project's Iron Gate Dam consistent with the 2013 BiOp issued on the Klamath

Irrigation Project. By lowering the disease risk, NMFS asserted that coho salmon abundance would likely improve over the next ten years for the Upper Klamath, Middle Klamath, Shasta, and Scott river populations.

However, the first years of 2013 BiOp implementation included severe drought conditions, and although the USBR was operating the Klamath Irrigation Project in accordance with the 2013 BiOp, the infection rate for *C. shasta* in the Klamath River downstream of Iron Gate Dam greatly exceeded the incidental take maximum (U.S. District Court 2017a). As described in Section 3.1.6 *Summary of Available Hydrology Information for the Proposed Project*, this led to a court order requiring USBR to implement three specific flows in the Klamath River, as measured immediately downstream of Iron Gate Dam: annual winter-spring surface flushing flows, biennial winter-spring deep flushing flows, and spring-summer emergency dilution flows (U.S. District Court 2017a–c). The court also required that USBR re-initiate consultation with NMFS and the USFWS regarding the effects of the Klamath Irrigation Project operations on coho salmon in the Klamath River and Lost River and shortnose suckers in the Upper Klamath Basin (U.S. District Court 2017a–c). The court-ordered flushing flows and emergency dilution flows are not part of existing conditions for the Proposed Project, because they went into effect after the Notice of Preparation was filed by the State Water Board in December 2016, and because the data evaluating the effectiveness of the flows and their potential impacts is not yet robust. The flushing and emergency dilution flows are detailed in Section 4.2.1.1 *[Alternative Description] Summary of Available Hydrology Information for the No Project Alternative* as part of the No Project Alternative because they would likely only apply if Iron Gate Dam were to remain in place or the disease nidus remains. These flows are also discussed in Section 4.4 *Continued Operations with Fish Passage Alternative*.

<u>Steelhead</u>

Steelhead are highly adaptive salmonids, with multiple life histories (Hodge et al. 2016). Klamath Basin summer steelhead and winter steelhead populations both belong to the Klamath Mountain Province ESU, which is not listed under the ESA. The NMFS (2001) status review found that this ESU was not in danger of extinction or likely to become so in the foreseeable future, based on estimated populations for the ESU and lower estimates of genetic risk from naturally spawning hatchery fish than estimated in previous reviews, and consideration of existing conservation efforts that are benefiting steelhead in the ESU.

Summer Steelhead

The Klamath Mountain Province ESU of summer steelhead is a CDFW Species of Special Concern and is distributed throughout the Klamath River downstream from Iron Gate Dam and in its tributaries. This species historically used habitat upstream of Upper Klamath Lake prior to the construction of Copco No. 1 Dam (Hamilton et al. 2005). However, some populations such as the Salmon River summer steelhead have declined significantly in the past several decades (Quiñones et al. 2013), and in general summer steelhead populations in the ESU are currently in low abundance (Moyle et al. 2017). Based on available escapement data from summer direct observation surveys, approximately 55 percent of summer steelhead spawn in the Trinity River and other lower-elevation tributaries (CDFW and USDA Forest Service 2002, unpubl. data). Most remaining summer steelhead are believed to spawn in tributaries between the Trinity River (RM 43.3) and Seiad Creek (RM 132.7), with high water temperatures limiting their use of tributaries to the Klamath River farther upstream (NRC 2004). Adult summer steelhead use the mainstem Klamath River primarily as a migration corridor to access holding and spawning habitat in tributaries.

Summer steelhead adults enter and migrate up the Klamath River from March through June while sexually immature (Hopelain 1998), then hold in cooler tributary habitat until spawning begins in December (USFWS 1998) (Table 3.3-6). Forty to 64 percent of summer steelhead in the Klamath River exhibit repeat spawning, with adults observed to migrate downstream to the ocean after spawning (also known as “runbacks”) (Hopelain 1998). Summer steelhead in the basin also have a “half-pounder” life-history pattern, in which an immature fish emigrates to the ocean in the spring, returns to the river in the fall, spends the winter in the river, then emigrates to the ocean again the following spring (Busby et al. 1994, Moyle 2002). Table 3.3-6 provides a generalized life history periodicity for summer steelhead life stages, with additional timing provided in Appendix E.3.1.4.

Table 3.3-6. Life-history Timing of Summer Steelhead in the Klamath River Basin Downstream of Iron Gate Dam. Peak Life-history Periods are Shown in Black.

Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Incubation												
Emergence												
Rearing												
Juvenile outmigration												
Half-pounder residence												
Adult migration in mainstem												
Adult holding in tributaries												
Spawning												
Run-backs												

Juvenile summer steelhead in the Klamath Basin may rear in freshwater for up to three years before outmigrating. Although many juveniles migrate downstream at age-1 (Scheiff et al. 2001), those that outmigrate to the ocean at age 2 appear to have the highest survival (Hopelain 1998). Juveniles outmigrating from tributaries at age-0 and age-1 may rear in the mainstem or in non-natal[81] tributaries (particularly during periods of poor water quality) for one or more years before reaching an appropriate size for smolting. Age-0 juvenile steelhead have been observed migrating upstream into tributaries, off-channel ponds, and other winter refuge habitat in the Lower Klamath River (Stillwater Sciences 2010). Juvenile outmigration occurs primarily during spring. Smolts are captured in the mainstem and estuary throughout the fall and winter (Wallace 2004), but peak smolt outmigration normally occurs from April through June, based on estuary captures (Wallace 2004). Temperatures in the mainstem are generally suitable for juvenile steelhead, except during periods of the summer, especially upstream of Seiad Valley (for more species information see USFWS 1998, Moyle 2002, NRC 2004, and Stillwater Sciences 2009a). Critical limiting factors for summer steelhead include degraded habitats, passage impediments, predation, and competition (Moyle et al. 2008).

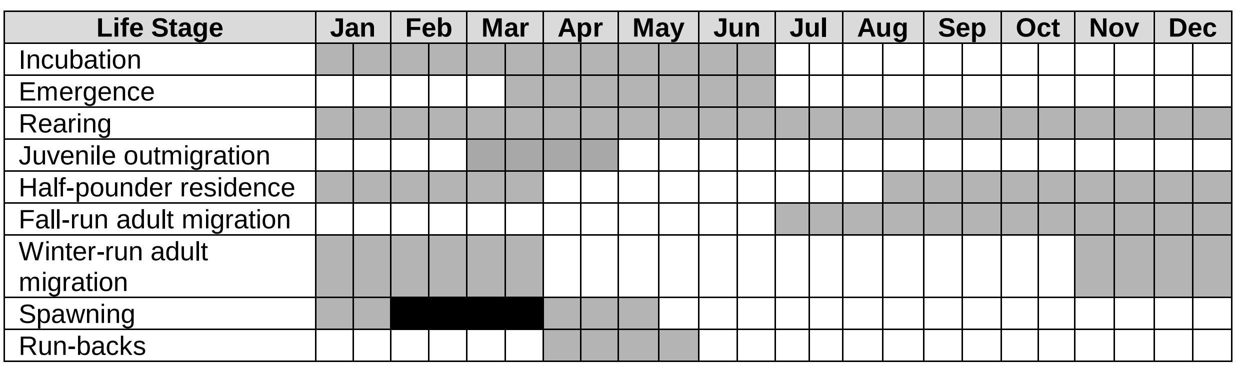
Winter Steelhead

[81] Tributary other than the one in which it was born.

Moyle (2002) describes steelhead in the Klamath Basin as having a summer- and winter-run. Some divide the winter-run into fall and winter-runs (Barnhart 1994, Hopelain 1998, USFWS 1998, Papa et al. 2007). In this section, “winter steelhead” refers to both fall- and winter-runs except in cases when the distinction is pertinent to the discussion, and wherever data was sufficient to analyze them separately.

Winter steelhead are widely distributed throughout the Klamath River and its tributaries downstream from Iron Gate Dam, and historically used habitat upstream of Upper Klamath Lake (Hamilton et al. 2005). Butler et al. (2010) found that 93 percent of the 41 *Oncorhynchus mykiss* specimens excavated from archeological sites above Upper Klamath Lake were anadromous (indicating occurrence of steelhead historically upstream of Upper Klamath Lake). Winter steelhead adults generally enter the Klamath River from July through October (fall-run) and from November through March (winter-run) (USFWS 1998, Stillwater Sciences 2010). They spawn mainly in tributaries throughout the Klamath River Basin downstream of Iron Gate Dam, and occasionally within the mainstem (NRC 2004). Winter steelhead migrate upstream primarily from January through April (USFWS 1998), with peak spawn timing in February and March (ranging from January to April) (NRC 2004) (Table 3.3-7). Adults may repeat spawning in subsequent years after returning to the ocean in the spring following spawning. Immature ”half-pounders” return after a short (<1 year) ocean residence each year in September through March and typically use the mainstem Klamath River to feed until returning to the ocean (NRC 2004), although they also use larger tributaries such as the Trinity River (Dean 1994, 1995). Table 3.3-7 provides a generalized life history periodicity for spring-run Chinook salmon life stages, with additional timing provided in Appendix E.3.1.4.

Table 3.3-7. Life-history Timing of Fall-and Winter-run Steelhead and Rainbow Trout in the Klamath River Basin Downstream of Iron Gate Dam. Peak Life-history Periods are Shown in Black.



Fry emerge in spring (NRC 2004), with fry observed in outmigrant traps in Bogus Creek and Shasta River from March through mid-June (Dean 1994). Age-0 and age-1 juveniles have been captured in outmigrant traps in spring and summer in tributaries to the Klamath River upstream of Seiad Creek (CDFG 1990a, b). These fish are likely rearing in the mainstem or non-natal tributaries before outmigrating to the ocean as age-2 outmigrants.

Juvenile outmigration appears to primarily occur between May and September with peaks between April and June, although smolts are captured in the estuary as early as

March and as late as October (Wallace 2004). Most adult returns originate from fish that smolt at age-2, representing 86 percent of adult returns; in comparison with only 10 percent for age-1 juveniles and 4 percent for age 3+ juveniles (Hopelain 1998).

Similar limiting factors listed for summer steelhead also affect winter steelhead populations, including degraded habitats, decreased habitat access, fish passage, predation, and competition (for more species information see USFWS 1998, NRC 2004, Wallace 2004, and Stillwater Sciences 2009a).

Coastal Cutthroat Trout

Klamath River coastal cutthroat trout belong to the Southern Oregon/California Coasts ESU. Coastal cutthroat trout within the Area of Analysis for aquatic resources is listed as a CDFW Species of Special Concern and a USDA Forest Service Sensitive Species. In a 1999 status review, NMFS determined that the Southern Oregon/California Coasts ESU did not warrant ESA listing (Johnson et al. 1999). Coastal cutthroat trout are distributed primarily within smaller tributaries to the 22 miles of the Klamath River mainstem upstream of the estuary (NRC 2004), but also within tributaries to the Trinity River (Moyle et al. 1995).

Coastal cutthroat trout have not been extensively studied in the Klamath Basin, but it has been noted that their life history is similar to fall- and winter-run steelhead in the Klamath River (NRC 2004). Both resident and anadromous life histories are observed in coastal cutthroat trout in the Klamath Basin. Anadromous adults enter the river to spawn in the fall. Moyle (2002) noted that upstream migration in northern California spawning streams tends to occur from August to October after the first substantial rain. Generally, spawning of anadromous and resident coastal cutthroat trout may occur from September to April (Moyle 2002). “Sea-run” adults spend some time in the ocean without fully adopting a fixed anadromous life history may either return to rivers in summer to feed or return in September or October to spawn and/or possibly overwinter (NRC 2004). Cutthroat with a resident life history remain in freshwater for their entire lives and may use mainstem and/or tributary habitats.

Juvenile coastal cutthroat trout may spend anywhere from one to three years in freshwater to rear. Anadromous or sea-run juveniles outmigrate during April through June, at the same time as Chinook salmon juvenile downstream migration (Moyle 2002, NRC 2004). These juveniles also appear to spend at least some time rearing in the estuary. Wallace (2004) found that estuary residence time ranged from 5 to 89 days, with a mean of 27 days, based on a mark-recapture study.

Pacific Lamprey

Pacific lamprey are the only anadromous lamprey species in the Klamath Basin. Pacific lamprey, along with three other lamprey species found in California, Oregon, Washington and Idaho, were petitioned for ESA listing in 2003 (Nawa 2003). Although the USFWS halted species status review in December 2004 due to inadequate information (USFWS 2004), efforts to resume the review Pacific lamprey are anticipated as more information is obtained. Although no historical abundance data are available, recent estimates are that there are annual runs of over 4,000 Pacific lamprey in the Klamath Basin (Goodman and Reid 2012, Table 3.3-2).

Pacific lamprey are found in Pacific Ocean coast streams from Alaska to Baja California. They occur throughout the mainstem Klamath River downstream from Iron Gate Dam and its major tributaries including: Trinity, Salmon, Shasta, and Scott River basins (Stillwater Sciences 2009a). Although the evidence is inconclusive as to whether Pacific lamprey were historically present upstream of Iron Gate Dam, the record of evidence shows that access to habitat would benefit Pacific lamprey by providing additional spawning and rearing grounds (NMFS 2006a). Pacific lamprey are capable of migrating long distances and show similar distributions to anadromous salmon and steelhead (Hamilton et al. 2005).

Pacific lamprey are anadromous nest builders that die shortly after spawning. They enter the Klamath River on their own volition during all months of the year, with peak upstream migration occurring from December through June (Stillwater Sciences 2009a) (Table 3.3-8, life history timing detailed in Appendix E.3.1.5). As adults, Pacific lamprey do not feed in freshwater. Spawning occurs at the upstream edge of riffles in sandy gravel from mid-March through mid-June (Stillwater Sciences 2009a). After lamprey eggs hatch, the larvae (ammocoetes) drift downstream to backwater areas and burrow into the substrate, feeding on algae and detritus (FERC 2007). Based on observations and available habitat, most ammocoete rearing likely occurs in the Salmon, Scott, and Trinity rivers, as well as throughout the mainstem Klamath River from Iron Gate downstream to the estuary (FERC 2007). The Klamath River upstream of the Shasta River appears to have less available spawning and rearing habitat, and Pacific lamprey are not regularly observed there (FERC 2007). Juveniles remain in freshwater for five to seven years (with slower growing individuals leaving at older ages) before they migrate to the ocean and transform into adults (Moyle 2002). Pacific lamprey spend one to three years in the marine environment (with no documented cause of variability in marine residency), where they parasitize a wide variety of ocean fishes, including Pacific salmon, flatfish, rockfish, and pollock (Close et al. 2010). For more species information see Close et al. (2010), Stillwater Sciences (2009a), and PacifiCorp (2004a).

Table 3.3-8. Life-history Timing of Pacific Lamprey in the Klamath River Basin Downstream of Iron Gate Dam. Peak Activity is Indicated in Black.

Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Incubation												
Rearing												
Juvenile outmigration												
Adult migration												
Spawning												

Major factors believed to be affecting their populations include barriers to upstream migration at dams, dewatering of larval habitat through flow regulation, stranding due to rapid downramping, reduced larval habitat by increasing water velocity and/or reducing sediment deposition areas when sediment is trapped at dams, and mortality due to exposure to contaminants in the larval stage (Close et al. 2002, as cited in Hamilton et al. 2011).

<u>Green Sturgeon</u>
Green sturgeon are an anadromous species that occurs in coastal marine waters from Mexico to the Bering Sea. NMFS has identified two DPSs: (1) the Northern Green Sturgeon DPS, which is not listed as threatened or endangered but is on NMFS' Species of Concern list and which includes populations spawning in coastal watersheds from the

Eel River north, and (2) the Southern Green Sturgeon DPS, listed as threatened under the federal ESA and encompassing coastal or Central Valley populations spawning in watersheds south of the Eel River (NMFS 2006b). Although the Southern Green Sturgeon DPS is considered a separate population from the Northern Green Sturgeon DPS based on genetic data and spawning locations, their ranges outside of the spawning season tend to overlap (CDFG 2002b, Israel et al. 2004, Moser and Lindley 2007). The Klamath Basin may support most of the spawning population of Northern Green Sturgeon DPS (Adams et al. 2002). Although Southern Green Sturgeon DPS may enter other west coast estuaries to feed in the summer and fall, there has been no documentation of them entering the Klamath River or its estuary (USBR 2010). No Northern Green Sturgeon DPS tagged by the Yurok Tribe within the Klamath River have ever been detected in the range of Southern Green Sturgeon DPS (primarily San Francisco Bay) despite the presence of numerous receivers that would have detected tagged Klamath River fish if they had ventured there (McCovey 2011a). No Southern Green Sturgeon DPS tagged in the Sacramento/San Joaquin and/or San Francisco Bay region have ever been detected in the Klamath River. Southern Green Sturgeon DPS have been detected immediately offshore of the Klamath River, but have not been detected in the Klamath River Estuary or mainstem despite the presence of functioning acoustic receivers in the Klamath River Estuary (McCovey 2011a). Based on the available evidence it appears unlikely that sturgeon from the Southern Green Sturgeon DPS currently occur within the Klamath River or nearshore environment. Therefore, the rest of this section pertains only to the Northern Green Sturgeon DPS.

Northern Green Sturgeon DPS in the Klamath River sampled during their spawning migration ranged in age from 16 to 40 years (Van Eenennaam et al. 2006). It is believed that in general green sturgeon have a life span of at least 50 years, and spawn every four years on average after around age-16, for approximately eight spawning efforts in a lifetime (Klimley et al 2007). Green sturgeon enter the Klamath River to spawn from March through July (Table 3.3-9). Green sturgeon spawn primarily in the lower 67 miles of the mainstem Klamath River (downstream from Ishi Pishi Falls, directly upstream of the confluence with the Salmon River), in the Trinity River, and occasionally in the lower Salmon River (KRBFTF 1991, Adams et al. 2002, Benson et al. 2007). Most green sturgeon spawning occurs from the middle of April to the middle of June (NRC 2004). After spawning, approximately 25 percent of green sturgeon migrate directly back to the ocean (Benson et al. 2007), and the remainder hold in mainstem pools in the Klamath River between RM 13 and RM 66.3 through November prior to migrating downstream to the ocean. Table 3.3-9 illustrates the periodicity of green sturgeon in the Klamath River. Additional timing detail is provided in Appendix E.3.1.6.

Table 3.3-9. Life-history Timing of Green Sturgeon in the Klamath River Basin Downstream of Iron Gate Dam. Peak Activity is Indicated in Black.

Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Incubation/emergence												
Rearing												
Juvenile outmigration												
Adult migration												
Spawning												
Post-spawning adult holding												

During the onset of fall rainstorms and increased river flow, adult sturgeon move downstream and leave the river system (Benson et al. 2007). Juvenile green sturgeon may rear for one to three years in the Klamath River Basin before they migrate to the estuary and ocean (NRC 2004, FERC 2007, CALFED 2007), usually during summer and fall (Emmett et al. 1991, as cited in CALFED 2007, CH2M Hill 1985, Hardy and Addley 2001).

Adult green sturgeon that have held over the summer in the Klamath River after spawning appear to migrate downstream to the ocean in conjunction with increases in discharge in the fall. Attenuation of high flows downstream from Iron Gate Dam as a result of USBR Klamath Irrigation Project operations may affect a key environmental cue used to stimulate the fall outmigration of adult green sturgeon that have remained in holding pools over the summer (Benson et al. 2007). Historically Klamath River below Iron Gate Dam was relatively responsive to discharge increases related to rainfall events, and the timing of peak flows changed significantly following implementation of USBR Klamath Irrigation Project operations on the Klamath River (Balance Hydrologics, Inc. 1996). When compared to pre- Klamath Irrigation Project operations, existing flows in October are higher and flows in late spring and summer are lower (Balance Hydrologics, Inc. 1996).

Resident Riverine Fish Species

Rainbow and Redband Trout

Rainbow trout exhibit a wide range of life-history strategies, including anadromous forms (steelhead, described above) and resident forms, described here. The Klamath Basin has two subspecies of rainbow trout. Behnke (1992) identifies the inland form as the Upper Klamath redband trout, *Oncorhynchus mykiss newberrii*, but considers steelhead and resident rainbow trout downstream from Upper Klamath Lake to be primarily coastal rainbow trout, *Oncorhynchus mykiss irideus*. Since construction of Copco No. 1 Dam and Iron Gate Dam, resident trout upstream of Iron Gate Dam are considered redband trout, and resident trout downstream from Iron Gate Dam are considered coastal rainbow trout (FERC 2007). Coastal rainbow trout are widely distributed downstream of Iron Gate Dam, including occasionally within the mainstem Klamath River, and predominately within every major tributary and most smaller tributaries with perennial flow as well. Their habitat requirements, sensitivities to disease and water quality are the same as those described above for steelhead. Rainbow trout are distinguished from steelhead by a life history that is limited to freshwater. Juveniles rear in mainstem and tributary habitat from two to three years before reaching sexual maturity (with faster growing individuals maturing sooner), and adults spawn in tributaries.

Behnke (2002) indicates that two distinct groups of redband trout may be in the Upper Klamath Basin: one that is adapted to lakes and another that is adapted to streams. These fish are a popular recreational fishery. The Upper Klamath Basin supports the largest and most functional adfluvial[82] redband trout population of Oregon's interior basins (Hamilton et al. 2011). In the Hydroelectric Reach, most redband trout spawning is thought to occur in Spencer and Shovel creeks. Redband trout need to migrate among habitats, mainstem, tributaries, and reservoirs to meet their life-history requirements. Redband trout are considered resistant to *C. shasta* or other diseases potentially brought upstream by anadromous fishes (Hamilton et al. 2011).

For more information on rainbow and redband trout, see USFWS (1998); USFWS (2000); Behnke (2002); Moyle (2002); NRC (2004); PacifiCorp (2004a); Starcevich et al. (2006); and Messmer and Smith (2007).

Resident Lampreys

In addition to the anadromous Pacific lamprey, described above, at least three resident species are present in the California portion of the Klamath Basin (PacifiCorp 2006, Hamilton et al. 2011):

- Northern California brook lamprey (*Entosphenus folletti*);
- Western brook lamprey (*Lampetra richardsoni*); and
- Klamath River lamprey (*Lampetra similis*).

No lamprey species are listed as threatened or endangered on either the California or Federal ESA lists (CDFW 2018a). However, all three resident species are listed in California as Species of Special Concern (Moyle et al. 2015). All resident lamprey species have a similar early life history where ammocoetes drift downstream to areas of low velocity with silt or sand substrate and proceed to burrow into the stream bottom and live as filter feeders for two to seven years (USFWS 2004). After they transform into adults, the non-parasitic species (Northern California brook lamprey, western brook lamprey) do not feed, while the parasitic Klamath River lamprey feed on a variety of fish species (FERC 2007).

Klamath River lamprey are found both upstream and downstream from Iron Gate Dam, from Spencer Creek downstream, and are common in the Lower Klamath River and the low-gradient tributaries there (NRC 2004). They are also found in the Trinity River, and in the Link River of the Upper Klamath Basin (Lorion et al. 2000, as cited in Close et al. 2010).

In the Klamath River Basin, Western brook lamprey are known to occur only in Hunter and McGarvey creeks, near the mouth of the Klamath River (Close et al. 2010). Early studies of Western brook lamprey were conducted outside of California (Moyle et al. 2015), and therefore there is no information on the life history, distribution, or abundance of this species in the Klamath River Basin prior to the construction of the Lower Klamath Project. Because they are known to occur only in streams near the mouth of the Klamath River, the effects from the existing dams would be confined to flow alteration in the mainstem, to the extent that Western brook lamprey use the mainstem for dispersal or other life history events.

[82] Life history strategy in which adult fish spawn and juveniles subsequently rear in streams but migrate to lakes for feeding as subadults and adults.

Northern California brook lamprey (also known as the Modoc brook lamprey) are found upstream of Iron Gate Dam (Close et al. 2010). They have been reported from a tributary to the Lost River in the Clear Lake Basin and are potentially also found in Fall Creek (Close et al. 2010). Moyle et al. (2015) report that Northern California brook lamprey are known to occur in Willow and Boles creeks above Clear Lake Reservoir. Northern California brook lamprey was not described as a separate species until 1976 (based on museum specimens) and was not recognized as a species by the American Fisheries Society until 2013 (Moyle et al. 2015). Therefore, there is no information on the life history, distribution, or abundance of this species prior to the construction of the Lower Klamath Project. Moyle et al. (2015) states that the only known populations are above large reservoirs, which suggests that they are isolated from other populations. Moyle et al. (2015) reports that dams and diversions on the upper Klamath River and Lost River alter downstream flows and habitats, potentially negatively affecting the downstream populations.

Cyprinids

The native blue chub (*Gila coerulea)* and tui chub (*Gila bicolor*) are both found in the Klamath Basin, including Lost River, Lower Klamath Lake, Tule Lake, and Iron Gate and Copco No. 1 reservoirs (CH2M Hill 2003). These species prefer habitat with quiet water, well-developed beds of aquatic plants, and fine sediment or sand bottoms. Although blue and tui chubs can withstand a variety of conditions including cold, clear lake water, and can also tolerate low dissolved oxygen levels, they are most often found in habitats with summer water temperatures higher than 68°F. These fish are omnivores, they feed on sediment detritus, and can play an important role in nutrient cycling through the excretion of nutrients into the water column in forms available to primary producers (e.g., phytoplankton). Both species of chub found in the Klamath Basin spawn from April through July, in shallow rocky areas in temperatures of 59 to 64.4°F (Moyle 2002). Presumably dams and diversions have benefitted both of these species by increasing the availability of its preferred warmer, low-velocity habitat.

Sculpin

Several sculpin species are found in coastal streams and rivers from Alaska to southern California. Several species of sculpin are known to occur in the California portion of Klamath River and its estuary, including Pacific staghorn (*Leptocottus armatus*), prickly (*Cottus asper*), slender (*Cottus tenuis*), sharpnose (*Clinocottus acuticeps*), coastrange (*Cottus aleuticus*), and marbled (*Cottus klamathensis*). Of these, only the marbled and slender sculpins are known to occur upstream of Iron Gate Dam (Carter and Kirk 2008). Mainstem Klamath River habitat may be important to sculpin populations as it can provide an important migration corridor from the estuary to upstream riverine reaches (White and Harvey 1999). Pacific staghorn sculpin are found predominantly in brackish waters of the estuary. Coastal populations of prickly and coastrange sculpin are generally assumed to be dependent on the estuary for part of their early life history (White and Harvey 1999). The marbled sculpin is a relatively wide-ranging species found in a variety of habitats in northern California and southern Oregon (Daniels and Moyle 1984). Marbled sculpin are found mainly in low gradient, spring-fed streams and rivers where the water temperature is less than 68°F in the summer and in habitat with fine substrate that can support beds of aquatic plants. They are typically found in 60 to 70 centimeters of water and in velocities around 23 centimeters per second (approximately 0.36 gallons per minute) (Moyle 2002). Slender sculpin were likely historically common in the Williamson, Sprague, Sycan, and Lost rivers and in Upper

Klamath Lake (Bentivoglio 1998, cited in NRC 2004). Bentivoglio (1998) collected sculpins throughout the upper basin in 1995–1996 and found slender sculpins only in the lower Williamson River and a few in Upper Klamath Lake. Little is known about the species' biological requirements (NRC 2004). Sharpnose sculpin are primarily found in marine and brackish conditions, although they can tolerate freshwater (Love 2011). As such, they are likely restricted to the Klamath River Estuary and possibly the lower mainstem Klamath River.

Lost River and Shortnose Suckers

The Lost River sucker (*Deltistes luxatus*) and shortnose sucker (*Chasmistes brevirostris*) are endemic to the Upper Klamath Basin of southern Oregon and northern California (Moyle 2002). These species share similar distribution and habitat requirements, and thus are typically managed together. The Lost River sucker and the shortnose sucker are listed as endangered under the ESA (USFWS 1988) and are endangered under CESA. A Revised Recovery Plan for the Lost River sucker and Shortnose sucker (revised recovery plan) was published in 2013 (USFWS 2013a). The final designation of critical habitat for both species was published by the USFWS on December 11, 2012 (USFWS 2012). Both species are also fully protected species under California Fish and Game Code Section 5515(a)(3)(b)(4) and (6), respectively. Under Fish and Game Code section 2081.11, take of the Lost River and shortnose suckers may be authorized for Klamath River dam removal, so long as the take will not result in jeopardy for the species, is minimized, and mitigation incorporates information from sampling efforts.

The 2013 revised recovery plan (USFWS 2013a) identifies a recovery unit for both of these species within the California portion of the Area of Analysis: the reservoirs along the Klamath River downstream of Keno Dam (including Iron Gate and Copco reservoirs), known as the Klamath River Management Unit. Populations in the Klamath River Management Unit are comprised mostly of adults (USFWS 2013a). The USFWS (2013a) recovery plan considers these populations as "sink populations", as they are not likely self-sustaining because of low recruitment due to the lack of access to spawning habitats, citing Moyle (2002), and NRC (2004). Extensive sampling was conducted by Oregon State University (Desjardins and Markle 1999) in J.C. Boyle, Copco No. 1 and Iron Gate reservoirs during 1998 and 1999 using multiple gear types (trammel nets, beach seines, cast nets, trap nets, backpack electrofishing, and otter trawls). Sampling gears, seasons and locations were selected to maximize the collection of suckers and different sucker life stages, and thus the results may not be representative of the larger fish community. Adult suckers were sampled for in 1997, 1998 and 1999 (with trammel nets), while larval and juvenile suckers were only sampled in 1998 and 1999. Over three years of study, a total of 50 shortnose sucker adults were collected in J.C. Boyle Reservoir, 165 in Copco No. 1 Reservoir and 22 in Iron Gate Reservoir. Lost River suckers were present in J.C. Boyle Reservoir and Copco No. 1 Reservoir, but at much lower numbers, with just one collected in Copco No.1 Reservoir and two in J.C. Boyle Reservoir. Larval suckers (species unknown) were more abundant with 275 collected over two years in J.C. Boyle Reservoir, 8,729 in Copco No. 1 Reservoir, and 1,177 in Iron Gate Reservoir. A total of 23 juveniles were collected in J.C. Boyle Reservoir and 3 in Copco No.1 Reservoir. In all, shortnose sucker represented 1 percent (1998) and 2 percent (1999) of the trammel net catch in J.C. Boyle Reservoir, 12 percent (1998) and 14 percent (1999) in Copco No.1 Reservoir and 0.3 percent (1998) and 2 percent (1999) in Iron Gate Reservoir. Juveniles were only a significant portion of the seine net catch in J.C Boyle Reservoir, representing 17 percent of the catch in 1998 and 9 percent in 1999. In larval trawls, sucker larvae represented only 0.2 to 5 percent of the catch in all reservoirs in 1998, but those percentages increase to 27 percent (J.C. Boyle Reservoir), 44 percent (Copco No.1 Reservoir) and 30 percent (Iron Gate Reservoir) in 1999.

To minimize and mitigate for adverse effects to both sucker species, PacifiCorp prepared an HCP for its interim operations of the Klamath Hydroelectric Project (i.e., prior to dam removal) (PacifiCorp 2013). This HCP includes the conservation strategy and measures that PacifiCorp would undertake to address anticipated effects on suckers and their habitat in the Klamath Basin. The conservation measures outlined follow a two-pronged approach: (1) manage the shutdown of East- and West-side powerhouses (which are part of the Klamath Hydroelectric Project in Oregon, see Figure 3.3-1) in such a way as to minimize effects on listed suckers, resulting in additional benefits by reducing possible entrainment, ramping events, and false attraction to powerhouse tailraces; and (2) improve habitat conditions for listed suckers by facilitating/funding specific enhancement projects, a sucker conservation fund, and the Nature Conservancy's (TNC) Williamson River Delta Restoration Project.

In the 2013 BiOp (NMFS and USFWS 2013), USFWS consulted on both sucker species. USFWS concluded that the proposed USBR Klamath Irrigation Project operations affects both Lost River and shortnose suckers. In the Klamath River Management Unit, USFWS concluded that effects of the proposed operations on both species are likely small in comparison to other effects because there are fewer suckers present in the reservoirs, so effects are primarily limited to changes in water quality (USFWS 2007).

Existing threats to the sucker populations include: the damming of rivers, instream flow diversions, hybridization (e.g., between shortnose sucker and Klamath largescale suckers [*Catostomus snyderi*]), competition and predation by exotic species, dredging and draining of marshes, water quality problems associated with timber harvest, the removal of riparian vegetation, livestock grazing, agricultural practices, and low lake elevations, particularly in drought years (USFWS 1993). Reduction and degradation of lake and stream habitats in the Upper Klamath Basin is considered by USFWS to be the most important factor in the decline of both species (USFWS 1993).

Miller and Smith (1981) claimed that sucker hybridization was most pronounced in the Lower Klamath Project reservoirs, and Markle et al. (2005) reported hybridization between small scale sucker and both Lost River and shortnose suckers in the Hydroelectric Reach. Hybridization prompted Buettner et al. (2006) and others to caution against supporting migration of individuals from Iron Gate and Copco reservoirs into the Upper Klamath Lake population.

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 and Lost River up to Anderson-Rose Dam (USFWS 1993), and the Klamath River downstream of Iron Gate Reservoir (USFWS 1993). Shortnose suckers occur in Gerber Reservoir and its tributaries, but Lost River suckers do not.

Lost River and shortnose suckers are lake-dwelling, but spawn in tributary streams or springs (USFWS 1988). They spawn from February through May, depending on water depth and stream temperature (Buettner and Scoppettone 1990, Andreasen 1975, USFWS 2008). Spawning locations appear to be both substrate and flow dependent (although specific preferred flow velocities are unknown), with an apparent preference for gravel substrates (where eggs incubate in the interstices). When spawning occurs over cobble and armored substrate, eggs fall between crevices or are swept downstream and lost (Buettner and Scoppettone 1990). Larval Lost River and shortnose suckers spend relatively little time in tributary streams, migrating to lake habitat shortly after emergence, typically in May and early June (Buettner and Scoppettone 1990). Adults return to Upper Klamath Lake soon after spawning. Lake fringe emergent vegetation is the primary habitat used by larval suckers (Cooperman and Markle 2004). Juvenile suckers use a wide variety of habitat including near-shore areas with or without emergent vegetation and off-shore habitat (Hamilton et al. 2011).

Smallscale Sucker

The Klamath smallscale sucker (*Catostomus rimiculus*) is common and widely distributed in the Klamath River and its tributaries downstream from the city of Klamath Falls, Oregon, and in the Rogue River (Moyle 2002). They tend to inhabit deep, quiet pools in mainstem rivers and slower-moving reaches in tributaries; however, they can be found in faster-flowing habitats when feeding or breeding (Moyle 2002). McGinnis (1984) reported that this species spawns in small tributaries to the Klamath and Trinity rivers. Spawning in tributaries to has been observed from mid-March to late April (Moyle 2002). Juveniles are most commonly found in the streams that are used for spawning. The larger adults observed have been from fish measuring 18 in, and have been aged through scale analysis as being approximately 15 years old (Scoppetone 1988, as cited in Moyle (2002). Moyle (2002) speculated that dams and diversions have benefitted this species by increasing the availability of its preferred warmer, low-velocity habitat.

Electrofishing conducted by PacifiCorp and ODFW in the J.C. Boyle Peaking Reach revealed the existence of a population of smallscale suckers in moderate velocity habitat, and they were the most prevalent species in the majority of the collected samples (W. Tinniswood, pers. comm., June 2011). J.C. Boyle Dam blocks the migration of smallscale suckers to potential spawning habitat in Spencer Creek. Currently, spawning occurs in the mainstem of the Klamath River where smallscale suckers are subject to flow fluctuations that can displace their broadcast spawning[83] or strand and dry the eggs during power peaking[84] operations (Dunsmoor 2006). Electrofishing in Jenny Creek revealed adult smallscale suckers occupying deep, moderate-velocity habitat among boulders (W. Tinniswood, pers. comm., June 2011).

Non-native Fish Species

Introduced non-native fish species threaten the diversity and abundance of native fish species through competition for resources, predation, interbreeding with native populations, and causing potential physical changes to the invaded habitat (Moyle 2002). Non-native fish species occurring within the Area of Analysis are described below, including descriptions of interactions with native fish species.

[83] Broadcast spawning takes place when suckers release their eggs and sperm into the water, where fertilization occurs externally.
[84] Power peaking is rapid changes in flow associated with hydropower generation.

Yellow Perch

Yellow perch (*Perca flavescens*) prefer weedy rivers and shallow lakes. They are found in reservoirs and ponds along the Klamath River, and are a popular recreational fishery. Optimal temperature for growth is between 71.6 and 80.6°F but yellow perch can survive in temperatures up to 86 to 89.6°F. They can also survive low levels of dissolved oxygen (less than one milligram per liter [mg/L]) but are most abundant in areas with low turbidity, as they are visual feeders. Larval and juvenile yellow perch feed on zooplankton; adults are opportunistic predators that may feed on larger invertebrates and small fish, including younger yellow perch, white bass, and smelt (Knight et al. 1984); and may also prey on larval suckers (USFWS 1993). The preferred habitat of the yellow perch includes large beds of aquatic plants for spawning and foraging; habitat that is common in Lower Klamath Project reservoirs. Their spawning takes place in 44.6 to 66.2°F water in April and May and usually occurs in their second year (Moyle 2002).

Bass and Sunfish

Several species of bass (*Micropterus* spp.) and sunfish (*Lepomis* spp.) have been introduced into the Klamath Basin, including largemouth bass, white and black crappie, bluegill, pumpkinseed, and green sunfish. All are a popular recreational fishery, especially the bass species. Largemouth bass and sunfish prefer lakes, ponds, or low-velocity habitat in rivers, and are mostly found in Lower Klamath Project reservoirs upstream of Iron Gate Dam. They prefer habitats with aquatic vegetation and will spawn in a variety of substrates. They prefer water temperatures above 80.6ºF. Juvenile and adult largemouth bass tend to feed on larger invertebrates and fish (Moyle 2002), potentially including suckers (USFWS 1993). Smaller members of the family, such as sunfish, are opportunistic feeders and eat a variety of aquatic insects, fish eggs, and planktonic crustaceans (Moyle 2002).

Catfish

Several species of catfish have been introduced into the Klamath Basin, including channel catfish (*Ictalurus punctatus*), black bullhead (*Ameiurus melas*), brown bullhead (*Ameiurus nebulosus*), and yellow bullhead (*Ameiurus natalis*) (NRC 2004). Catfish prefer slow moving, warm water habitat. Brown bullhead (*Ameiurus nebulosus*) can tolerate a wide range of salinities and live at temperatures of 32 to 98.6°F, but their optimum temperature range is 68 to 91.4°F. Brown bullhead are most active at night and form feeding aggregations. Catfish are opportunistic omnivores and scavenge off the bottom of their habitat (Moyle 2002).

Trout

Brook trout (*Salvelinus fontinalis)* is an introduced species in the Upper Klamath Basin within the California portion of the Area of Analysis (FERC 2007) found in clear, cold lake and stream habitats. They prefer temperatures between 57.2 and 66.2°F but can survive in temperatures ranging from 33.8 to 78.8°F. Brook trout feed predominantly on terrestrial insects and aquatic insect larvae, though they may also opportunistically feed on other types of prey such as crustaceans, mollusks, and other small fish. Brook trout spawn in the fall and prefer habitats with small-sized gravel and nearby cover (Moyle 2002).

Brown trout (*Salmo trutta*) have also been introduced to the Klamath River and are found in both the Upper and Lower Klamath Basin. Brown trout prefer clear, cold water and can utilize both lake and stream habitats. Like brook trout, they spawn in the fall in streams with areas of clean gravel. Brown trout become piscivorous (fish eaters) once they reach a size where their gape can accommodate small fish available as prey.

American Shad

American shad are an introduced, anadromous fish species found in the Klamath River downstream of Ishi Pishi Falls, and are a popular sport fish. They feed primarily on plankton, mostly mysids and copepods, and occasionally on small fishes such as smelt. Adult American shad spend three to six years in the ocean before returning to spawn in the Klamath River (Pearcy and Fisher 2011). The preferred spawning habitat of the American shad includes sandy or pebbly substrate, water temperatures between 59 and 64.4°F, and where water velocities are less than 0.7 m/s (approximately 2.3 feet per second) (Moyle 2002).

Estuarine Species

The estuary is the mixing zone for freshwater and saltwater from the ocean. The balance of freshwater to saltwater changes over the course of the day with tides and is also strongly influenced by river flows. Due to this, both marine and freshwater species can often be found in different portions of the estuary at various times. All anadromous fish pass through the estuary during their migrations from freshwater to the ocean and back again, and salmonid smolts may rear in the estuary for varying periods of time, prior to moving into the ocean. Surveys in the freshwater portion of the estuary commonly find Klamath speckled dace (*Rhinichthys osculus klamathensis*), Klamath smallscale sucker (*Catostomus rimiculus*), prickly sculpin, and Pacific staghorn sculpin. Other fairly common species include northern anchovy (*Engraulis mordax*), saddleback gunnel (*Pholis ornate*), and bay pipefish (*Syngnathus leptorhyncus*). Other species in the estuary include federally-listed eulachon, state-listed longfin smelt (*Spirinchus thaleichthys*) (described below), non-native Mississippi silversides (*Menidia beryllina*), surf smelt (*Hypomesus pretiosus*), three-spined stickleback (*Gasterosteus aculeatus*), and several species of gobies. Impacts to the estuarine species were assessed based on effects on specific sensitive species such as eulachon and EFH for groundfish and pelagic fish, as described in the Essential Fish Habitat subsection of Section 3.3.2.3 *Habitat Attributes Expected to be Affected by the Proposed Project*.

Eulachon

Eulachon is an anadromous fish that occurs in the lower portions of certain rivers draining into the northeastern Pacific Ocean, ranging from northern California to the southeastern Bering Sea in Bristol Bay, Alaska (McAllister 1963, Scott and Crossman 1973, Willson et al. 2006, as cited in NMFS 2010b). The Yurok Tribe consider eulachon a “Tribal Trust Species,” and the fish has major cultural significance (Larson and Belchik 1998). The southern population of Pacific eulachon consists of populations spawning in rivers south of the Nass River in British Columbia, Canada, to and including the Mad River in California (NMFS 2009a). On March 18, 2010, NMFS listed the southern DPS of eulachon as threatened under the ESA (NMFS 2010b). Final critical habitat was designated in October of 2011 and includes the Klamath River Estuary (NMFS 2011). NMFS has issued a draft recovery plan (NMFS 2016b) and has formed a Eulachon Recovery Team to support recovery planning.

Historically, the Klamath River was described as the southern limit of the range of eulachon (Gustafson et al. 2010). Other accounts have described large spawning aggregations of eulachon occurring regularly in the Klamath River (Fry 1979, Moyle et al. 1995, Larson and Belchik 1998, Moyle 2002, Hamilton et al. 2005), and occasionally in the Mad River (Moyle et al. 1995, Moyle 2002) and Redwood Creek in Humboldt County (Moyle et al. 1995). In addition, small numbers of eulachon have been reported from the Smith River (Moyle 2002). The only reported commercial catch of eulachon in northern California occurred in 1963 when a combined total of 25 metric tons (56,000 lbs) was caught from the Klamath River, the Mad River, and Redwood Creek (Odemar 1964). Since 1963, the run size has declined to the point that only a few individual fish have been caught in recent years. Moyle (2002) indicates that eulachon have been scarce in the Klamath River since the 1970s, with the exception of three years: they were plentiful in 1988, 1989, and 1998. After 1998, eulachon were thought to be extinct in the Klamath Basin until a small run was observed in the estuary in 2004. According to accounts of Yurok Tribal elders, the last noticeable runs of eulachon were observed in the Klamath River in 1988 and 1989 by Tribal fishermen (Larson and Belchik 1998).

Larson and Belchik (1998) reported that eulachon have not been of commercial importance in the Klamath since the 1980's. However, in January 2007, six eulachon were reportedly caught by tribal fishermen on the Klamath River. Another seven were captured between January and April of 2011 at the mouth of the Klamath River (McCovey 2011b). More recently, 40 adult eulachon were captured in spring 2012 (McCovey 2012), and 112 in spring 2012 (McCovey and Walker 2013) by Yurok Indian tribal biologists in presence/absence surveys, using seines and dip nets in the Klamath River.

According to the 2016 status review update of southern DPS eulachon (Gustafson et al. 2016), adult spawning abundance of the southern DPS of eulachon has increased since the listing occurred in 2010. A number of data sources indicate that eulachon abundance in some subpopulations within the southern DPS was substantially higher in 2011 through 2015 compared to indications of very low abundance in 2005 through 2010. The improvement in estimated abundance in the Columbia, Naselle, Chehalis, Elwha, and Klamath rivers, relative to the time of listing, reflects both changes in biological status and improved monitoring (Gustafson et al. 2016).

Historically, eulachon runs in northern California were said to start as early as December and January and peak in abundance during March and April. Large numbers of eulachon migrated upstream in March and April to spawn, but they rarely moved more than eight miles inland (NRC 2004). Eulachon spawn at an age of three to five years, and usually die after spawning (Larson and Belchik 1998). Spawning occurs in gravel riffles, with hatching about a month later. The larvae generally move downstream to the estuary following hatching (Larson and Belchik 1998).

<u>Longfin Smelt</u>

Longfin smelt are a state-listed threatened species and a CDFW Species of Special Concern throughout their range in California. The USFWS denied the petition for federal listing because the population in California (and specifically San Francisco Bay) was not believed to be sufficiently genetically isolated from other populations (USFWS 2009). This species generally has a two-year lifespan, although three-year-old fish have been observed (Moyle 2002). They typically live in bays and estuaries and have sometimes been observed in the nearshore ocean from San Francisco Bay to Prince William Sound, Alaska, including the Klamath River. Longfin smelt prefer salinities of 15 to 30 parts per thousand (ppt), although they can tolerate salinities from freshwater to full seawater. They prefer temperatures of 60.8 to 64.4°F and generally avoid temperatures higher than 68°F. Longfin smelt may occur in the Klamath River throughout the year. They would only be expected to use the estuary, the lowest reaches of the river, and infrequently in the Pacific Ocean nearshore. Longfin smelt spawning occurs primarily from January to March, but may extend from November into June, in fresh or slightly brackish water over sandy or gravel substrates. Temperatures during spawning in the San Francisco estuary are 44.6 to 58.1°F. Embryos hatch in approximately 40 days in 44.6°F water temperature (approximately 25 days in 51°F water) and are quickly swept downstream by the current to more brackish areas. The importance of ocean rearing is unknown. Longfin smelt were common in the Klamath River Estuary during 1978–1989, but the population has significantly declined since. In 1992, two were found in the Klamath River Estuary, and in 2001 only one adult longfin smelt was collected (CDFG 2009).

Freshwater Mollusks

While life history traits of individual species of freshwater mussels have not been fully studied, the general life cycle is as follows. Eggs within female freshwater mussels are fertilized by sperm that is brought into the body cavity. From April through July thousands of tiny larvae, called glochidia, are released into the water where they must encounter a host fish for attachment within hours, otherwise they perish (Haley et al. 2007). Most juvenile freshwater mussels from these species drop off the fish hosts to settle from June to early August. The juvenile freshwater mussels spend an undetermined amount of time buried in the sediment where they grow to the point where they can maintain themselves at or below the substrate surface in conditions that are optimal for filter feeding (Nedeau et al. 2009). Freshwater mussels are fed upon by muskrats, river otters, and sturgeon (Nedeau et al. 2009). They are also a food of cultural significance for the Karuk Tribe (Westover 2010) and The Klamath Tribes. Adult freshwater mussels are generally found wedged into gravel rock substrate or partially buried in finer substrates, using a muscular foot to maintain position. Freshwater mussels filter feed on plankton and other organic material suspended in the water column.

Four species of native freshwater mussels have been observed within the Klamath Basin (FERC 2007, Westover 2010). PacifiCorp surveys conducted in 2002 and 2003 found Oregon floater (*Anodonta oregonensis*), California floater (*Anodonta californiensis*) and western ridged mussel (*Gonidia angulata*) along Klamath River reaches from the Keno Impoundment/Lake Ewauna to the confluence of the Klamath and Shasta rivers. Westover (2010) also found western pearlshell mussel (*Margaritifera falcata*) in addition to these species along the Klamath River from Iron Gate Dam to the confluence of the Klamath and Trinity rivers. Byron and Tupen (2017) surveys also conducted during in 2002 and 2003 upstream of Iron Gate Dam documented Oregon floater and western ridged mussel in the Keno Reach, Oregon floater in the J.C. Boyle Peaking Reach, and both species in the mainstem Klamath River between Copco No. 2 Reservoir and J.C. Boyle Dam.

Downstream of Iron Gate Dam, Davis et al. (2013) found that *Anodonta sp.* occurred only in the farthest upstream survey sites; western ridged mussel was present in most reaches and often at high densities, and western pearlshell mussel was present in high numbers downstream of the confluence with the Salmon River. All surveyed mussel populations declined in abundance with increasing distance downstream of Iron Gate Dam, due to more mobile substrate. The Shasta River was the only tributary to the Klamath River with Oregon floater, California floater, and western ridged mussel all detected. Western ridged mussel and western pearlshell mussel were more common in reaches farther downstream in the Klamath River from Iron Gate Dam, probably due to thicker shells which allow them to withstand scouring in high flow events.

A full understanding of western ridged mussels former and current distribution is difficult to assemble due to the lack of data, but it is believed to have been extirpated in central and southern California and has probably declined in many other watersheds, including the Columbia and Snake River basins (Jepsen et al. 2010). The Klamath River appears unusual in that western ridged mussels dominates its mussel community, unlike other rivers in the Pacific Northwest (Westover 2010).

Western pearlshell mussels have also been observed within the Klamath Basin downstream from Iron Gate Dam, though in lesser abundance than other mussel species (Westover 2010). Western pearlshell mussels occupies habitats with low water velocity (e.g., pools and near banks) and pockets within bedrock and cobble (Howard and Cuffey 2003).

Anodonta spp. (commonly referred to as “floaters”) are more tolerant of lake conditions than other native mussel species (Nedeau et al. 2005), and have been observed in Lower Klamath Project reservoirs. Floaters are also more tolerant of siltier substrates, as their thin shells allow individuals to “float,” or rest on top of silt-dominated streambeds. Byron and Tupen (2017) found that low-energy areas where finer sediments accumulate and where hydrology is consistent were most suitable for *Anodonta spp.*

Western ridged mussels are the largest and most common type of freshwater mussel found within the Klamath Basin (Nedeau et al. 2005). They are known to prefer cold, clean water, but can tolerate seasonal turbidity, and can be found in aggrading, or depositional areas as it can partially bury itself within bed sediments without affecting filter feeding (Vannote and Minshall 1982, Westover 2010). Byron and Tupen (2017) found that they appeared to prefer faster waters and, consequently, coarser substrates such as medium- and coarse sands. Even areas with boulder and bedrock substrates had pockets of finer materials in which *G. angulata* were aggregated. Commonly, *G. angulata* were found buried to depths of 15 centimeters and often stacked atop one another. In general, *G. angulata* were always buried at least 80 percent, with only the tops of shells visible (Byron and Tupen 2017). Known fish hosts of juvenile *G angulata* include hardhead (*Mylopharodon conocephalus*), Pit sculpin (*Cottus pitensis*), and tule perch (*Hysterocarpus traski*), but a full list of host fish species for western ridged mussels are unknown (Jepsen et al. 2010). However, Mageroy (2016) found that *G. angulata* hosts in Canada included primarily sculpin species (*Cottus* spp.) but that northern pikeminnow (*Ptychocheilus oregonensis*), leopard dace (*Rhinichthys falcatus*), and longnose dace (*Rhinichthys cataractae*) are potential hosts as well. Therefore, it appears that the species has significant range of hosts.

Seven to eight species of fingernail clams and peaclams (Family: Sphaeriidae) were also found in the Hydroelectric Reach and from Iron Gate Dam to Shasta River during re-licensing surveys (FERC 2007). One of the clam species, the montane peaclam (*Pisidium ultramontanum)*, has special status as a federal species of concern and a USDA Forest Service Sensitive Species. The montane peaclam is generally found on sand-gravel substrates in spring-influenced streams and lakes, and occasionally in large spring pools. The historic range included the Klamath and Pit rivers in Oregon and California, as well as some of the larger lakes (Upper Klamath, Tule, Eagle, and possibly, Lower Klamath lakes) (FERC 2007). On USDA Forest Service lands they are currently present or suspected in streams and lakes of Lassen and Shasta-Trinity National Forests. Fingernail clams and peaclams are relatively short-lived (one to three years) compared to freshwater mussels (typically 10 to 15 years although in some cases 100 or more years for some species). These small clams live on the surface or buried in the substrate in lakes, ponds or streams. They bear small numbers of live young several times throughout the spring and summer (Thorp and Covich 2001).

There are also many species of freshwater snails, some of which are endemic to the Klamath Basin and have restricted ranges, often associated with cold-water springs. Several of these have recently been petitioned for listing. Based on their restricted distribution to areas outside of Klamath River reaches that could be affected by the Proposed Project, no further analysis was undertaken for freshwater snails for this EIR.

Benthic Macroinvertebrates

Benthic macroinvertebrates (BMI) are small aquatic animals and the aquatic larval stages of insects. They lack a backbone, are visible with the naked eye and are found in and around water bodies during some period of their lives. BMI include immature, aquatic stages of insects such as midges, mayflies, caddisflies, stoneflies, dragonflies, and damselflies. They also include immature and adult stages of aquatic beetles; crustaceans such as crayfish, amphipods and isopods ; clams and snails; aquatic worms; and other major invertebrate groups. Many BMI are the primary consumers in riverine food webs, feeding on primary producers—algae, aquatic plants, phytoplankton, bacteria, as well as leaves and other organic materials from terrestrial plants, and detritus. By converting organic material into biomass available to a wide variety of consumers, these organisms form an important component of the aquatic food web. Some BMI are secondary consumers, feeding on the primary consumers. BMI are the primary food source for most freshwater fish species, and therefore, changes in abundance, distribution, or community structure can affect fish populations. BMI are also used as general indicators of water quality. This is assessed based upon the relative abundance or diversity of each group (taxa) and their tolerance of water quality impairment or habitat degradation. BMI are also particularly sensitive to changes in fine and coarse sediment, which would occur during the Proposed Project. A diminished food supply can limit growth of salmonids, and this is especially true at higher temperatures because as water warms, a fish's metabolic rate increases and it needs more food to sustain growth (Brett 1971, McCullough 1999). Growth is critical to juvenile salmonids because a larger size fish often has a survival advantage during the overwintering period, smolt outmigration, and ocean residence. If fish are chronically exposed to warm water temperatures and food availability is low, growth rates are reduced and fish experience physiological stress, often resulting in increased mortality from disease, parasites, and predation. However, in a productive system with high densities of BMI or forage fish, a high rate of growth can be sustained at temperatures higher than would be considered optimal under conditions where food is limiting.

Relicensing studies for PacifiCorp's Klamath Hydroelectric Project evaluated BMI populations in the Klamath River from Link River Dam to the Shasta River and within Fall Creek in 2002 and 2003 (FERC 2007). These studies show that BMI are abundant, with typical densities of 4,000 to 8,000 individuals per square meter. BMI densities in the fall of 2002 ranged from approximately 2,200 per square meter in the Copco No. 2 Bypass Reach of the Klamath River to approximately 21,600 per square meter below Keno Dam (FERC 2007). Abundance of BMI in both the J.C. Boyle Peaking Reach of the

Hydroelectric Reach and the Middle Klamath River downstream of Iron Gate Dam was as low as approximately 500 per square meter in the spring of 2003. The Lower Klamath Project reservoirs had high abundance of BMI, but low diversity, and were dominated by species tolerant of impaired water quality conditions.

The Yurok Tribe conducted studies in 2005 and 2008 (Burks and Cowan 2007) evaluating the biological community of the Klamath River within the Yurok Indian Reservation (RM 0 to RM 43.3) through BMI surveys. Data collected during these studies were used to calculate an Index of Biological Integrity (IBI)—composite scores generated by assigning values to variables, such as species richness, percent intolerant individuals, percent predator individuals, and others.

The Index of Biological Integrity values generated in 2005 indicated that two of the nine sites on the Klamath River within the Yurok Indian Reservation were in the “impaired” range (i.e., score of 52 or below), and the majority of the other sites were in “fair” condition (i.e., score of 53 to 60) (Burks and Cowan 2007). In 2008, the Index of Biological Integrity values suggested a slight improvement in stream health, with the majority of sites scoring in the “good” range (i.e., score of 61 to 80) (Sinnott and Hanington 2008).

Marine Mammals

Pinnipeds (seals and sea lions), and Southern Resident Killer Whales potentially occur within the Pacific Ocean nearshore environment, off Northern California. Redwood National Park lists harbor seals (*Phoca vitulina richardsi*), California sea lions (*Zalophus californianus*), Steller sea lions (*Eumetopias jubatus*), and Northern elephant seals (*Mirounga angustirostris*) as occurring at least seasonally in the vicinity of the Klamath River Estuary. Elephant seal diets consist primarily of rays, sharks, pelagic squid, ratfish, and Pacific hake, and are not expected to consume salmonids, but other pinnipeds and Southern Resident Killer Whales may feed on adult salmon from the Area of Analysis. In particular, pinnipeds are a documented predator within the Klamath River Estuary and nearshore environment. During radio telemetry studies, Strange (2007a, 2007b, 2008) found that between 14 and 33 percent of tagged Chinook salmon were consumed by pinnipeds (primarily California sea lions). However, the Chinook salmon tagged in those studies were disoriented and potentially fatigued as a result of being captured, anesthetized, and handled, and were therefore more vulnerable to predation. In these studies, most of the observed predation occurred within minutes to hours of release.

In a study of pinniped predation in the Klamath River Estuary using visual observations in August through mid-November 1998 (Williamson and Hillemeir 2001), approximately 3,077 adult salmon were consumed (including fall-run Chinook salmon, spring-run Chinook salmon, coho salmon, and steelhead). Most predation was on fall-run Chinook salmon (2,559 consumed) and was equivalent to 2.6 percent of the estimated fall-run Chinook salmon run that year. An estimated 438 spring-run Chinook, 63 coho salmon, and 110 steelhead were also consumed. California sea lions were the primary predator, and Pacific harbor seals, and Steller sea lions were also observed feeding upon salmonids. Efforts such as “seal bombs” have been used to reduce pinniped predation on salmonids in the estuary, but have not been observed to be effective (Strange 2008).

Southern Resident Killer Whale

The Southern Resident Killer Whale (*Orcinus orca*) DPS is listed as endangered under the ESA (NMFS 2005). This DPS primarily occurs in the inland waters of Washington State and southern Vancouver Island, although individuals from this population have been observed off coastal California in Monterey Bay, near the Farallon Islands, and off Point Reyes (Heimlich-Boran 1988, Felleman et al. 1991, Olson 1998, Osborne 1999, NMFS 2005). Survival and fecundity of Southern Resident Killer Whales are correlated with Chinook salmon abundance (Ward et al. 2009, Ford et al. 2009). Hanson et al. (2010) found that Southern Resident Killer Whale stomach contents included several different ESUs of salmon, including Central Valley fall-run Chinook salmon, but none from the Klamath River Basin. More recent studies have confirmed that salmon from the Klamath River are consumed, although in small numbers (Hanson 2015). During most of the year Southern Resident Killer Whale are present in Washington inland waters where their diet consists primarily of Chinook salmon. During occasional and short-duration winter visits to the California Coast their diet is primarily chum, Chinook and coho salmon, augmented with smaller numbers of steelhead and sockeye (Hanson 2015). No data are available to determine the contribution of salmon from the Klamath River Basin to their overall diet, but it is believed to be small (<1 percent) on an annual basis given the work of Hanson et al. (2010) and Hanson (2015).

3.3.2.2 Physical Habitat Descriptions

Upper Klamath River and Connected Waterbodies

Aquatic habitat in the Upper Klamath Basin includes both lacustrine (lake) and riverine (river) habitats and large thermally stable coldwater springs. The Upper Klamath River upstream of Iron Gate Dam once supported large populations of anadromous salmon and steelhead by providing spawning and rearing habitat (Hamilton et al. 2005, Butler et al. 2010, Hamilton et al. 2016), as discussed in detail in Section 3.3.5.8 *Aquatic Habitat*.

Upper Klamath Lake is the most prominent feature in this part of the basin, although other lakes and reservoirs are also present. Lake Ewauna, another lake on the Klamath River mainstem, is formed by Keno Dam, which regulates water surface elevations in the impoundment to facilitate agricultural diversions. Lake Ewauna connects to Upper Klamath Lake via the Link River.

Upper Klamath Lake and Lake Ewauna are affected by poor water quality conditions. During the summer months, these waterbodies exhibit episodic high pH, broad daily shifts in dissolved oxygen, and elevated ammonia concentrations (Hamilton et al. 2011). In Upper Klamath Lake several incidents of mass adult mortality of shortnose and Lost River sucker have been associated with low dissolved oxygen levels (Perkins et al. 2000, Banish et al. 2009). Instances of pH levels above 10 and extended periods of pH levels greater than nine lasting for several weeks are associated with large algal blooms occurring in the lake (Kann 2010). On a diel (i.e., 24-hour) basis, algal photosynthesis can elevate pH levels during the day, with changes exceeding two pH units over a 24-hour period. During November through April, pH levels in Upper Klamath Lake are near neutral (Aquatic Scientific Resources 2005).

Implementation of the Proposed Project would result in the reintroduction of anadromous fish into Upper Klamath Lake and Lake Ewauna and their tributary streams. Fish passage over Link Dam is provided by a ladder. This ladder is designed to modern standards to allow the passage of shortnose and Lost River suckers and other migratory fish, including resident and anadromous salmonids and Pacific lamprey, if present. Keno Dam is equipped with a 24-pool weir and orifice type fish ladder, which rises 19 feet over a distance of 350 feet, designed to pass trout and other resident fish species (FERC 2007). The fishway at Keno Dam currently complies with passage criteria for salmonid fish. Although Lost River and shortnose suckers (in addition to other sucker species), have been observed to use the Keno Dam fish ladder, the ladder was not designed for sucker passage and is considered generally inadequate for sucker passage (USBR 2002). Plans are being developed to have the fishway rebuilt to criteria for suckers, lamprey, and for larger anadromous salmonid runs (T. Reaves Gilmore, USBR, pers. comm., October 2018).

The Williamson and Wood rivers are the largest and second largest tributaries to Upper Klamath Lake, respectively. The Sprague River is tributary to the Williamson River, and the Sycan River is tributary to the Sprague River (Hamilton et al. 2011). These tributaries currently provide habitat for redband trout, bull trout, shortnose sucker and Lost River sucker, as well as other species. Historically these tributaries provided substantial habitat for Chinook salmon and steelhead (Hamilton et al. 2005, 2016). Important flow contributions from springs into these tributaries provide cool summer baseflows with water temperatures and dissolved oxygen levels generally adequate to support coldwater fish habitat requirements (Hamilton et al. 2011).

Upper Klamath River – Hydroelectric Reach

The Hydroelectric Reach, from the upstream extent of J.C. Boyle Reservoir to Iron Gate Dam, includes four reservoirs (J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate) and two riverine reaches. Several coldwater tributaries enter the Klamath River and reservoirs in this reach. The reservoirs are productive and nutrient rich and tend to have warm surface waters during the summer months, with mean daily temperatures sometimes reaching 73ºF (FERC 2007). During the late spring/early summer, water quality in Copco No. 1 and Iron Gate reservoirs declines, becoming quite poor due to warm surface waters and annual blooms of the blue-green algae species *Aphanizomenon flow-aquae, Anabaena flos-aquae,* and *Microcystis aeruginosa* (see also Section 3.4 *Phytoplankton and Periphyton*). *Microcystis aeruginosa,* and to an unknown extent *Anabaena flos-aquae,* produce toxins that can be harmful to fish and other animals and humans. Routine sampling from areas frequented by recreational users of the reservoirs has documented cell counts up to 4,000 times greater than what the World Health Organization considers a moderate health risk (see Section 3.4 *Phytoplankton and Periphyton*). This has resulted in Copco No. 1 and Iron Gate reservoirs being posted with health advisory warnings against human and animal contact with the water by local health officials every summer since 2005.

The 21-mile long riverine reach between J.C. Boyle and Copco No. 1 reservoirs is divided into two reaches: the 4.6-mile long J.C. Boyle Bypass Reach, which receives bypass flows from J.C. Boyle Dam, and the 17-mile long Peaking Reach, which receives variable flow from hydroelectric operations (see also Section 2.3.1 *J.C. Boyle Dam and Associated Facilities*). The downstream 6.2 miles in California is designated by CDFW as a Wild Trout Area with the whole reach managed by CDFW for wild trout, including angling restrictions and reduced stocking, and habitat enhancements targeted for native trout (CDFG 2005). The reach from the J.C. Boyle Powerhouse to the Oregon-California state line is designated as a National Wild and Scenic River. Approximately 100 cubic feet per second (cfs) is released from J.C. Boyle Dam to the Bypass Reach through a minimum flow outlet and the fish ladder. This is augmented by inflows from Big Springs of about 220 to 250 cfs (FERC 2007). In the Peaking Reach, this flow is added to flows from the powerhouse, which can range from zero to over 3,000 cfs, depending on operations (FERC 2007). Peaking operations can occur daily, or cycles may extend over several days, depending on water availability, power demands, and whitewater boating needs. The 1.4-mile Copco No. 2 Bypass Reach has flows of about 5 cfs provided by Copco No. 2 Dam. Both of these riverine reaches provide complex physical habitat suitable for salmonid spawning and rearing.

A number of tributary streams join the Klamath River in this reach, including Spencer, Shovel, Fall, Spring, and Camp creeks. These streams provide suitable coldwater spawning and rearing habitat for fish (including potentially salmon and steelhead).

As described in detail in Section 3.20.2.3 *Lower Klamath Project Reservoir-Based Recreation*, the reservoirs currently provide a recreational fishery for non-native fishes including largemouth bass, trout, catfish, crappie, and sunfish (Hamilton et al. 2011). Fishing is popular in Copco No. 1 and Iron Gate reservoirs, especially for yellow perch (Hamilton et al. 2011). These reservoirs also support small numbers of native shortnose and Lost River suckers that are believed to be individuals that have migrated down from the upstream reservoirs and that are thought to not be self-sustaining populations or to be contributing to populations in upstream areas (Hamilton et al. 2011). Riverine sections between reservoirs support populations of speckled dace, marbled sculpin, tui chub, and rainbow and redband trout. This area historically supported anadromous fish populations, including Chinook and coho salmon, steelhead, and Pacific lamprey. These fish can no longer access this area because of the lack of adequate facilities for fish passage at the dams (Hamilton et al. 2011).

Middle and Lower Klamath River

The Klamath River flows unobstructed for 190 river miles downstream from Iron Gate Dam before entering the Pacific Ocean. Downstream from Iron Gate Dam, the Klamath River has a gradient of approximately 0.25 percent and four major tributaries enter this reach: Shasta, Scott, Salmon, and Trinity rivers.

The Klamath Basin downstream from Iron Gate Dam provides hundreds of miles of suitable habitat for anadromous and resident fish. Recreational fishing within this area is popular for steelhead and Chinook salmon, and tribal fishing is common for Chinook salmon with gillnets, and Pacific lamprey with basket traps. Freshwater mussels are also common in this reach. Most of the anadromous salmonid species spawn primarily in the tributary streams, although fall-run Chinook salmon and coho salmon do spawn in the mainstem. The mainstem also serves as a migratory corridor and as rearing habitat for juveniles of many salmonid species (FERC 2007). The ability of the mainstem Klamath River to support the rearing and migration of anadromous species is reduced by periodic high water temperatures during summer, poor water quality (low dissolved oxygen and high pH; see Sections 3.2.2.5 *Dissolved Oxygen* and 3.2.2.6 *pH*), and disease outbreaks during spring. Aquatic habitat quality in the tributaries is also affected by high temperatures. The Shasta and Scott Rivers also are impaired by low flows, high water temperatures, stream diversions, non-native species, and degraded spawning habitat (Hardy and Addley 2001, FERC 2007, North Coast Regional Board 2010). In the Salmon River, past and present high severity fires and logging roads in the watershed contribute to high sediment yields, and continued placer mining has disturbed spawning and holding habitat (NRC 2004).

Klamath River Estuary

Wallace (1998) surveyed the Klamath River Estuary and noted formation of a sand berm at the river mouth each year in the late summer or early fall, raising the water level in the estuary, reducing tidal fluctuation, and restricting saltwater inflow. The surveys found a brackish water layer along the bottom of the estuary may be extremely important to rearing juvenile salmonids, as they appeared to be more abundant near the freshwater/saltwater interface. Juvenile Chinook salmon may also use the cooler brackish water layer as a thermal refuge.

The Klamath River Estuary supports a wide array of fish species and also serves as breeding and foraging habitat for marine and estuarine species. These species include, but are not limited to Pacific herring (*Clupea pallasii*), surf smelt, longfin smelt, eulachon, top smelt, starry flounder (*Platichthys stellatus*) and other flatfish, Klamath speckled dace, Klamath smallscale sucker, prickly sculpin, Pacific staghorn sculpin, northern anchovy, saddleback gunnel, and bay pipefish. Recreational fishing for Chinook salmon is popular in the estuary, as well as tribal fishing for Chinook salmon with gillnets and Pacific lamprey with hooks.

Pacific Ocean Nearshore Environment

The Pacific Ocean nearshore environment includes the Klamath River Management Zone (KMZ), the California portion of which extends from the Oregon-California state line south to Horse Mountain (40° 05’ 00” N. latitude) and out three nautical miles from the coast. Physical habitat within this environment includes sandy beach, rocky intertidal, and a sand-dominated seafloor at depths less than 200 ft within one mile of the coast, ranging to depths greater than 500 ft on the continental shelf. During winter high flows fine sediment deposits on the seafloor shoreward of the 196-feet isobath along the coast, with greater quantities depositing in close proximity to the mouth of the Klamath River. After fine sediment loading onto the continental shelf during river floods, fluid-mud gravity flows typically transport fine sediment offshore. Summer coastal upwelling naturally resuspends some of the river sediments that are transported to the nearshore environment and deposited on the continental shelf, especially those deposited during the previous winter (Ryan et al. 2005, Chase et al. 2007; see Potential Impact 3.2-8).

The Pacific Ocean nearshore environment supports a wide array of fish species and serves mostly as foraging habitat for marine and anadromous species. These species include, but are not limited to all of the anadromous fish listed previously, as well as federally threatened Southern DPS green sturgeon, Pacific halibut (*Hippoglossus stenolepis*), Pacific herring, surf smelt, longfin smelt, eulachon, top smelt, starry flounder and other flatfish, northern anchovy, saddleback gunnel, lingcod (*Ophiodon elongates*), rockfish species (*Sebastes spp.*). Within the Pacific Ocean nearshore, recreational and commercial fishing for Chinook salmon, halibut, lingcod, and rockfish species is common.

3.3.2.3 Habitat Attributes Expected to be Affected by the Proposed Project

The Proposed Project would affect the physical, chemical, and biological components of aquatic habitat within portions of the Klamath Basin. These effects would result from changes in suspended sediment, bedload sediment, water quality, water temperature, disease and parasites, habitat availability, and flow-related habitat. As described in the following sections, these changes would act in both beneficial and harmful ways on species, critical habitat, and EFH. Some of the changes would be short-term, and others permanent. The overarching long-term effect would be to bring the habitat closer to a more natural riverine system, from the current reservoir and reservoir-influenced baseline.

Appendices E and F provide more detailed technical descriptions of suspended sediment and bedload sediment under existing conditions. Anticipated changes in water quality under the Proposed Project are discussed in greater detail in Section 3.2 *Water Quality*, and a description of the effects of implementing the Proposed Project on algae is found in Section 3.4 *Phytoplankton and Periphyton*.

Suspended Sediment

Suspended sediment dynamics would be altered by the Proposed Project within the Hydroelectric Reach and reaches downstream of Iron Gate Dam. Existing conditions with respect to algal-derived (organic) suspended material and mineral (inorganic) suspended material in the Klamath River upstream and downstream from Iron Gate Dam are summarized in Section 3.2.2.3 *Suspended Sediments* and in Appendix C.

Hydroelectric Reach

Organic suspended material originating from Upper Klamath Lake (in Oregon) is the predominant form of suspended material entering the Hydroelectric Reach. Interception, decomposition, and retention of suspended materials in the Lower Klamath Project reservoirs, as well as dilution from coldwater springs downstream of J.C. Boyle Dam, can decrease organic suspended material concentrations in this reach; however, seasonal increases in organic suspended material also occur in Copco No. 1 and Iron Gate reservoirs due to large summertime phytoplankton blooms (see Section 3.2.2.3 *Suspended Sediments* and Appendix C – *Section C.2.1* for more detail). In the winter months, suspended material in the Hydroelectric Reach is dominated by mineral sediment loads from several tributaries that join the river in this reach (primarily Shovel Creek, Spencer Creek, Jenny Creek, and Fall Creek), which are primarily transported during high flow events and generally settle out in the Lower Klamath Project reservoirs. On the scale of the entire Klamath Basin, the trapping of fine sediments and suspended materials does not appear to be a critical function of the Lower Klamath Project reservoirs with respect to the overall cumulative sediment delivery including downstream tributaries (see also Section 3.11.2.4 *Sediment Load*), since a relatively small percentage (3.4 percent) of total sediment supplied to the Klamath River on an annual basis originates from the Upper and Middle Klamath River (i.e., from J.C. Boyle Dam to the confluence with the Shasta River).

Middle and Lower Klamath River

In general, available data (existing conditions) (detailed in Appendix C.2.2.1) indicate that suspended sediment concentrations (SSCs) downstream from Iron Gate Dam range from less than 5 mg/L during summer low flows to greater than 5,000 mg/L during winter high flows. During large winter storms or following landslides in the Klamath Basin, extremely high SSCs have been observed in the Klamath River mainstem and tributaries (M. Belchik, Fisheries Biologist, Yurok Tribe, pers. comm., August 2008). Large rivers such as the Klamath River, Columbia River, and Sacramento River have large fluctuations in SSCs even under unimpaired conditions, and aquatic species have adapted to survive in this environment. Appendix E provides a detailed analysis of the effects of suspended sediment on aquatic species downstream from Iron Gate Dam under existing conditions.

During all water year types, SSCs of the magnitude and duration modeled under existing conditions (multiple months with concentrations over 50 mg/L) are expected to cause major stress to migrating adult and juvenile salmonids primarily during winter and early spring (Newcombe and Jenson 1996, see also Appendix E). Under existing conditions, Iron Gate Dam traps most suspended sediment from upstream sources, and downstream of Iron Gate Dam SSCs generally increase in a downstream direction from the contribution of tributaries (Appendix C.2).

Klamath River Estuary

Under existing conditions, SSCs within the Klamath River Estuary (modeled at Klamath Station at RM 5; Figure 3.3-1) are relatively high compared to SSCs observed farther upstream due to SSC contribution of major tributaries downstream of Iron Gate Dam (Appendix E). The Lower Klamath River downstream from the Trinity River confluence to the estuary is currently listed as sediment-impaired under Section 303(d) of the Clean Water Act (CWA) (North Coast Regional Board 2010). Modeling in the Klamath River (from Seiad Valley at approximately RM 132.7 downstream to the Klamath Station at RM 5) indicates that under normal conditions SSCs are relatively high during winter and spring (typically 50 to 100 mg/L), and lower (less than 10 mg/L) during summer. Under existing extreme conditions (wet water year) SSCs are generally 10 to 100 mg/L in summer and fall, with peaks between 100 and 1,000 mg/L during winter and spring.

Pacific Ocean Nearshore Environment

Under existing conditions, a plume of Klamath River water extends into the Pacific Ocean nearshore environment in the Klamath River vicinity that is subject to strong land runoff effects following winter rainfall events. The plume can create areas of low-salinity, high levels of suspended particles, high sedimentation, and low light, and potential exposure to land-derived contaminants (Farnsworth and Warrick 2007). The extent and shape of the plume is variable, and influenced by wind patterns, upwelling effects, shoreline topography (especially Point Saint George), and longshore currents. High riverine SSC events contribute to the plume, especially during floods. In northern California, plume zones are primarily north of river mouths because longshore currents and prevailing winds are northward during periods of strong runoff (Geyer et al. 2000, Pullen and Allen 2000). River plumes and the associated habitat conditions they create support areas of high productivity for marine organisms (Grimes and Finucane 1991, Morgan et al. 2005), and create abrupt changes in marine water quality conditions (e.g., water temperature, salinity, sediment) that support salmonids (Schabetsberger et al. 2003, De Robertis et al. 2005).

Bed Elevation and Grain Size Distribution

Section 3.11.2.4 *Sediment Load* and Appendix F of this EIR describe sediment dynamics and channel conditions in the Area of Analysis and assess changes in channel bed elevation and sediment grain size in response to increased bedload supply and transport for existing conditions and under the Proposed Project. The sections below provide a brief summary of the analyses of bedload supply, transport, and channel change provided elsewhere. Bedload supply and transport are vital to the creation and maintenance of functional aquatic habitat. Natural river dynamics include transportation of coarse sediment (e.g., sand, gravel, cobble, and boulder) downstream. Natural sediment pulses that result from heavy rainfall and snowmelt events are incorporated by stream and river processes into spawning beds, gravel bars, side channels, pools, riffles, and floodplains that provide habitat and support food chains of aquatic species. These periodic inputs and movement of coarse sediment are necessary for the long-term maintenance of aquatic habitats. Salmonids evolved to depend on continued sediment delivery to provide substrate suitable for spawning and early rearing in streams and rivers. These natural processes have been disrupted in the Klamath River since the construction of dams.

Under existing conditions, dams have disrupted geomorphic and vegetative processes that can form channels and create spawning grounds downstream from Iron Gate Dam, by trapping sediment and preventing its transport downstream (Buer 1981, PacifiCorp 2004a, KRBFTF 1991). Since the construction of the Lower Klamath Project, sediment and gravel have been intercepted by Lower Klamath Project reservoirs, with Iron Gate Dam cutting off sediment supply from the Upper Klamath Basin. The resultant reduction in spawning gravels downstream of Iron Gate Dam has been identified as one of the causes of the decline in salmonid fry production in this reach of the Klamath River (Buer 1981). In response to this recognized limiting factor, the California Department of Water Resources developed (but never implemented) gravel augmentation programs for spawning gravel downstream from Iron Gate Dam (Buer 1981). Per the interim operations of the Klamath Hydroelectric Project HCP (PacifiCorp 2012), PacifiCorp developed and implemented a plan to augment gravel immediately downstream of Iron Gate Dam beginning in 2014 (PacifiCorp 2014). Per the interim operations of the Klamath Hydroelectric Project HCP (PacifiCorp 2012), PacifiCorp developed and implemented a plan to augment gravel immediately downstream of Iron Gate Dam beginning in 2014 (PacifiCorp 2014). Gravel augmentation occurred immediately downstream of Iron Gate Dam in 2014, 2016, and 2017, with approximately 4,600 cubic yards total placed downstream of the dam as of December 2017 (PacifiCorp 2018). The placed gravel has been moved downstream by high flows (PacifiCorp 2018), although additional details on the extent of downstream movement have not been reported.

Water Quality

Section 3.2.2 *[Water Quality] Environmental Setting* provides information regarding existing conditions for water quality from J.C. Boyle Reservoir to the Klamath River Estuary, including those parameters that can directly affect beneficial uses for aquatic species (i.e., water temperature, suspended sediments, dissolved oxygen, pH, and algal toxins such as microcystin). Multiple waterbodies in the Area of Analysis, including the mainstem of the Klamath River, are listed under section 303(d) of the CWA for a variety of water quality parameters such as water temperature, sediment, nutrients, dissolved oxygen, pH, ammonia, chlorophyll-*a*, and microcystin (North Coast Regional Board 2011). Existing conditions for water temperature and algal toxins are evaluated in greater detail below with respect to implications on fish health and survival in the Klamath Basin. Microcystin toxin concentrations are also addressed in Section 3.2 *Water Quality* and Section 3.4 *Phytoplankton and Periphyton*.

Water Temperature

The Klamath River, from Keno Dam to the Klamath River Estuary, has been listed as impaired for water temperature (North Coast Regional Board 2011; see Section 3.2 *Water Quality* and Appendix C.1 of this EIR for discussion of existing water temperature conditions). Water temperatures in the Klamath River are of special concern as they are elevated with a greater frequency and remain elevated for longer periods of time than temperatures in adjacent coastal anadromous streams, and they are unsuitable in the lower mainstem for anadromous salmonids at times during the summer (Bartholow 2005). Acute thermal effects for salmonids are expected to occur as mean daily water temperatures begin to exceed 68°F (Bartholow 2005). These elevated temperatures are especially detrimental to anadromous species during the warmer portions of the year (ODEQ 2002). Bartholow (2005) expressed concern that if observed increases in water temperature over the last several decades in the mainstem Klamath River downstream from Iron Gate Dam, which may be related to the cyclic Pacific Decadal Oscillation, continue, some stocks may decline to levels insufficient to ensure survival of the population. Klamath River salmonids are generally more tolerant of high water temperatures than salmonids from other basins (FERC 2007, Foott et al. 2012). Moreover, NMFS (2006a) concluded that available evidence indicates that juvenile steelhead can withstand incrementally higher temperatures exceeding 71.6°F provided food is abundant and by finding thermal refuge or by living in areas where nocturnal temperatures drop below the thermal threshold. Elevated temperatures can affect the timing of different life-history events, altering migration patterns, delaying and shortening the spawning season, impairing reproductive success, reducing growth, and resulting in a reduction of the diversity in the timing of migration (Hamilton et al. 2011). High water temperatures can contribute to low dissolved oxygen events by reducing dissolved oxygen solubility and accelerating oxygen-demanding processes, and can facilitate the spread of disease (Wood et al. 2006). Stress associated with high water temperatures can make cold water species more vulnerable to disease and parasites, and have been associated with fish kills in the Klamath River downstream from Iron Gate Dam during low flow periods in late summer (Hardy and Addley 2001).

Upper Klamath River and Connected Waterbodies
Both Upper Klamath Lake and the Keno Impoundment/Lake Ewauna are relatively shallow and temperatures in both are generally warm during the late spring through early fall (FERC 2007). In the summer, instantaneous maximum water temperatures of 71.6 to 75.2°F are common in the upper three to six feet of Upper Klamath Lake, and temperatures can approach a maximum of 86°F near the surface (PacifiCorp 2004c). Although prolonged exposure to these high temperatures could be lethal for some species, the water temperature remains within tolerance criteria for migrating adult anadromous salmonids during migratory periods (i.e., not during summer) (Dunsmoor and Huntington 2006, Hamilton et al. 2011). Anadromous salmonids successfully navigated through Upper Klamath Lake to spawn in the Upper Klamath Basin prior to their access being blocked by the Lower Klamath Project. Temperatures in Upper Klamath Lake are cooler than those in the Klamath River downstream from Iron Gate Dam in the late summer and early fall when fall-run Chinook salmon are migrating. In addition, thermal refugia are available in this reach where fish can avoid high water temperatures. Upper Klamath Lake supports a population of redband trout that moves into cooler tributary habitats during the summer, but which have high growth rates while in the lake. Those in the lake over the summer can find thermal refuge in Pelican Bay, which is fed by springs and remains cool (Dunsmoor and Huntington 2006). Wetlands surround this bay and would be expected to provide juvenile salmonids with suitable rearing habitat (Dunsmoor and Huntington 2006).

The Keno Impoundment/Lake Ewauna has generally poor water quality in the summer, with instantaneous maximum water temperatures exceeding 77°F and low dissolved oxygen (Hamilton et al. 2011). These warm temperatures are also present downstream from Keno Dam. However, from November through mid-June, the reach from Link River Dam to Keno Dam is cooler (below 68°F) and meets criteria for migrating adult anadromous salmonids (Hamilton et al. 2011). Temperatures in the Link River and the Keno Impoundment/Lake Ewauna tend to increase in the summer; however, maximum water temperatures (71.6 to 77°F) are still within the preferred range for warm- and some cold-water species found in the Upper Klamath Basin (yellow perch, catfish, sunfish, largemouth bass, and spotted bass).

Upper Klamath River – Hydroelectric Reach

Water temperatures in the Hydroelectric Reach are generally warm in the Lower Klamath Project reservoirs from late spring through early fall, but tributaries in this reach are generally cool. In addition, numerous cold-water springs contribute flows to both Copco No. 1 and Iron Gate reservoirs. Average monthly water temperatures within reservoirs from 2001 to 2004 ranged from just over 41°F in November to more than 71.6°F in June through August (FERC 2007), with thermal stratification in Copco No. 1 and Iron Gate reservoirs resulting in relatively warm discharge waters during summer months. Water temperatures at the downstream end of the J.C. Boyle Bypass Reach and in the Klamath River upstream of Shovel Creek are consistently cooler than other sites sampled between Link Dam and the Shasta River (PacifiCorp 2004b). Temperatures in the J.C. Boyle Bypass Reach are cooled by the contribution of 200 to 250 cfs of groundwater at a relatively constant 51.8 to 53.6°F within the reach (PacifiCorp 2006, Kirk et al. 2010). The input from the Bypass Reach during the summer results in a relatively lower daily water temperature range in the Klamath River in the J.C. Boyle Peaking Reach (FERC 2007).

Further downstream in the Peaking Reach, near the confluence of the Klamath River and Shovel Creek (Figure 3.3-1), there are natural hot springs that contribute flows to the mainstem river. The natural hot springs were not found to result in consistent substantial warming of the Klamath River based on two sets of measurements made in November and December 2017 (KRRC 2018). Water temperature data collected upstream and downstream of the confluence of the Klamath River and Shovel Creek showed a 1.4˚F increase in the downstream direction during the November 2017 measurement, but a 0.2˚F decrease during the December 2017 measurement (KRRC 2018). Water temperatures in Shovel Creek itself are generally low year-round, with reported values consistently below 59°F in the summer (PacifiCorp 2004a). Water temperatures recorded in Shovel Creek in late fall/early winter 2017 were 46°F (on November 1) and 39.9°F (December 5) (KRRC 2018).

Temperature data for other tributaries entering the Hydroelectric Reach are based on a limited study period (between 2001 and 2003) (PacifiCorp 2004c). Fall Creek, which flows into Iron Gate Reservoir, is generally cold year-round and does not exceed 57.2°F during the summer (PacifiCorp 2004c). Temperatures in Jenny Creek, which also flows into Iron Gate Reservoir, vary seasonally, ranging from less than 50°F in the spring to more than 71.6°F in July and August (PacifiCorp 2004c). As noted above, temperatures in Shovel Creek are generally low year-round and do not exceed 59°F in the summer (PacifiCorp 2004c). Spencer Creek temperatures are low during spring (<59°F) and are generally below 64.4°F, but can exceed 68°F for short durations (PacifiCorp 2004c).

Iron Gate and Copco No. 1 reservoirs are the two deepest reservoirs in the Hydroelectric Reach. These reservoirs thermally stratify each year beginning in April/May and the warmer (64.4°F to 73.4°F) surface and colder (46.4°F to 62.6°F) bottom waters do not mix again until October/November (see also Section 3.2.2.2 *Water Temperature*). Surface waters in these reservoirs reach maximum temperatures exceeding 77°F during the summer (PacifiCorp 2004c). Colder water temperatures occur at depths greater than six to ten meters below the reservoir surfaces during periods when the reservoirs are stratified (see Appendix C, Section C.1.1.1 and Figure C-1) (PacifiCorp 2004c, Asarian and Kann 2011). The powerplant intakes in both reservoirs are relatively shallow, at approximately nine to ten meters below the surface, such most of the reservoirs' discharge waters are from the warmer surface waters. Consequently, discharges from Copco No. 1 and Iron Gate reservoirs increase late summer/fall water temperatures downstream of Iron Gate Dam by approximately 4˚F to 18˚F (approximately 2˚C to 10˚C) (see also *Middle and Lower Klamath River*). Further, even though Copco No. 1 and Iron Gate reservoirs retain large volumes (approximately 9,000 acre-feet and 23,000 acre-feet, respectively) of colder bottom waters during periods of stratification, these waters are typically hypoxic (dissolved oxygen less than 2 mg/L), particularly in Copco No. 1 Reservoir (Appendix C, Section C.4.1.1). Although summertime water temperatures documented in the Hydroelectric Reach are within the tolerance ranges of the species observed there (e.g., perch, bass), these temperatures regularly exceed the range of chronic effects temperature thresholds (approximately 55 to 68°F [13 to 20°C]) for full salmonid support in California (North Coast Regional Board 2010).

Middle and Lower Klamath River

The large thermal mass of the stored water in Copco No. 1 and Iron Gate reservoirs delays the natural warming and cooling of riverine water temperatures on a seasonal basis such that spring water temperatures in the Middle Klamath River immediately downstream of Iron Gate Dam are generally cooler than would be expected under natural conditions, and summer and fall water temperatures are generally warmer (Figure 3.2-3; see also Section 3.2.2.2 *Water Temperature*). This "thermal lag" diminishes downstream from Iron Gate Dam, and there is no noticeable alteration in water temperatures by just upstream of the Salmon River confluence. Summer weather conditions can be very hot from June through September and rising ambient air temperatures can lead to increased water temperatures (Hamilton et al. 2011). Downstream from Iron Gate Dam, monthly mean temperatures in the river are 37.4 to 42.8°F in January and 68 to 72.5°F in July and August (Bartholow 2005). Substantial losses of juvenile salmonids have occurred during their migration through the Lower Klamath River, and losses were especially severe during low-water years with periods of sustained high-water temperatures. Exposure to high water temperature reduces the resistance of these fish to disease and other stressors (Scheiff et al. 2001, Ray et al. 2014). Consequently, during periods of high water temperature juvenile salmonids have been observed to crowd into areas with suitable water temperature such as at tributary confluences (thermal refugia). Summary statistics compiled by the United States Environmental Protection Agency (USEPA) indicate that water temperatures at locations between Iron Gate Dam and the Klamath River's confluence with the Scott River range from about 60.8 to 71.6°F in June, and from 60.8 to 78.8°F in July (FERC 2007). From May through September (peaking in June–August) summer water temperatures in the Lower Klamath Basin begin to warm to stressful levels for cold water species such as salmon, steelhead, and Pacific lamprey.

Klamath River Estuary and Pacific Ocean Nearshore Environment

Water temperatures in the estuary range from 41 to 53.6°F from December through April (Hiner 2006). Warmer air temperatures and lower flows in summer and fall months result in increased water temperatures ranging from 68 to 75.2°F (Wallace 1998) or greater than 75.2°F (Hiner 2006). When flows become low during some summer conditions, water temperatures in the Klamath River Estuary sometimes exceed criteria for optimal growth, and occasionally are warm enough to result in potential mortality for Chinook salmon, coho salmon, and steelhead (Stillwater Sciences 2009a). However, observed warm water conditions in the Klamath River Estuary are typically short in duration, due to input of cool ocean water and a high prevalence of coastal fog. Water temperatures in the Pacific Ocean nearshore environment are moderated by the Pacific Ocean currents and patterns that appear unrelated to the contribution of the Klamath River.

Disease and Parasites

Fish diseases, specifically the myxozoan parasites *Ceratomyxa shasta* (*C. shasta*) and *Parvicapsula minibicornis (P. minibicornis),* regularly result in substantial mortality of Klamath River salmon (Fujiwara et al. 2011, True et al. 2013); however, steelhead are generally resistant to *C. shasta*. Additional diseases that may affect fish in the Klamath Basin include *Ichthyophthirius multifis* (Ich) and *Flavobacterium columnare* (columnaris). These parasites and diseases occur throughout the watershed but appear to cause the most severe mortality in the mainstem Klamath River downstream from Iron Gate Dam where *C. shasta* has been observed to result in high rates of mortality in salmon (True et al. 2013). Ich and columnaris occasionally result in substantial mortality (e.g., the 2002 fish kill of primarily adult Chinook salmon, as discussed below).

Both *C. shasta* and *P. minibicornis* spend part of their life cycle in an invertebrate host and another part in a fish host (Figure 3.4-9). Transmission of these parasites is limited to areas where the invertebrate host is present. In the Klamath River, their invertebrate host is the annelid polychaete worm *Manayunkia speciosa* (Bartholomew et al. 1997, 2007). Once the polychaetes are infected, they release *C. shasta* and *P. minibicornis* actinospores into the water column. Actinospores are generally released when temperatures rise above 50°F and remain viable from three to seven days at temperatures from 51.8 to 64.4°F, with temperatures outside that range resulting in a shorter period of viability (Foott et al. 2007). The longer the period of viability, the wider the distribution of the actinospores within the river, and thus the higher the risk of exposure for salmon (Bjork and Bartholomew 2010). Actinospore abundance, a primary determinant of infectious dose, is controlled by the number of polychaetes and the prevalence and severity of infection within their population. The river channel downstream from Iron Gate Dam has been atypically stable since dam construction, and has provided favorable habitat for the polychaete worm host, likely increasing the parasite load to which the fish are exposed. High parasite loads are believed to lead to higher rates of mortality (Fujiwara et al. 2011). Ray et al. (2014) evaluated *in situ* juvenile salmonid exposure using sentinel cages. Studies found that increasing parasite concentrations and water temperatures were positively associated with the proportion of juvenile fish that experienced infection and mortality. Spore concentration and water temperature were more important determinants of exposure and mortality of juvenile Chinook and coho salmon, than was river flow. The location of peak actinospore concentrations varies among years, and Som et al. (2016a) report that the most frequent location of the peak in concentrations occurs near the confluence of Beaver Creek.

Figure 3.3-2. Lifecycle of *Ceratomyxa shasta*. Source: NMFS 2012.

Salmon become infected when the actinospores enter the gills, eventually reaching the intestines where the parasite replicates and matures to the myxospore stage. Myxospores are shed by the dying and dead salmon, and the cycle continues with infection of polychaete worms by the myxospores (Figure 3.4-9) (Bartholomew and Foott 2010). Som et al. (2016a) states that myxospores released from adult salmon carcasses contribute the bulk of myxospores to the system; mostly from carcasses upstream of the confluence with the Shasta River.

The polychaete host for the parasite is present in a variety of habitat types, including runs, pools, riffles, edge-water, and reservoir inflow zones, as well as sand, gravel, boulders, bedrock, aquatic vegetation, and it is frequently found among mats of filamentous periphytic algal species (e.g., Cladophora) that traps fine sediment and detritus (Bartholomew and Foott 2010).

The highest densities of polychaetes have been observed in slow-flowing and more stable, depositional habitats (e.g., pools with sand) (Bartholomew and Foott 2010), especially if instream flows remain constant. The mobilization of particles on the bed of the channel downstream from Iron Gate Dam depends directly upon the size of the substrate and magnitude of peak flows. The greater the flows, the larger the particles likely to be moved, and the smaller the particle, the lower the flow required for mobilization. Polychaetes are more persistent if the substrate remains immobile for long periods (on the order of years). Under historical conditions, frequent flood events and natural sediment supply, combined with considerable intra-annual flow variability, ensured that the substrate was frequently mobilized. Under existing conditions with dams in place, sediment supply is reduced, flow variability is decreased, and conditions supporting the persistence of polychaetes are more prevalent (Shea et al. 2016).

Susceptibility to *C. shasta* is also influenced by the genetic type of *C. shasta* encountered by the fish (Som et al. 2016a). Atkinson and Bartholomew (2010) conducted an analysis of the genotypes of *C. shasta* and the association of these genotypes with different salmonid species, including Chinook and coho salmon, steelhead, rainbow trout, and redband trout. In a genetic analysis, the *C. shasta* genotypes were characterized as Type 0, Type I, Type II, and Type III (Table 3.3-10). In the Williamson River, although parasite densities had been found to be high, sentinel Chinook salmon were resistant to infection because the genotype specific to Chinook salmon was absent (Hurst et al. 2012).

Table 3.3-10. *Ceratomyxa Shasta* Genotypes in the Klamath Basin.

***C. shasta* Genotype**	**Distribution**	**Affected Species**	**Notes**
Type 0	Upper and Lower Klamath Basin	native steelhead, rainbow, and redband trout	Usually occurs in low densities, is not very virulent, and causes little or no mortality
Type I	Lower Klamath Basin	Chinook salmon	If the Type I genotype were carried into the Upper Klamath Basin, only Chinook salmon would be affected
Type II	Klamath Lake, Upper and Lower Klamath Basin	coho salmon in Lower Klamath Basin and non-native rainbow trout	The “biotype” found in the Upper Klamath Basin does not appear to affect coho salmon in sentinel studies
Type III	Assumed widespread in Klamath Basin based on presence in fish	all salmonid species	Prevalence of this genotype is low and it infects fish but does not appear to cause mortality

Native populations of salmonids in waters where *C. shasta* is endemic generally develop a high degree of resistance to the disease. Stocking et al. (2006) conducted studies of the seasonal and spatial distribution of *C. shasta* in the Klamath River. The study included the exposure of fall-run Chinook salmon (Iron Gate Hatchery strain). The study found the polychaete host, *M. speciosa*, from Upper Klamath Lake to the mouth of the river. Although infection rates were high in non-native, non-resistant rainbow trout, used as sentinel fish in the upper Klamath River upstream of Iron Gate Dam and downstream from the Williamson River, mortality rates were very low (Stocking et al. 2006). Chinook salmon at this location did not become infected. Minimal mortality in both was likely due to low levels of parasites in this area and a predominance of Type 0 genotype of *C. shasta*. Because the parasites are endemic to the watershed, the native salmonid populations have some level of resistance to the disease.

Upper Klamath River and Connected Waterbodies

Many of the diseases and parasites described above can occur in the Upper Klamath River. *C. shasta* and *P. minibicornis* are both known to occur in the Upper Klamath Basin (NMFS 2006a), and *C. shasta* densities have been reported to be as high in the

Williamson River (Hurst et al. 2012) as in the area downstream from Iron Gate Dam (Hallett and Bartholomew 2006). However, in the section of the river upstream of J.C. Boyle Reservoir, *C. shasta* does not have the same serious effects as it does downstream from Iron Gate Dam, because of the genotype of the parasite (Type 0, II, and III) and the higher resistance of the redband trout to the disease. Historically *C. shasta* and *P. minibicornis* occurred in the Upper Klamath Basin and resident fish upstream of the dams evolved with these parasites (Hamilton et al. 2011). The current infectious zone and high parasite loads below Iron Gate Dam are the result of a synergistic effect of numerous factors (FERC 2007, Hamilton et al. 2011), including: (1) close proximity of myxospore-shedding carcasses (concentration of carcasses); (2) abundant polychaete populations that are found in atypically stable habitats; (3) suitable water temperatures (greater than 59°F) during periods when juvenile salmonids are present; and 4) low flow variability (Bartholomew and Foott 2010). This synergy would be unlikely in the Upper Klamath River (Hamilton et al. 2011), and the NMFS (2006a, USFWS/NMFS Issue 2(B)) concluded that the movement of anadromous fish upstream of Iron Gate Dam presents a relatively low risk of introducing pathogens to resident fish (e.g., redband trout, cutthroat trout).

Upper Klamath River – Hydroelectric Reach

As described above, Stocking et al. (2006) found the polychaete host for *C. shasta* and *P. minibicornis* throughout the mainstem Klamath River, including the reach from J.C. Boyle Reservoir to Iron Gate Dam (the Hydroelectric Reach), and within the Lower Klamath Project reservoirs. However, these polychaete populations are most abundant at reservoir inflow areas with densities decreasing with distance from reservoir/river interface, but not disappearing entirely (Stocking and Bartholomew 2007). In order for an area to develop as an infectious zone, several factors need to coincide, including microhabitats with low velocity, and stable flows, which are rare within this reach (Bartholomew and Foott 2010).

Middle and Lower Klamath River

In the Klamath River downstream of Iron Gate Dam, the polychaete host for *C. shasta* and *P. minibicornis* is aggregated into small, patchy populations. The reach of the Klamath River from the Shasta River to Seiad/Indian Creek is known to be a highly infectious zone with high actinospore exposure, particularly from May through August (Beeman et al. 2008, Bartholomew and Foott 2010). This portion of the river contains dense populations of polychaetes within low-velocity habitats with *Cladophora* (a filamentous green periphytic algae), sand-silt, and fine organic material in the substrate (Stocking and Bartholomew 2007). As described above, the reduced bedload mobility has increased the persistence of polychaetes under existing conditions (Som et al. 2016b). High parasite prevalence in the Lower Klamath River is considered to be a combined effect of high spore input from heavily infected, spawned adult salmon that congregate downstream from Iron Gate Dam and Iron Gate Hatchery, and the proximity to dense populations of polychaetes (Bartholomew et al. 2007). The highest rates of infection occur in the Lower Klamath River downstream from Iron Gate Dam, generally in the reach from Shasta River to Seiad (Stocking and Bartholomew 2007, Bartholomew and Foott 2010, Bartholomew et al. 2017).

Despite potential resistance to *C. shasta* and *P. minibicornis* in native populations, salmon exposed to high levels of the parasite may be more susceptible to disease—particularly juvenile salmon, and more so at higher (>59ºF [>15ºC]) water temperatures. In summarizing data collected from 2005 through 2008, Bartholomew and Foott (2010) reported that juvenile Chinook and coho salmon migrating downstream had infection rates as high as 90 percent and 50 percent, respectively. During April to August 2009 True et al. (2010) found 54 percent of juvenile Chinook salmon in the Klamath River upstream of the confluence with the Trinity River had parasitic infection from *C. shasta*, and 85 percent were infected with *P. minibicornis*. Water temperatures were not reported. During April to August 2012 True et al. (2013) found 30 percent of juvenile Chinook salmon in the Klamath River upstream of the confluence with the Trinity River had parasitic infection from *C. shasta*, and 69 percent were infected with *P. minibicornis.* True et al. (2013) reported that both *C. shasta* prevalence of infection increased in 2012 compared to 2011 (2011 results not reported). Environmentally, 2012 consisted of a relatively normal temperature profile for the Klamath River. No manipulated pulse flow from Iron Gate Dam (as in 2011) or extended period of precipitation (as in 2010) occurred. True et al. (2013) concluded that the typically warm river temperatures (59–75.2°F) observed in May–July, coupled with earlier high *C. shasta* actinospore densities (May versus June in 2011) in the infectious zone, resulted in an increase in annual infection prevalence compared to the previous monitoring year. Overall, the 2012 annual infection prevalence for juvenile Chinook salmon during outmigration was relatively moderate compared to historical levels observed for the monitoring program (2006–2011).

High disease infection rates are apparently resulting in high mortality of outmigrating smolts. Studies of outmigrating coho salmon smolts by Beeman et al. (2008) estimated that mortality rates were between 35 and 70 percent in the Klamath River near Iron Gate Dam. Their studies also suggested that higher spring discharge increased smolt survival (Beeman et al. 2008).

Between May and July 2004, the USFWS, the Yurok Tribe, and the Karuk Tribe reported high levels of mortality and disease infections among naturally-produced juvenile Chinook salmon captured in downstream migrant traps fished in the Klamath River (Nichols and Foott 2005). Visible symptoms observed included bloated abdominal cavities, pale gills, bloody vents, and pop-eye. Infected fish also exhibited lethargic behavior, poor swimming ability and increased vulnerability to handling stress. The primary cause of the disease was found to be *C. shasta*, with *P. minibicornis* observed as well. Weekly prevalence of *C. shasta* infection for all sites combined ranged from 15 to 56 percent, with the peak observed in fish captured in late May. Expanding from the trap efficiency data the authors estimated 45 percent of the population passing Big Bar was infected with *C. shasta.* Weekly prevalence of *P. minibicornis* infection for all sites combined ranged from 36 to 93 percent with the peak observed in fish captured on mid-June. Expanding from the trap efficiency data the authors estimated 94 percent of the population passing Big Bar was infected with *P. minibicornis.* The authors concluded that the high incidence of dual myxozoan infection (98 percent of *Ceratomyxa* infected fish), and associated pathology suggested that most of the *C. shasta* infected juvenile Chinook salmon would not survive. The 2004 mortality event was not quantified because of limited resources and other problems associated with sampling small fish in a large river system.

Other recent fish kills include the June 1998 and June 2000 fish kills. CDFG (2000) estimated 10,000 to 300,000 individuals, mostly young-of-year, killed in the June 2000 event. CDFG (2000) stated that, "we did not attempt to systematically or statistically quantify total [young of the year] chinook and steelhead mortality. CDFG's initial assessment of mortality in the "tens of thousands" range should be considered a very conservative minimum. I [CDFW staff] believe many more fish died than we originally observed during our surveys because of the time period involved (mid-to-late June; approximately three weeks) and the apparent high rate of scavenging (dead fish being quickly consumed and therefore unavailable for observation). It is probable that a number on an order of magnitude greater (i.e., >100,000 to 300,000) may be more realistic."

The cause of the 2000 fish kill was believed to be infection with *C. shasta* and columnaris. For comparison, in 2010 through 2012, years with lower river temperatures and conditions less conducive to disease infection, prevalence of *C. shasta* in emigrating juvenile Chinook salmon during the peak migration period was less than 30 percent (True et al. 2013).

For adult salmon, disease has been less frequent and of a different nature. Ich, a protozoan parasite that spreads horizontally from fish to fish, and columnaris have occasionally had a substantial impact, particularly when habitat conditions include exceptionally low flows, high water temperatures, and high densities of fish (such as adult Chinook salmon migrating upstream in the fall and holding at high densities in pools). For adult salmon the effects of Ich and columnaris are generally not as harmful as the observed effects of the myxozoan parasites on juveniles, although the 2002 fish kill in the Lower Klamath River provided dramatic evidence of the ability of Ich and columnaris to cause significant adult salmon mortality, with more than 33,000 adult salmon and steelhead lost during a disease outbreak (CDFG 2004). Most of the fish affected by the 2002 fish die-off were fall-run Chinook salmon in the lower 36 miles of the Klamath River (CDFG 2004). Based on a review of available literature and historical records, this was the largest known pre-spawning adult salmonid die-off recorded on the Klamath River and possibly the Pacific Coast (USFWS 2003). Subsequent reviews of the 2002 fish kill by CDFG (2004), NRC (2004), and USFWS (2003) determined several factors contributed to the epizootic outbreak of Ich and columnaris. An above-average number of Chinook salmon entered the Klamath River during this period. Flows in September 2002 were among the lowest recorded in the last 50 years (CDFG 2004), which may have caused crowding in holding areas that increased transmission of disease. Low flows can also be associated with high water temperature and lower than normal dissolved oxygen concentrations (NRC 2004). While high temperatures may have contributed to the fish kill, temperatures were not unusually high in 2002 when compared to the historical record (Belchick et al. 2004). There is little historical data on dissolved oxygen, but it has been monitoring since 2001—and dissolved oxygen concentrations were similar in 2001 and 2002. During the 2002 fish kill, dissolved oxygen concentrations did not fall below 6.0 mg/L and were eliminated as a potential cause (Belchick et al. 2004). Low river discharges were apparently unsuitable for migrating adult salmon, resulting in a large number congregating in the warm water of the Lower Klamath River (USFWS 2003). Fish passage may also have been impeded by low flows, contributing to crowding (CDFG 2004). The NRC did not rule out low flows as a contributing factor but hypothesized that high water temperatures may have also inhibited the fish from moving upstream (NRC 2004). Whether inhibited by low flows, high temperatures, or both, fish in the Lower Klamath River stopped migrating upstream, resulting in crowded, stressful conditions and possibly longer residence times in a confined reach of the river. Belchick et al. (2004) states that "consideration of all pertinent data led to the conclusion that in 2002 a relatively robust run of adult fall Chinook entered the Klamath River approximately one week earlier than usual. Environmental conditions in the River at the time of the 2002 fall-run Chinook salmon run were characterized by low flow rates and volume, and an apparent lack of migration cues to proceed upriver. The resultant migration delay, crowded conditions, and warm water temperatures provided an ideal environment for the proliferation of Ich and columnaris.

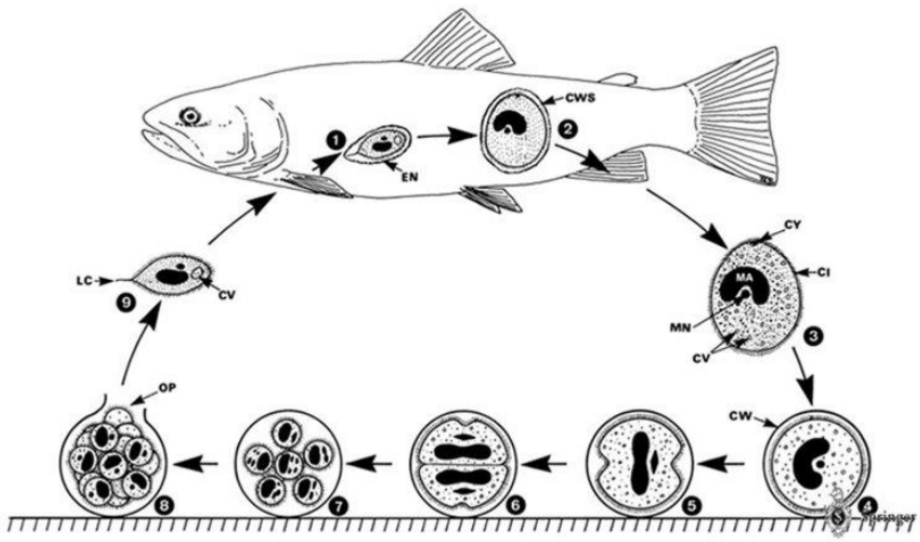


Figure 3.3-3. Lifecycle of *Ichthyophthirius multifis* (Ich). In stages 1 and 2 the adult parasite lives within the fish host; in stage 3 the adult parasite is motile outside of the host fish and attaches to a bottom substrate before dividing into an immature form; in stages 4 through 8 the immature form divides numerous times and is then released as stage 9, the infective stage of the parasite. Source: Strange 2010.

Although losses of adult salmonids can be substantial when events such as the 2002 fish die-off occur, the combination of factors that leads to adult infection by Ich and columnaris disease are not be as frequent as the annual exposure of juvenile salmon to *C. shasta* and *P. minibicornis*, as many juveniles must migrate each spring downstream past established populations of the invertebrate polychaete worm host.

FERC (2007) concluded that the Klamath Hydroelectric Project has likely contributed to conditions that foster disease and lead to salmon losses in the Middle and Lower Klamath River by (1) increasing the density of spawning adult fall-run Chinook salmon downstream from Iron Gate Dam; (2) promoting the development of attached algae beds that provide favorable habitat for the polychaete alternate host for *C. shasta* and *P. minibicornis*; and (3) contributing to water quality conditions that increase the stress level of juvenile and adult salmonids and increase their susceptibility to disease. The water quality conditions that may increase stress levels include: (1) increased water temperatures in the late summer and fall; (2) elevated ammonia concentrations and swings in dissolved oxygen and pH associated with algal blooms in project reservoirs; and (3) effects of exposure to elevated levels of microcystin produced from microcystis blooms in Klamath Hydroelectric Project reservoirs, which may also result in direct mortality. Dissolved oxygen and pH dynamics, including dissolved oxygen concentrations that do not meet the Basin Plan minimum dissolved oxygen criteria and pH concentrations that exceed the Basin Plan instantaneous maximum of 8.5 s.u., for the Hydroelectric Reach, the Middle and Lower Klamath River, and the Klamath River Estuary, are discussed in Section 3.2.2.5 *Dissolved Oxygen* and Section 3.2.2.6 *pH.* A discussion of fish exposure to microcystin toxin in the Hydroelectric Reach and the Klamath River downstream from Iron Gate Dam is presented below in Section 3.3.2.3 *Habitat Attributes Expected to be Affected by the Proposed Project – Algal Toxins*. Seasonal production of ammonia occurs in the hypoxic (dissolved oxygen less than 2 mg/L) or anoxic (no dissolved oxygen) bottom waters of Copco No. 1 and/or Iron Gate reservoirs on a seasonal basis. But, no actual ammonia toxicity events have been reported in the reservoirs or in the Middle Klamath River downstream from Iron Gate Dam, and no acute or chronic toxicity exceedances of Basin Plan criteria for ammonia have been observed in the river (Appendix C – *Sections C.3.11* and *C.3.2.1*).

In 2013, NMFS and USFWS issued a joint BiOp (NMFS and USFWS 2013) of the proposed operations of the Klamath Irrigation Project by the USBR in Klamath County in Oregon, and Siskiyou and Modoc counties in California. In this 2013 BiOp, NMFS concluded that flow variability would increase mainstem Klamath River flows when precipitation and snow melt is occurring in the Upper Klamath Basin, which would help to dilute actinospore concentrations and/or disturb polychaetes and their habitats. In addition, it found that flow variability would provide dynamic fluvial environments in the mainstem Klamath River that may impair polychaete fitness, reproductive success, or infection with *C. shasta* and *P. minibicornis*. Compared to observed conditions during the period of record, NMFS concluded that proposed operations of the Klamath Irrigation Project under the 2013 BiOp would increase the magnitude and frequency of peak flows, which would likely decrease the abundance of polychaetes in the spring and summer following a channel maintenance flow event (NMFS and USFWS 2013). The proposed operations of the Klamath Irrigation Project would increase the magnitude and frequency of channel maintenance flows between 5,000 and 10,000 cfs relative to the observed period of record (e.g., the Klamath Irrigation Project would have an estimated two-year flood frequency of 5,454 cfs whereas the observed period of record had 5,168 cfs). This conclusion is also supported by the analysis of Shea et al. (2016), who examined the flow history in the Klamath River relative to sediment mobilization. The increase in magnitude and frequency of channel maintenance flows between 5,000 and 10,000 cfs would likely decrease the abundance of polychaetes in the spring and summer following a channel maintenance flow event (NMFS and USFWS 2013, Alexander et al. 2016, Som et al. 2016b). In the 2013 BiOp, NMFS concluded that the increase in magnitude and frequency of channel maintenance flows between 5,000 and 10,000 cfs would likely decrease the actinospore concentrations relative to the observed period of record when the channel maintenance flow event occurs in the spring, particularly in May and June.

However, the first years of 2013 BiOp implementation included severe drought conditions, and although the USBR was operating the Klamath Irrigation Project in accordance with the 2013 BiOp, the infection rate for *C. shasta* in the Klamath River downstream of Iron Gate Dam greatly exceeded the incidental take maximum (U.S. District Court 2017a). As described in Section 3.1.6 *Summary of Available Hydrology Information for the Proposed Project*, this led to a court-order requiring USBR to provide, as necessary, three specific flows in the Klamath River, as measured immediately downstream of Iron Gate Dam: annual winter-spring surface flushing flows, biennial winter-spring deep flushing flows, and spring-summer emergency dilution flows, if needed (U.S. District Court 2017a–c). The court-ordered flushing flows and emergency dilution flows are not part of existing conditions for the Proposed Project, because they went into effect after the Notice of Preparation was filed by the State Water Board in December 2016, and because the data evaluating the effectiveness of flows and their potential impacts is not yet robust. The flushing and emergency dilution flows are detailed in Section 4.2.1.1 *Summary of Available Hydrology Information for the No Project Alternative* as part of the No Project Alternative because they would likely only continue to apply if Iron Gate Dam remains in place, or if a nidus remains despite dam removal (these flows are also discussed in Section 4.4 *Continued Operations with Fish Passage Alternative*).

Klamath River Estuary and Pacific Ocean Nearshore Environment

While disease and parasites occur in the Klamath River Estuary and Pacific Ocean nearshore environment, these areas are not known to be important source areas for these stressors. Juvenile salmonids that are weakened by disease or parasites upstream may succumb to those diseases once they enter the estuary or ocean as a result of the additional stress created by adapting to the saline environment, but there is no evidence or observations of disease effects in this environment to date.

Fish Hatcheries

Under existing conditions, there are two fish hatcheries located along the Klamath River: Fall Creek Hatchery and Iron Gate Hatchery. Fall Creek Hatchery was built in 1919 by the California Oregon Power Company in Fall Creek, near its confluence with the Klamath River (RM 200.3), as compensation for the loss of spawning grounds that occurred with the construction of Copco No. 1 Dam. Fall Creek Hatchery facilities were last used by CDFW periodically from 1979 to 2003 to raise Chinook salmon yearlings. Fall Creek Hatchery yearlings were released into the Klamath River at Iron Gate Hatchery. Although many of the Fall Creek Hatchery facilities remain operable, the hatchery has not produced fish since 2003 when all fish production was moved to Iron Gate Hatchery.

Iron Gate Hatchery is part of the Lower Klamath Project and was originally constructed in 1962 as mitigation for blockage of fish passage caused by the construction of Iron Gate Dam. Iron Gate Hatchery facilities are located approximately 0.5 miles downstream of Iron Gate Dam, adjacent to the Bogus Creek tributary. CDFW operates Iron Gate Hatchery with the following annual production goal (CDFW 2014):

- 75,000 yearling coho salmon (age-1 releases during spring)
- 900,000 yearling fall-run Chinook salmon (age-1 releases during fall)
- 5,100,000 fall-run Chinook salmon smolts (age-0 releases during spring)
- 200,000 yearling steelhead (age-1 releases during spring)

However, the ability to meet the above production goals varies annually based on adult returns and hatchery performance. Coho salmon production has averaged 75,000 yearlings (achieving production goals) and 866 adult returns on an annual basis (CDFW 2014). Coho returns to Iron Gate Hatchery have significantly and steadily declined from a high of 2,466 adults in the 2001/2002 return year to a low of 38 adults in the 2015/2016 return year (CDFW 2016b). From 2005 through 2018 actual fall-run Chinook salmon yearling production has averaged 955,931 (exceeding production goals), and actual smolt production has averaged 4,276,728 (around a million fewer smolts than the goal on average) (K. Pomeroy, CDFW, pers. comm., 2018). The fall-run Chinook salmon hatchery spawner return goal is 8,000 fish. Total Chinook salmon returns to Iron Gate Hatchery between 1978 and 2016 ranged from 2,558 to 72,474 and averaged

16,206 fish (CDFW 2017). From 2000 to 2016, adult winter steelhead returns to Iron Gate Hatchery averaged 242, and peaked at 631 in 2001 (CDFW 2016b). Returns have been declining, and in 2016 no adult steelhead returned to the hatchery (CDFW 2016b). The low adult returns of steelhead have resulted in no production of steelhead yearlings from Iron Gate Hatchery since 2012.

It appears that progeny from Iron Gate Hatchery releases have contributed significantly to the ocean and in-river fisheries since the late 1960s (PacifiCorp 2004a). PacifiCorp (2004a) estimates that based on smolt-to-adult survival studies conducted on Iron Gate fall Chinook salmon, the Iron Gate Hatchery production contributes about 50,000 fish annually to the Chinook salmon, coho salmon, and steelhead fisheries, in addition to escapement back to the hatchery.

The net effect of hatchery releases on naturally occurring stocks is difficult to assess, with both positive and negative consequences potentially occurring due to a multitude of factors including, brood stock source, system carrying capacity, timing of release, degree of competition, and environmental selection pressures (NMFS 2017), as discussed below. Potential benefits of hatchery releases include increases in adult abundance supporting fisheries and increased marine-derived nutrient transfer to freshwater systems from returning hatchery-origin adults (NMFS 2017). Potential negative effects include genetic risks, competition and predation, hatchery facility effects on water quality, effects of weirs and other hatchery infrastructure, masking of current wild population status due to the presence of large numbers of hatchery-origin fish, incidental fishing pressure, and disease transfer from hatchery to wild fish. CDFW (2014) noted that in the Klamath River, adverse hatchery-related effects pose a very high stress to all life stages of natural salmon populations because hatchery origin adults make up greater than 30 percent of the total number of adults. Data from Ackerman et al. (2006) indicate that substantial straying of Iron Gate Hatchery fish may be occurring into important tributaries of the Middle Klamath River. Straying has the potential to reduce the reproductive success of natural salmonid populations (Mclean et al. 2003, Chilcote 2003, Araki et al. 2007) and negatively affect the diversity of the populations via outbreeding depression[85] (Reisenbichler and Rubin 1999). Returns of adult salmon to Iron Gate Hatchery, and fall-run Chinook salmon in particular, influence aquatic resources in the Middle and Lower Klamath River. 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 origin decreased with distance from the hatchery. Natural origin Chinook sampled in Bogus Creek (RM 192.6), Shasta River (RM 179.5), and the Scott River (RM 145.1) had decreasing proportions of hatchery genetics with increasing distance from the hatchery. The influence of Iron Gate Hatchery genetics on fall Chinook salmon is greatly diminished by the confluence with the Scott River.

A Hatchery Genetic Management Plan (HGMP) for the Iron Gate Hatchery (CDFW 2014) recently redefined the operation of this hatchery from a mitigation hatchery to one now operated to protect and conserve the genetic resources of the Upper Klamath population unit of the SONCC coho salmon ESU. Included in the HGMP are defined monitoring and evaluation activities to evaluate effects of the hatchery activities on the abundance, productivity, spatial structure, and diversity of the SONCC coho salmon and

[85] Outbreeding depression is the displacement of locally adapted genes in a wild population.

the magnitude or relative impact of the hatchery program on other actions that influence SONCC coho salmon.

Fall-run Chinook salmon returns to Iron Gate Hatchery and the blockage created by Iron Gate Dam, concentrate spawners and post-spawn carcass densities between Iron Gate Dam and the Shasta River confluence. As described in the *Disease and Parasites* section above, high parasite prevalence in the Lower Klamath River is considered to be a combined effect of high spore input from heavily infected, spawned adult salmon that congregate downstream from Iron Gate Dam and Iron Gate Hatchery and the proximity to dense populations of polychaetes (Bartholomew et al. 2007).

The release of Chinook salmon smolts and yearlings from Iron Gate Hatchery also affects disease interactions. The release from Iron Gate Hatchery overlaps temporally and spatially with the period of high infection potential, and studies suggest that therefore a high proportion of the Iron Gate Hatchery Chinook salmon stock can become infected with *C. shasta* and *P. minibicornis* (Som et al. 2016a). The hatchery-released juvenile fish that become infected and experience mortality lower in the Klamath River may become another source of myxospores to the Lower Klamath River.

The Chinook salmon released to the Klamath River annually also likely result in deleterious effects on natural spawning populations, including competitive pressure between hatchery-derived and natural origin fish in the limited habitat areas (e.g., thermal refugia) used by rearing juveniles in the Klamath River (NMFS 2010a). Iron Gate Hatchery releases Chinook salmon from the middle of May to the end of June, a period when discharge from Iron Gate Dam is in steep decline and water temperatures are rapidly rising, which may create competition between hatchery and natural fish (Chinook salmon, coho salmon, and steelhead) for food and limited resources, especially limited space and resources in thermal refugia (NMFS 2010a). Negative hatchery effects due to competition, leading to displacement and lower growth, are well documented (Flagg et al. 2000, McMichael et al. 1997). In the Clackamas River, Oregon, hatchery steelhead released in the upper basin resulted in an exceedance of system carrying capacity, resulting in negative outcomes for natural-origin fish (Kostow et al. 2003 and Kostow and Zhou 2006) and up to a 50 percent decline in the number of recruits per spawner and a 22 percent decline in the maximum number of natural-origin recruits. These trends appear to have reversed after releases of hatchery fish were discontinued in 2000. Such density-dependent negative effects of hatchery-released fish can extend even into the marine environment, especially during periods of poor ocean conditions (Beamish et al. 1997, Sweeting et al. 2003).

Algal Toxins

Algae produced in Upper Klamath Lake and the reservoirs in the Klamath Hydropower Reach (Copco No. 1 and Iron Gate reservoirs) may be deleterious to the health of aquatic organisms in Upper Klamath Lake and the Klamath River. Some cyanobacteria species, such as *Microcystis aeruginosa*, produce toxins that can cause irritation, sickness, or in extreme cases, death to exposed organisms (see Section 3.2.2.7 *Chlorophyll-a and Algal Toxins* and Appendix C.6). While direct links to fish health are still somewhat unclear, data collected from the Klamath Basin indicates that algal toxins bioaccumulate in tissue from fish and mussels at concentrations that may be detrimental to the affected species (Fetcho 2011), as discussed below.

While the Proposed Project would not affect the occurrence of algal toxins in Upper Klamath Lake, the following summary is provided to characterize ongoing research regarding the potential effects of microcystin toxin on native fish species in the Klamath Basin. A reconnaissance study was conducted in Upper Klamath Lake to evaluate the presence, concentration, and dynamics of microcystin exposure by Lost River sucker and shortnose sucker. The U.S. Geological Survey (USGS) collected water samples at multiple lake sites from July to October 2007 and June through September 2008 and found evidence of gastrointestinal lesions in juvenile suckers sampled from around the lake, although organ damage was absent from many fish and most of the affected fish were collected in the northern portion of the lake. The pathology of the lesions was consistent with exposure to microcystin, and evidence of a route of exposure was suggested by gut analysis showing that juvenile suckers had ingested chironomid larvae, which had in turn ingested *Aphanizomenon flos-aquae* and colonies of *Microcystis aeruginosa*. The lesions were observed when liver necrosis was either present or absent suggesting that the gastro-intestinal tract was the first point of toxin contact. The authors hypothesized that the lesions were caused by algal toxins, and that the route of exposure to toxins was an oral route through the food chain, rather than exposure to dissolved toxins at the gills (VanderKooi et al. 2010). However, there were other possible explanations for the lesions, including the potential for an undetected viral infection. Conclusive pathology experiments demonstrating that exposure of juvenile suckers to algal toxins via the described oral routes can cause the types of lesions observed have not yet been done. The pathologies and evidence therefore are consistent with the hypothesis of exposure to algal toxins but do not constitute proof of a causal mechanism. Additional work to describe the observed pathologies is ongoing.

In the Hydroelectric Reach and the Klamath River downstream from Iron Gate Dam, the occurrence of microcystin toxin in fish and mussel tissue has been reported in multiple studies with variable results depending on season, location, and fish species (Fetcho 2006; Kann 2008; CH2M Hill 2009a,b; Prendergast and Foster 2010; Kann et al. 2010 a,b; Kann et al. 2013; Fetcho 2011). During July through September 2007, 85 percent of fish and mussel tissue samples collected from the Klamath River, including samples from Iron Gate and Copco No. 1 reservoirs, exhibited microcystin bioaccumulation, with the total microcystin congeners ranging from less than detection levels to 2,803 ng/g (Kann 2008). While it is not known whether the levels of microcystin bioaccumulation measured in 2007 were harmful to fish and/or mussel populations, levels exceeded the public health guidelines defined by Ibelings and Chorus (2007), indicating that ingestion of the fish or mussels would potentially pose a health hazard to humans (Kann 2008). Within Copco No. 1 and Iron Gate reservoirs, samples of muscle and liver tissues from resident fish (e.g., yellow perch [*Perca flavescens*] and crappie [*Pomoxis nigromaculatus*]) exhibited detectable levels of two of eight microcystin congeners (i.e., chemically different forms of microcystin) in muscle and liver tissues of 36 yellow perch samples during September 2007 (Kann 2008). Unbound or “free” microcystin (the form of microcystin that could be further bioaccumulated if the fish were to be ingested by humans or other predators) was not detected in muscle tissues of yellow perch and crappie during May, June, July, September, and November 2008 (total samples = 196) (CH2M Hill 2009a). In 2010, algal toxins were found in salmonid tissues collected from the Middle Klamath River near Happy Camp (Kann et al. 2013). In contrast, data from 2008 and 2009 did not show microcystin bioaccumulation in the tissue and liver samples from fish collected from Copco No. 1 and Iron Gate reservoirs (CH2M Hill 2009, PacifiCorp 2010).

Further downstream in the Lower Klamath River, Fetcho (2006) reported that liver and muscle tissue samples from five Chinook salmon taken from the Klamath River at or near Weitchpec (near RM 43.3) in 2005 did not contain detectable levels of microcystin. However, two steelhead liver samples, collected on October 3, 2005 did contain measurable levels of microcystin at trace and 0.54 ug/g concentrations. PacifiCorp collected liver and muscle tissue samples from five Chinook salmon and three steelhead in the middle Klamath River and the Lower Klamath River downstream from the Trinity River in October 2007 and reported that no detectable levels of un-bound or "free" microcystin (the form of microcystin that could be further bioaccumulated if the fish were to be ingested by humans or other predators) were found (CH2M Hill 2009b). Because fish livers are not typically consumed, those fish exhibiting elevated microcystin levels in liver tissue may not have posed a public health concern with respect to consumption.

As noted above, while it is not known whether the levels of microcystin measured in the Lower Klamath River fish tissue samples were harmful to fish populations, the range of concentrations (up to approximately 2,800 ng/g) indicate that direct effects to fish health due to microcystin exposure such as stress and/or disease are a possibility (Kann et al. 2013). During the October period that Chinook salmon samples were collected, the 2010 longitudinal microcystin sampling in river water showed very high microcystin levels being exported from Iron Gate Reservoir and transported downstream to areas where Chinook salmon were migrating upstream. The variation in fish tissue results in Copco No. 1 and Iron Gate reservoirs and the Klamath River downstream from Iron Gate Dam across multiple studies suggests that a combination factors is likely to influence the concentration of microcystin in fish tissue, including patchy distributions of algal blooms within the Lower Klamath Project reservoirs and the downstream Klamath River, the ability of fish to move in and out of algal bloom areas where microcystin is likely most prevalent, and food web interactions that may result in differing degrees of bioaccumulation depending on the fish species.

Microcystin can also bioaccumulate in the tissue of mussels in the Lower Klamath River. Kann (2008) reported on the concentrations of eight individual microcystin congeners in freshwater mussel tissue samples obtained from the Klamath River in July and November 2007. Microcystin congeners were detected in July in composite and individual tissue samples from the Klamath River near the Klamath Highway Rest Area (at RM 178), near Seiad Valley (at RM 132.7) and at Big Bar (near RM 51). Individual mussel samples taken later in the year in November from the Klamath River near Orleans (at RM 59), near Happy Camp (at RM 108), near Seiad Valley (at RM 132.7), at the Brown Bear River Access (at RM 157.5), and near the Klamath Highway Rest Area (at RM 178) did not contain detectable levels of microcystin congeners. As noted above, 85 percent of fish and mussel tissue samples collected during July through September 2007 in the Klamath River, including Iron Gate and Copco No. 1 reservoirs, exhibited microcystin bioaccumulation (Kann 2008). While it is not known whether the levels of microcystin measured in the Lower Klamath River mussel tissue samples were harmful to mussel populations, results indicated that all of the World Health Organization (WHO) total daily intake guideline values were exceeded, including several observations of values exceeding acute total daily intake thresholds (Kann 2008). In a retrospective letter to PacifiCorp (August 6, 2008), the California OEHHA stated that they "would have recommended against consuming mussels from the affected section of the Klamath River, and yellow perch from Iron Gate and Copco No. 1 Reservoirs, because their average concentrations exceeded 26 nanograms per gram (ng/g)," which is the OEHHA upper bound of advisory tissue levels fish or shellfish consumption (for a single serving per week based on 8 ounces uncooked fish). Additional public health advisories were issued in 2009 and 2010 in Copco No. 1 and Iron Gate reservoirs, as well as downstream locations in the Klamath River (including locations on the Yurok Reservation), for microcystin levels in ambient and/or freshwater mussel tissue (Kann et al. 2010a,b, Fetcho 2011).

Aquatic Habitat and Instream Flows

Instream flows influence habitat availability for aquatic species. USBR manages Upper Klamath Lake to meet the requirements of the 2013 BiOp (NMFS and USFWS 2013)[86] and its contract requirements for USBR's Klamath Irrigation Project (USBR 2010). The Klamath Irrigation Project affects instream flows in the Klamath River downstream of Upper Klamath Lake, including the California portion of the Area of Analysis for aquatic resources. Studies to determine how fish habitat changes with flow have been conducted in portions of the Klamath River, including two reaches between J.C. Boyle Reservoir and Iron Gate Dam, for selected life stages of rainbow trout (BLM 2002) and seven locations between Iron Gate Dam and the Klamath River Estuary for selected life stages of Chinook salmon, coho salmon, and steelhead (Hardy et al. 2006).

The following sections describe the amount of flow-related aquatic species habitat in various portions of the Klamath. Where specific information is not available for a species or area, the analysis contained herein uses hydrologic changes, species habitat requirements, and comparisons with those species for which there is specific information to qualitatively assess changes in flow-related habitat. This information was used to evaluate how the Proposed Project might result in changes to the amount of flow-related habitat. It was not possible to rely on the hydrologic record of the past decade for describing the amount of habitat available under existing conditions because of management actions made over the past eight years to protect listed fish species (e.g., minimum Upper Klamath Lake elevations, minimum flows downstream from Iron Gate Dam). These changes are described in the 2013 BiOp for the Klamath Irrigation Project (NMFS and USFWS 2013), and the instream flows under existing conditions are described in Table 3.6-8 in Section 3.6.2.2 *Basin Hydrology*.

The natural hydrograph (flow regime) of a river is the characteristic pattern of flow quantity, timing, rate of change of hydrologic conditions, and variability across time scales (hours to multiple years), all without the influence of human activities (Poff et al. 1997). There are no measured river discharge data downstream from Keno Dam prior to implementation of USBR's Klamath Irrigation Project. However, modeled flows downstream of Iron Gate Dam that explicitly remove the Klamath Irrigation Project flow component offer a reasonable approximation of natural discharge downstream of Keno Dam (USBR 2005). Model results indicate that the historical, natural hydrograph for the Klamath River and its tributaries was characterized by high spring flows triggered by melting snow, typically near the end of April, followed by receding flows during summer months, and the base flow condition by September (NRC 2004). This recurring

[86] As described in Section 3.1.6 *Summary of Available Hydrology Information for the Proposed Project*, following implementation of the 2013 BiOp, a court-order required USBR to implement three specific flows in the Klamath River: winter-spring surface flushing flows, winter-spring deep flushing flows, and spring-summer emergency dilution flows (U.S. District Court 2017a–c). The court-ordered flushing flows and emergency dilution flows are not part of existing conditions for the Proposed Project, because they went into effect after the Notice of Preparation was filed by the State Water Board in December 2016.

seasonal flow pattern influenced the adaptations of native aquatic organisms, as reflected in the timing of their key life history stages (NRC 2004). Given the diversity of flows inherent to the natural hydrograph, the Klamath River historically supported a range of riverine habitats and allowed the various anadromous fish species and life history strategies to evolve over time.

Upper Klamath River and Connected Waterbodies

USBR manages Upper Klamath Lake to meet the requirements of the 2013 BiOp (NMFS and USFWS 2013)[87] and its contract requirements for USBR's Klamath Irrigation Project (USBR 2010). Aquatic habitat and instream flows in the Upper Klamath River upstream of the influence of J.C. Boyle Reservoir are not thoroughly analyzed for this EIR, since aquatic species within California are not heavily influenced by these flows other than through the operation of the USBR's Klamath Irrigation Project, where the latter is controlled through the requirements of the 2013 BiOp (see below discussions).

Upper Klamath River – Hydroelectric Reach

Under its existing license, PacifiCorp operates the J.C. Boyle Powerhouse as a peaking facility, meaning that water is run through the powerhouse to generate electricity cyclically depending on water availability and power demand. Rapid changes in flow associated with hydropower peaking operations, can result in inhospitable conditions for aquatic species downstream. Peaking operations at J.C. Boyle Powerhouse result in fluctuating flows in the Hydroelectric Reach of the Upper Klamath River that vary based on power generation needs. For example, substantial changes in flow (from 350 to 3,000 cfs) can occur within the course of a single day in the 17-mile long J.C. Boyle Peaking Reach (the reach of the Klamath River between J.C. Boyle Powerhouse and Copco No. 1 Reservoir). These flow fluctuations in this reach can also result in rapid temperature changes between 5 and 59°F during the summer months (ODEQ 2010). These flow fluctuations may also result in stranding of fish and invertebrates (Dunsmoor 2006), reductions in aquatic invertebrate production (City of Klamath Falls 1986, as cited in Hamilton et al. 2011), displacement of fish, and higher energetic costs to fish to maintain their position (FERC 2007). In the trial-type hearing for the relicensing of the Klamath Hydroelectric Project (NMFS 2006a), it was found that this reach had lower macroinvertebrate drift rates than would occur without the hydroelectric project operations, suggesting a reduced food base for fish.

Fish studies in the Lower Klamath River have shown considerable biological impacts due to power peaking flows (City of Klamath Falls 1986, FERC 2007, BLM 2002, Wales and Coots 1950). From June 1948 to May 1949, Wales and Coots (1950) estimated that hydropower peaking operations resulted in the loss of over 1.8 million salmonid fingerlings downstream from Copco No. 1 and Copco No. 2 dams. Daily mean flows fell below 100 cfs in the Klamath River downstream from Copco No. 2 Dam and near Fall Creek (USGS Gage No. 11512500) on fifty occasions between water years 1931 and 1937.

[87] As described in Section 3.1.6 *Summary of Available Hydrology Information for the Proposed Project*, following implementation of the 2013 BiOp a court-order required USBR to implement three specific flows in the Klamath River: winter-spring surface flushing flows, winter-spring deep flushing flows, and spring-summer emergency dilution flows (U.S. District Court 2017a–c). The court-ordered flushing flows and emergency dilution flows are not part of existing conditions for the Proposed Project, because they went into effect after the Notice of Preparation was filed by the State Water Board in December 2016.

Middle and Lower Klamath River

As described in Section 3.1.6.1 *Klamath River Flows under the Klamath Irrigation Project's 2013 BiOp*, the 2013 BiOp provides minimum flows downstream of Iron Gate Dam for the protection of coho salmon. The 2013 BiOp also includes an Environmental Water Account (EWA) with provisions for flow alterations to protect ESA-listed species, including the release of dilution/flushing water from Upper Klamath Lake to reduce juvenile coho salmon disease below Iron Gate Dam. Consultation with NMFS and USFWS has been reinitiated on the Klamath Irrigation Project in the Upper Klamath Basin (see Section 3.1.6 *Summary of Available Hydrology Information for the Proposed Project*). Additional detail on flows and habitat in the Middle and Lower Klamath River are provided in Section 3.6.2.2 *Basin Hydrology*.

Klamath River Estuary and Pacific Ocean

Aquatic habitat within the Klamath River Estuary is highly influenced by freshwater inflows from upstream, and physical processes in the estuary such as sand-berm dynamics at the river mouth. The Klamath River Estuary spans approximately four to five miles upstream of the mouth. Wallace (1998) notes the formation of a sill at the river mouth in late summer or early fall causing a standing water backup up to six miles upstream. During high tides, saltwater was observed in the summer and early fall from the mouth upstream, ranging approximately 2.5 to four miles depending on the time period in which samples were taken (Wallace 1998).

Water temperatures in the Klamath River Estuary are related to temperatures and flows entering the estuary, the presence and location of a salt water wedge, and the timing and duration of the formation of a sand berm across the estuary mouth. The salt water wedge is formed when the estuary mouth is open and denser salt water from the ocean sinks below the lighter fresh river water; the resulting wedge moves up and down the estuary with the daily tides. The salt water wedge results in thermal stratification of the estuary with cooler, high salinity ocean waters remaining near the estuary bottom, and warmer, low salinity river water near the surface. Input of cool ocean water and fog along the coast minimizes extreme water temperatures much of the time (see also Section 3.2.2.2 *Water Temperature*).

Critical Habitat

The ESA requires that USFWS and NMFS designate critical habitat[88] for the listed species they manage. Critical habitat has been designated for four species within the California portion of the Area of Analysis for aquatic resources: coho salmon, shortnose suckers, Lost River suckers, and eulachon. The endangered population of Southern Resident Killer Whales that includes Klamath River salmon in its diet is also discussed here, and critical habitat for green sturgeon is discussed as well, despite the exclusion of Klamath River from the critical habitat designation.

[88] The ESA defines critical habitat as "the specific areas within the geographical area occupied by the species, at the time it is listed, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and specific areas outside the geographical area occupied by the species at the time it is listed that are determined by the Secretary to be essential for the conservation of the species."

Coho Salmon

Critical habitat for the SONCC coho salmon ESU was designated on May 5, 1999 and includes the water, substrate, off-channel habitat, and adjacent riparian zones of estuarine and riverine reaches accessible to listed coho salmon between Cape Blanco, Oregon and Punta Gorda, California. Marine areas were excluded from the final critical habitat designation. "Accessible reaches" are defined as those within the historical range of the ESU that can still be occupied by any life stage of coho salmon. Specifically, in the Klamath Basin, all river reaches downstream from Iron Gate Dam on the Klamath River and Lewiston Dam on the Trinity River are designated as critical habitat (NMFS 1999b).

Features of critical habitat considered essential for the conservation of the SONCC ESU (NMFS 1997b) include (1) substrate, (2) water quality, (3) water quantity, (4) water temperature, (5) water velocity, (6) cover/shelter, (7) food, (8) riparian vegetation, (9) space, and (10) safe passage conditions. Primary Constituent Elements (PCEs) for SONCC coho salmon are described in NMFS (1999b) as follows: "In addition to these factors, NMFS also focuses on the known physical and biological features (PCEs) within the designated area that are essential to the conservation of the species and that may require special management considerations or protection. These essential features may include, but are not limited to, spawning sites, food resources, water quality and quantity, and riparian vegetation."

Shortnose Sucker and Lost River Sucker

The final designation of critical habitat for shortnose and Lost River suckers was published by the USFWS on December 11, 2012 (USFWS 2012). The proposed critical habitat area is within Klamath and Lake Counties, Oregon, and Modoc County, California. Critical habitat units include: (1) approximately 146 stream miles and 117,848 acres of lakes and reservoirs for Lost River sucker; and (2) approximately 128 stream miles and 123,590 acres of lakes and reservoirs for shortnose sucker (USFWS 2012).

The 2013 Revised Recovery Plan (USFWS 2013a) identifies a recovery unit for both shortnose and Lost River within the California portion of the Area of Analysis: the reservoirs along the Klamath River downstream of Keno Dam (including Copco No. 1, Copco No. 1, and Iron Gate reservoirs), known as the Klamath River Management Unit.

When proposing critical habitat, USFWS considers the physical and biological features essential to the conservation of the species which may require special management considerations or protection. These include, but are not limited to: (1) space for individual and population growth and for normal behavior; (2) food, water, air, light, minerals, or other nutritional or physiological requirements; (3) cover or shelter; (4) sites for breeding, reproduction, or rearing (or development) of offspring; and (5) habitats that are protected from disturbance or are representative of the historical, geographical, and ecological distributions of a species. PCEs are the specific elements of physical and biological features that are essential to the conservation of the species. The PCEs identified in the critical habitat designation are as follows: (1) water in sufficient depths and quantity; (2) spawning and rearing habitat; and (3) areas that contain abundant food (USFWS 2013a). The 2013 Revised Recovery Plan (USFWS 2013a) cites predominant threats to these suckers as lack of spawning habitat, continued loss of habitat, lake elevation fluctuations that reduce access to vegetated habitat, water diversions, competition and predation by introduced species, hybridization with other sucker species, isolation of remaining habitats, and drought. Degradation of water quality resulting from timber harvest, dredging activities, removal of riparian vegetation, and livestock grazing may also cause problems for these species (USFWS 2013a).

Green Sturgeon

In 2009, NMFS designated critical habitat for the Southern DPS of green sturgeon which encompasses all coastal marine waters of the United States less than 60 fathoms deep (approximately 360 ft) from Monterey Bay, California north to Cape Flattery, Washington. The estuary portion of the Eel and Klamath/Trinity rivers was specifically excluded from the critical habitat designation (NMFS 2009b). The Northern DPS of green sturgeon, the only DPS documented to occur in the Klamath Basin, is not federally listed and therefore critical habitat has not been designated for this DPS.

Eulachon

Critical habitat for the Southern DPS eulachon in the Klamath River was designated by NMFS on October 20, 2011 (NMFS 2011). NMFS designated approximately 539 miles of riverine and estuarine habitat in California, Oregon, and Washington within the geographical area occupied by the Southern DPS of eulachon. The designation includes 16 rivers and creeks extending from and including the Mad River, California to the Elwha River, Washington. NMFS did not include any nearshore marine or offshore areas in the Eulachon critical habitat designation. NMFS did not identify any unoccupied areas as being essential to conservation and thus, did not designate any unoccupied areas as critical habitat. Tribal lands were excluded from designation after evaluating the impacts of designation and benefits of exclusion associated with Tribal land ownership and management by the Tribes. NMFS excluded from designation all lands of the Lower Elwha Tribe, Quinault Tribe, Yurok Tribe, and Resighini Rancheria. These lands were excluded because designating these Tribes' Indian lands as critical habitat would have an impact on federal policies promoting Tribal sovereignty and self-governance. In the Lower Klamath River, designated critical habitat extends from the mouth of the Klamath River upstream to Omogar Creek, a distance of 10.7 miles, excluding tribal lands. The physical or biological features essential for conservation of this species include: (1) freshwater spawning and incubation sites with water flow, quality, and temperature conditions and substrate supporting spawning and incubation; (2) freshwater and estuarine migration corridors free of obstructions with water flow, quality and temperature conditions supporting larval and adult mobility, and with abundant prey items supporting larval feeding after the yolk sac is depleted; and (3) nearshore and offshore marine foraging habitat with water quality and available prey, supporting juveniles and adult survival.

Southern Resident Killer Whale

In November 2006, NMFS designated critical habitat for Southern Resident Killer Whales (NMFS 2006c). Critical habitat includes all waters seaward from a contiguous line delimited by the 20-foot depth relative to extreme high water within three designated areas: (1) the Haro Strait and waters around the San Juan Islands; (2) Puget Sound; and (3) the Strait of Juan de Fuca. Coastal and offshore areas have not been designated as critical habitat, though they are recognized as important for the Southern Resident Killer Whales. No critical habitat for Southern Resident Killer Whales occurs within the Area of Analysis for aquatic resources. However, the PCEs for Southern Resident Killer Whales includes: (1) water quality to support growth and development; (2) prey species of sufficient quantity, quality and availability to support individual growth, reproduction and development, as well as overall population growth; and (3) passage conditions to allow for migration, resting, and foraging.

Within the Area of Analysis, the PDE for "prey species" is relevant. During winter, two of the three pods of Southern Resident Killer Whales (named the K and L Pods) frequent the outer west coast of the United States as far south as California, eating Columbia/Snake River, Central Valley, Puget Sound, Fraser River, and other coastal stocks of Chinook salmon. While Southern Resident Killer Whales have been shown to consume Klamath River Chinook Salmon, the Klamath River is considered by NMFS and WDFW tenth out of the top ten priority Chinook Salmon populations for Southern Resident Killer Whales (NMFS 2018b, NMFS and WDFW 2018).

Essential Fish Habitat (EFH)

EFH is designated for commercially fished species under the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (Magnuson-Stevens Act). The Magnuson-Stevens Act (section 3) defines EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." Adverse effects occur when EFH quality or quantity is reduced by a direct or indirect physical, chemical, or biological alteration of the waters or substrate, or by the loss of (or injury to) benthic organisms, prey species and their habitat, or other ecosystem components. The Magnuson-Stevens Act requires federal fishery management plans, developed by NMFS and the Regional Fishery Management Councils, to describe the habitat essential to the fish being managed and to describe threats to that habitat from both fishing and non-fishing activities. To protect EFH, federal agencies are required to consult with NMFS on activities that may adversely affect EFH.

EFH has been designated for three species of salmon, 83 groundfish species, and five pelagic species in the Area of Analysis for aquatic resources. EFH includes freshwater, estuarine and marine waters for salmon, and marine waters for coastal pelagic and groundfish species. More specific descriptions of EFH are provided below.

Chinook and Coho Salmon

Coho and Chinook salmon are managed under the Magnuson-Stevens Act and EFH is described in Amendment 14 to the Pacific Coast Salmon Fishery Management Plan (PFMC 2012). EFH for Chinook salmon is also described in the same management plan and is identical to that for coho salmon in the Klamath Basin. EFH has been designated for the mainstem Klamath River and its tributaries from its mouth to Iron Gate Dam, and upstream the Trinity River to Lewiston Dam. EFH includes the water quality and quantity necessary for successful adult migration and holding, spawning, egg-to-fry survival, fry rearing, smolt migration, and estuarine rearing of juvenile coho and Chinook salmon.

Groundfish

EFH for Pacific Coast groundfish includes all waters and substrate within areas with a depth less than or equal to 1,914 fathoms (approximately 3,500 meters) shoreward to the mean higher high-water level or the upstream extent of saltwater intrusion (defined as upstream and landward to where ocean-derived salts measure less than 0.5 ppt during the period of average annual low flow). The Klamath River Estuary, which extends from the river's mouth upstream to near the confluence with Ah Pah Creek, is included in the Pacific groundfish EFH (50 CFR § 660.395).

Pelagic Fish

EFH for coastal pelagic species, including finfish (northern anchovy, Pacific sardine, Pacific [chub] mackerel, and jack mackerel) and market squid, occurs from the shorelines of California, Oregon, and Washington westward to the exclusive economic zone[89] (370 km off coast) and above the thermocline where sea surface temperatures range from 50 to 78.8ºF. During colder winters, the northern extent of EFH for coastal pelagic species may be as far south as Cape Mendocino, and during warm summers it may extend into Alaska's Aleutian Islands. In each of these seasonal examples, the Klamath River Estuary and coastline would be included as EFH for these species.

3.3.3 Significance Criteria

The Proposed Project could affect aquatic resources directly or indirectly, and through a variety of mechanisms. These effects could be additive or offsetting. In determining the significance criteria, the Lower Klamath Project EIR analysis considers the total effect of the factors described above on native fish populations and their habitat in relation to the Proposed Project. These impacts could vary substantially in intensity, severity, geographic extent, population-level impact, and duration. The intensity of an impact refers to how severely it affects an organism. This severity can range from sublethal behavioral adaptations such as avoidance of a specific condition, to mortality. The geographic extent refers to how much of the species' potential habitat is affected. Population-level impact refers to the proportion of the total population that is expected to be affected. As described above in Section 3.3.2.1 Aquatic Species [coho salmon], Williams et al. (2006) described nine population units of coho salmon in the Klamath Basin to support recovery planning for the listed coho salmon SONCC ESU. Analysis of coho salmon in this EIR considers impacts and benefits for each of the nine population units in the Klamath Basin separately but makes a significance determination for all population units combined within the Klamath Basin to be consistent with the approach to assessing other aquatic species populations. Duration refers to how long the effect is anticipated to persist (hours, days, months, or years), and considers resiliency of the population to the impact (e.g., resilient populations recovery more quickly to impacts). Criteria for determining significant impacts on aquatic resources are also informed by Appendix G of the CEQA Guidelines (California Code of Regulations title 14, section 15000 et seq.).

The Lower Klamath Project EIR considers short- and long-term effects to aquatic resources. For the Proposed Project aquatic resources impact analysis, short term is defined as less than five years following dam removal (unless otherwise indicated), which includes the periods of reservoir drawdown, dam deconstruction, and early restoration activities. A period of five years was selected as short-term, because for most aquatic resources this represents one to two generations. Long term is defined as more than five years following dam removal (unless otherwise indicated), which in most cases is more than two generations.

In the short term, effects of the Proposed Project would be significant if they:

- Substantially reduce the abundance (greater than 50 percent reduction) of a year class for aquatic species.
- Substantially decrease the quality or availability (greater than 50 percent reduction) of habitat for a native aquatic species.

[89] Exclusive economic zone is a sea zone prescribed by the United Nations Convention on the Law of the Sea over which a state has special rights regarding the exploration and use of marine resources.

- Substantially decrease the quality of designated PCEs, or availability (greater than 50 percent reduction) of designated critical habitat under the ESA, or EFH under the Magnuson-Stevens Act.

In the long term; five years after removal of all dams, effects of the Proposed Project would be significant if they:

- Substantially reduce the abundance (greater than 50 percent reduction) of an adult population or year class for aquatic species.
- Substantially decrease the quality or availability (greater than 50 percent reduction) of habitat for a native aquatic species.
- Substantially decrease the quality of designated PCEs, or availability (greater than 50 percent reduction) of designated critical habitat under the ESA, or EFH under the Magnuson-Stevens Act.

3.3.4 Impact Analysis Approach

This section provides an overview of the methods used in the evaluation of aquatic resources. This section is organized to describe methods used to evaluate effects on physical habitat (e.g., from suspended sediment, bed elevation, water quality, etc.), as well as the methods used to address effects on biological process such as fish disease and parasites. Methods are also described to specifically address aquatic habitat, critical habitat, Essential Fish Habitat (EFH), and communities that respond to environmental impacts unique from fish species such as freshwater mussels and benthic macroinvertebrates.

The following sources were assessed to determine the scope of existing local policies relevant to the Proposed Project:

- Del Norte County General Plan (Mintier & Associates et al. 2003):
  - Section 1 (Natural Resources/Conservation), Policies 1.A.1, 1.A.6, 1.A.14, 1.B.1, 1.C.1, 1.C.2, 1.C.3, 1.C.4, 1.E.2, 1.E.3, 1.E.8, 1.E.9, 1.E.11, 1.E.12, 1.E.28, and 1.E.29
- Humboldt County General Plan for Areas Outside of the Coastal Zone (Humboldt County 2017):
  - Conservation and Open Space Element, Water Resources Element, Policies BR-P4, BR-P11, BR-P12, BR-S2, BR-S4, BR-S6, WR-P5, WR-P23, WR-P39, and WR-P46
- Klamath County Comprehensive Plan (Klamath County 2010):
  - Goal 5 (Open Space, Scenic, and Historic Area and Natural Resources), Policy 16
- Siskiyou County General Plan (Siskiyou County 1980):
  - The Conservation Element (Siskiyou County 1973), Wildlife Habitat, Objectives 1, 5–8
  - The Land Use Element (Siskiyou County 1997), Policy 41.13

Most of the aforementioned policies (and objectives) are stated in generalized terms, consistent with their overall intent to protect aquatic resources, including special-status aquatic species. By focusing on the potential for impacts to specific aquatic resources within the Area of Analysis, consideration of the more general local policies listed above is addressed through the specific, individual analyses presented in Section 3.3.5 *[Aquatic Resources] Potential Impacts and Mitigation*.

The following sources were assessed to determine the scope of existing HCPs relevant to the Proposed Project and potential for overlap with the Primary Area of Analysis for Aquatic Resources: (a) PacifiCorp's Interim Operations Habitat Conservation Plan for the Klamath Hydroelectric Project (PacifiCorp 2012) and (b) Green Diamond Forest Habitat Conservation Plan (Green Diamond Resource Company 2018). These HCPs also provide generalized terms for protection of aquatic resources, including special-status aquatic species. Consideration of the HCPs is inherently addressed by the individual analyses presented in Section 3.3.5 *[Aquatic Resources] Potential Impacts and Mitigation*, which focus on the potential for impacts to specific special-status aquatic species and other aquatic resources defined in Area of Analysis.

3.3.4.1 Suspended Sediment

Suspended sediment can have a multitude of effects on aquatic species, including direct lethal impacts, or sublethal effects on behavior and physiology. The most commonly observed effects of suspended sediment on fish reported in the scientific literature include: (1) avoidance of turbid waters in homing adult anadromous salmonids, (2) avoidance or alarm reactions by juvenile salmonids, (3) displacement of juvenile salmonids, (4) reduced feeding and growth, (5) physiological stress and respiratory impairment, (6) damage to gills, (7) reduced tolerance to disease and toxicants, (8) reduced survival, and (9) direct mortality (Newcombe and Jensen 1996). Information on both concentration and duration of suspended sediment is necessary for understanding the potential severity of its effects on salmonids (Newcombe and MacDonald 1991). Herbert and Merkens (1961) stated that "there is no doubt that many species of fresh-water fish can withstand extremely high concentrations of suspended solids for short periods, but this does not mean that much lower concentrations are harmless to fish which remain in contact with them for a very long time." Effects of suspended sediment on fish may be exacerbated if pollutants or other stressors (e.g., water temperature, disease) are present as well.

As described in Appendix E of this EIR, the potential effects of suspended sediment on anadromous fish species for the Proposed Project were assessed using the SRH-1D model (Huang and Greimann 2010, as summarized in USBR 2012). The SRH-1D model provides an estimate of SSCs at different points on the Klamath River on a daily average estimate. This information is used to assess the impacts of SSCs on fish in dam removal years 1 and 2, based on the concentration and duration of exposure using an approach described by Newcombe and Jensen's (1996). Newcombe and Jensen (1996) reviewed and synthesized 80 published reports of fish responses to suspended sediment in laboratories, streams, and estuaries and established a set of equations to calculate "severity of ill effect" (SEV) indices. A suite of six equations were developed that evaluate the effects of suspended sediment (at various concentrations, durations of exposure, and particle sizes) on various taxonomic groups of fishes and life stages of species within those groups. These effects are compared to those that fish would be expected to encounter under existing conditions, as described in Section 3.6.1 *Summary of Available Hydrology Information for the Proposed Project*.

For each simulation year in the 48-year record, the duration of SSCs at a range of concentrations was calculated for each species and life-history stage (e.g., duration of SSC over 1,000 mg/L during spring-run Chinook salmon adult upstream migration). The results of modeling all potential years were summarized for each life-stage of each species assessed. Because the suspended sediment varies with hydrology, and in order to account for (and compare) the range of results and impacts that might occur under each alternative, three scenarios were selected for analysis, with the goal of defining a most likely impacts on fish scenario for the potential impacts to fish, as well as a reasonable range of potential impacts, encompassed by extremes—a "least impacts on fish scenario" and a "worst impacts on fish scenario." These represent the sediment concentrations for the median, the lowest 10 percent, and highest 10 percent of years in the available hydrological record.

- **Most-likely impacts on fish:** This scenario represents the conditions that are most likely to occur for each species and life stage—that is to say SSCs and durations with a 50 percent (median) exceedance probability for the mainstem Klamath River downstream from Iron Gate Dam. This means that there is an equal chance that the SSCs would be higher or lower than described. Exceedance probabilities were based on modeling SSCs for all water years from 1961 to 2009 under the Proposed Project.
- **Least impacts on fish:** This scenario represents the least impacts on fish from potential sediment-related impacts to a species and life stage. It uses suspended sediment concentrations and durations with a 90 percent exceedance probability. This means that under this rare, least-impacts-on-fish scenario the probability of these concentrations and durations being equal to or less than this level for each assessed species and life-stage in any one year is 10 percent, and the probability of them being exceeded is 90 percent.
- **Worst impacts on fish:** This scenario represents the worst impacts on fish of potential sediment-related impacts to the species and life stage. It uses SSCs and durations with a 10 percent exceedance probability. This means that under this rare, worst-impacts-on-fish scenario the probability of these concentrations and durations being equal to or greater than this level for each assessed species and life-stage in any one year is 10 percent, and the probability of them being less than this level is 90 percent.

The likelihood, however, that conditions under the Proposed Project would track the aforementioned scenarios precisely for each species is slim. It is more likely that different species and different life stages would be exposed to different SSCs and durations within the ranges described. For example, there are relatively few instances in modeled hydrologic record in which the median "most-likely impacts on fish" condition would occur in the same water year for all life-stages of a given species, and even fewer instances in which the median condition would occur in the same water year for all species and all life-stages. For the "least impacts on fish" and "worst impacts on fish" scenarios, the predicted SSCs and durations would be unlikely to occur (10 percent probability) during nearly all water years in the modeled hydrologic record. There are even fewer, and potentially no, instances in which the "least impacts on fish" and "worst impacts on fish" scenarios for SSCs and durations would occur in the same water year for all life-stages of a given species, and no instances in which they would occur in the same water year for all species and all life-stages.

An alternative analytic approach was considered using predicted SSCs and exposure durations associated with a particular water year type. However, it was determined that this approach had too much potential to exaggerate or understate the range of possible impacts, as it did not provide sufficient granularity in terms of the range of possible conditions experienced by particular species and/or life stages.

In assessing impacts, the above scenarios were applied for each species, and for each life stage of that species, taking into account when the species and what percent of the population is likely to be present in the Klamath River mainstem (including avoidance behavior). This EIR analysis describes the range of potential impacts to various life stages of aquatic species including relative mortality rates and sublethal impacts and were evaluated against the relevant significance criteria.

3.3.4.2 Bed Elevation and Grain Size Distribution

As described in Section 3.11 *Geology, Soils, and Mineral Resources* and Appendix F of this EIR, the analysis of potential changes in channel bed elevations and grain size distribution in response to increased bedload supply and transport also relied upon output from the SRH-1D model (Huang and Greimann 2010, USBR 2012). The changes were evaluated for a range of hydrologic conditions for short-term changes (using a 2-year timeframe) and long-term changes (including analysis of 5, 10, 25, 50 years in the future) changes using a range of flows taken from historical hydrology. For bedload dynamics two years following the changes associated with dam removal is considered sufficient for assessing short-term impacts. Long-term simulations were not conducted for the Klamath River upstream of Iron Gate Dam based on observations that the bedload sediment conditions in that reach are relatively stable and persistent, and therefore at the end of 2 years following dam removal would be representative and would persist through time, allowing for mild fluctuations as a function of hydrology rather than project effects (USBR 2012).

The effects determination used analysis of the model results and knowledge of habitat requirements of affected fish species to determine how changes in bed elevation and substrate composition would affect aquatic resources (e.g., pool habitat, spawning gravel, benthic habitat). Changes in substrate composition occurring as a result of dam removal that decreased habitat suitability were assumed to be harmful to aquatic resources and were evaluated against the relevant significance criteria.

Bedload transport in the area upstream of the influence of J.C. Boyle Reservoir are not anticipated to be affected by dam removal and are not expected to be substantially affected by the Proposed Project, are not within California, and are not evaluated further in this EIR. Link River Dam and Keno Dam would remain in place and would continue to affect hydrology and sediment transport as they do currently.

3.3.4.3 Water Quality

The analysis of potential short-term (0−5 years) and long-term (5 or more years) water quality-related effects on fish under the Proposed Project is based on the water quality impacts analysis (see Section 3.2.5 *[Water Quality] Potential Impacts and Mitigation*) for parameters to which fish are sensitive (e.g., suspended sediment concentrations [SSCs], dissolved oxygen, pH), as well as effects determinations for state and approved tribal designated beneficial uses that are directly related to fish.

This EIR evaluates the potential effects of sediment-associated toxins on fish under the Proposed Project by using the results of multiple screening-level comparisons of sediment contaminant levels identified in reservoir sediments that are currently trapped behind the dams. These water quality methods are described in greater detail in Section 3.2.4.7 *Inorganic and Organic Contaminants*. Alterations in water quality occurring as a result of dam removal under the Proposed Project that are projected to decrease (or increase) habitat suitability or to result in direct effects on aquatic species are evaluated against the relevant significance criteria.

3.3.4.4 Water Temperature

The EIR uses water temperature output from three quantitative models (see Section 3.2.4.1 *[Impact Analysis Approach] Water Temperature* and Appendix D for details regarding the water temperature models) to evaluate the potential impacts related to changes in water temperature on species within each study reach of the Area of Analysis. Water temperature modeling results were compared to the thermal tolerances of focal species and associated life stages to determine relative suitability for these species under the Proposed Project. Changes in water temperature occurring as a result of dam removal that were predicted to decrease (or increase) habitat suitability or result in direct effects on aquatic species were evaluated against the relevant significance criteria.

3.3.4.5 Fish Disease and Parasites

Fish diseases, specifically *C. shasta* and *P. minibicornis*, have periodically contributed to substantial mortality for Klamath River salmonids (discussed in detail in Section 3.3.2.3 *Habitat Attributes Expected to be Affected by the Proposed Project*). Environmental variables such as temperature, flow, sediment (bedload composition and stability), plankton (high quality food abundance), and nutrients are thought to affect the abundance of *P. minibicornis* and *C. shasta* via habitat for the intermediate invertebrate host (annelid polychaete worm *Manayunkia speciose*); therefore, differences in river habitat conditions that are predicted under the Proposed Project are anticipated to affect the abundance of these parasites and their infection rates in Klamath Basin salmonids. Bartholomew and Foott (2010) prepared a compilation of available information regarding Myxozoan disease relative to the Klamath River and, in their analysis they considered several factors that could, if co-occurring, lead to high disease infection rates of fish, including:

- Physical habitat components that support the invertebrate host species (pools, eddies, sediment, mats of filamentous green algae [periphyton])
- Microhabitats with low velocity and unnaturally stable flows
- Close proximity to salmon spawning areas
- Water temperatures higher than 59°F

Ich and columnaris may also occasionally have a substantial impact on aquatic resource (e.g., 2002 fish kill, CDFW 2004). Factors that could, if co-occurring, lead to high Ich and columnaris infection rates of fish, including:

- Exceptionally low flows
- Water temperatures higher than 59°F

- High densities of fish (such as adult Chinook salmon migrating upstream in the fall and holding at high densities in pools).

The potential effects of the Proposed Project on fish disease were evaluated based on the predicted effect of dam removal on the environmental factors that drive disease infection rates. The predicted outcome for increased or decreased fish disease and mortality were evaluated against the relevant significance criteria.

3.3.4.6 Aquatic Habitat

To assess the effect of the Proposed Project on available aquatic habitat, changes to habitat area were assessed for each life stage qualitatively, using available data on suitable habitat area upstream of existing barriers predicted to be affected by the alternatives, habitat requirements, and expected changes in instream flows under the alternatives. Qualitative analyses in this EIR rely on data evaluated for other affected factors (water temperature and fish passage) and expected changes in geomorphic processes, such as short- and long-term changes in sediment transport and deposition, to determine increases or decreases in habitat relative to existing conditions for the different species and life stages in the various reaches. Changes in aquatic habitat quality and quantity occurring as a result of dam removal were evaluated against the relevant significance criteria.

3.3.4.7 Critical Habitat

NMFS has designated critical habitat for coho salmon, Southern Resident Killer Whales, and eulachon, and USFWS has designated critical habitat for shortnose and Lost River suckers. Within critical habitat, NMFS and USFWS has determined that the PCEs essential for the conservation of these species are those sites and habitat components that support one or more life stage. Critical habitat for Southern Resident Killer Whales does not extend into coastal or offshore habitats (NMFS 2006c). The effects of each alternative on critical habitat were based on evaluation of the physical, chemical and biological changes that were expected to occur to designated critical habitat within the Area of Analysis for aquatic resources and how those changes would affect the PCEs (for those species for which PCEs have been designated) for that critical habitat in the short- and long-term; and were evaluated against the relevant significance criteria for critical habitat.

3.3.4.8 Essential Fish Habitat

The effects of the Proposed Project and each alternative on EFH were based on evaluation of the physical, chemical and biological changes that were expected to occur to EFH within the Area of Analysis for aquatic resources and whether those changes would have short- and long-term negative or beneficial effects on this habitat in terms of its quantity and quality; and were evaluated against the relevant significance criteria for EFH.

3.3.4.9 Freshwater Mollusks

Increased levels of fine sediment, both suspended in the water column and along the channel bed, can inhibit the growth, production, and abundance of freshwater mollusks (especially mussels and clams). Therefore, the analysis of impacts associated with the

Proposed Project focuses on short- and long-term changes in SSCs (Aldridge et al. 1987, as cited in Henley et al. 2000) and stream substrate texture (Howard and Cuffey 2003, Vannote and Minshall 1982). The evaluation focuses on freshwater mussels because of their similar distribution to other freshwater mollusks, similar habitat requirements, their longer life-span, and lack of information regarding the effects of sediment on clams and other mollusks. Suspended sediment impacts on freshwater mussel species were evaluated using output from the SRH-1D (Huang and Greimann 2010) sediment transport model as discussed above for suspended and bedload sediment.

Aldridge et al. (1987, as cited in Henley et al. 2000) showed that exposure to SSCs of 600-750 mg/L led to reduced survival of freshwater mussels found in the eastern United States. No duration of exposure was cited in the study. No comparable data are available for the species in the Klamath River. Using 600 mg/L as the minimum SSCs that would be detrimental to freshwater mussels, alternatives were compared to each other by determining the number of days during which this criterion threshold would be exceeded.

Analysis of impacts due to changes in bedload transport on the four species of freshwater mussels considered modeled changes in median sediment size, under the Proposed Project. Changes in habitat quality and quantity predicted for mussels and clams, as well as predictions of potential direct impacts (mortality), were evaluated against the relevant significance criteria.

3.3.4.10 Benthic Macroinvertebrates

Suspended sediment and turbidity can cause stress to benthic macroinvertebrate (BMI) populations through impaired respiration; reduced feeding, growth, and reproductive abilities; and reduced primary production (Lemly 1982, Vuori and Joensuu 1996). Therefore, potential short-term and long-term effects of the Proposed Project on BMIs were evaluated for both short- and long-term changes in SSCs and bedload sediment. Suspended sediment impacts on BMIs were evaluated using output from the SRH-1D (Huang and Greimann 2010) sediment transport model as discussed above for suspended and bedload sediment.

Changes in substrate size or embeddedness may influence the distribution, abundance, and community structure of BMIs (Bjornn et al. 1977, McClelland and Brusven 1980, Ryan 1991). Bed texture changes that would occur under the Proposed Project were qualitatively evaluated to determine whether changes in substrate composition would likely decrease macroinvertebrate abundance or alter the community composition to the extent that these communities could no longer support sufficient fish populations in the Area of Analysis for aquatic resources.

The effects on BMIs were based on water quality determinations (e.g., dissolved oxygen, toxicity) (see Section 3.2 *Water Quality*) and evaluated in the same manner as described for fish and mollusks. Changes in habitat quality and quantity predicted for BMIs, as well as predictions of potential direct impacts (mortality), were evaluated against the relevant significance criteria.

3.3.5 Potential Impacts and Mitigation

The Proposed Project would affect the physical, chemical, and biological components of habitat within portions of the Klamath Basin. These effects would result from changes in suspended sediment, bedload sediment, water quality, water temperature, disease and parasites, habitat availability, and flow-related habitat. As described in the following sections, these changes would act in both beneficial and harmful ways on species, critical habitat, and EFH. Some of the changes would be short-term, and others permanent. This section first describes the Proposed Project's anticipated effects on these key ecological attributes that could affect aquatic resources. As was the case under the descriptions of key attributes under the Section 3.3.2.3 *Habitat Attributes Expected to be Affected by the Proposed Project*, this section includes, as relevant, specific analysis relevant to specific segments of the Area of Analysis. More detailed technical descriptions of the Proposed Project's projected effects on suspended sediment, bedload sediment, and potential impacts on aquatic species, can be found in Appendices E and F of this EIR. Based on the analysis of effects to key ecological attributes, this section then goes on to discuss specific impacts and evaluate them under the significance criteria, discuss mitigation measures, and determine impact significance.

3.3.5.1 Suspended Sediment

Suspended sediment effects under the Proposed Project are summarized here, and are described in more detail in Potential Impact 3.2-3 *Short-term increases in suspended sediments due to release of sediments currently trapped behind the Lower Klamath Project dams*, and Appendix E. As discussed below, suspended sediment analysis interprets model output from USBR (2012) with modifications in light of proposed changes to the drawdown rate that would increase the peak sediment concentrations and decrease the duration of such elevated concentrations.

Hydroelectric Reach

Sediment transport modeling of the impacts of dam removal indicate high short-term SSCs in the Hydroelectric Reach under the Proposed Project (USBR 2012, 2016). Modeled SSCs downstream of J.C. Boyle Reservoir would be high (>1,000 mg/L) in the short term, but concentrations would be considerably less than those anticipated to occur downstream from Copco No. 1 and Iron Gate reservoirs due to the relatively small volume of the sediment deposits behind J.C. Boyle Dam (eight percent of total volume for the Lower Klamath Project). The suspended sediments released from J.C. Boyle would quickly move into the California portion of the Hydroelectric Reach. Elevated suspended sediments in the Hydroelectric Reach during reservoir drawdown would be a significant and unavoidable impact (see Potential Impact 3.2-3). Predicted SSCs decrease to less than 100 mg/L within five to seven months following drawdown, and concentrations further decrease to less than 10 mg/L within six to 10 months following drawdown of J.C. Boyle Reservoir.

Modeling of sediment concentrations downstream of Copco No. 1 Reservoir during drawdown also indicates short-term sediment concentrations would be high (>5,000 mg/L) in the California portion of the Hydroelectric Reach due to dam removal. Predicted spikes in SSC after one to two months of reservoir drawdown correspond to increases in Klamath River flow through the Hydroelectric Reach due to spring storm events, and within six to 10 months following drawdown would decrease to levels that exist under existing conditions (e.g., <100 mg/L).

Middle and Lower Klamath River

Under the Proposed Project, full removal of the Lower Klamath Project reservoirs would result in the release of 5.3 to 8.6 million cubic yards (1.2 to 2.3 million tons) of sediment stored in the reservoirs into the Klamath River downstream from Iron Gate Dam (USBR 2012), resulting in higher SSCs than would normally occur under existing conditions. Reservoir drawdown (lowering of reservoir water surface elevation) is expected to commence in dam removal year 1, and to be completed in dam removal year 2 (Section 2.7.2 *Reservoir Drawdown*). Based on the suspended sediment modeling (USBR 2012), SSCs are expected to exceed 1,000 mg/L directly downstream of Iron Gate Dam for around two to three continuous months, with the potential for peak concentrations exceeding 5,000 mg/L for hours or days, depending on hydrologic conditions during dam removal. Model results indicate SSC would be highest during the period of greatest reservoir drawdown (January through mid-March of dam removal year 2), as erodible material behind the dams is mobilized downstream (see Potential Impact 3.2-3). During normal to dry water years, modeled SSCs would begin to decline in late March of dam removal year 2 and would continue declining through early summer of dam removal year 2 (USBR 2012). If it is a wet year, it may take longer to drain the reservoirs and high (>250 mg/L) concentrations may extend until June. Differences between the modeled conditions and the Proposed Project would be expected to increase the magnitude of peak SSCs but decrease the duration of elevated SSCs compared to modeled SSCs (see Potential Impact 3.2-3). The Proposed Project incorporates a higher maximum drawdown rate (i.e., 5 feet per day compared to 3 feet per day) and sediment jetting during drawdown that would transport more erodible material, so less erodible material would be available to be transported after drawdown concludes and SSCs potentially would decline more rapidly after drawdown. However, modeled SSCs are used as a conservative estimate of the duration of elevated SSCs. The SSCs would be near background conditions for all water year types within the first year following removal. Tributaries between the Hydroelectric Reach and the estuary contribute a significant amount of both water and suspended sediments to the Klamath River mainstem. This causes the influence of Lower Klamath Project reservoir sediment releases to decline in the downstream direction. At Iron Gate Dam (Figure 3.2-11 through 3.2-13), where SSCs are artificially low under existing conditions (because of sediment trapping by the dam) SSCs would remain elevated above existing conditions throughout the first 2 years, and in the long term would decrease (as reservoir deposited sediments evacuated) to return to levels slightly higher than the current levels as sediment naturally transports downstream. At Orleans, where SSCs under existing conditions are higher because of inputs of tributaries, under a most-likely impact on fish scenario, the effects of the Proposed Project would be similar to existing conditions by late April when SSCs from the Proposed Project are predicted to decrease. Under a worst impacts on fish scenario SSCs are projected to remain somewhat elevated above existing conditions until October during the year of dam removal. By Klamath Station (downstream of confluence with Trinity River) SSCs under existing conditions are higher than at the upstream sites as a result of sediment input from tributaries. As a result, SSCs from the Proposed Project and those under existing conditions would be similar under all scenarios by late spring of the year of dam removal.

Klamath River Estuary

As a result of the influence of Lower Klamath Project reservoir sediment releases declining in a downstream direction, the difference between SSCs from the Proposed Project and those under existing conditions would be relatively minor in the Klamath

River Estuary (USBR 2012). The SSCs and durations under the most-likely impacts on fish scenario would be similar to those that occur under existing extreme conditions (10 percent exceedance) and resemble those that would be expected to occur about one in 10 years on average under existing conditions. Under the worst impacts on fish simulation, SSCs and durations would be slightly higher (around 10 percent) than those for the existing extreme conditions during the winter of dam removal.

Pacific Ocean Nearshore Environment

In contrast to the Lower Klamath River, modeled short-term SSCs following dam removal are not available for the nearshore marine environment adjacent to the Klamath River. Substantial dilution of the mainstem river SSCs is expected to occur in the nearshore under the Proposed Project. Based on data from 110 coastal watersheds in California, where nearshore SSCs were measured at greater than 100 mg/L during the El Niño winter of 1998 (Mertes and Warrick 2001), peak SSCs leaving the Klamath River Estuary from upstream sources including the Proposed Project may be diluted by 1 to 2 orders of magnitude; for example from greater than 1,000 mg/L to greater than 10–100 mg/L. Therefore, the SSCs in the nearshore ocean would be expected to be similar to what would occur during existing extreme conditions.

As described in detail in Potential Impact 3.2-3, during several large flood events on the geographically proximal Eel River in the winter of 1997 and 1998, Geyer et al. (2000) found that: 1) flood conditions were usually accompanied by strong winds from the southern quadrant; 2) the structure of the river plume was strongly influenced by the wind-forcing conditions; and 3) during periods of strong southerly (i.e., downwelling favorable) winds, the plume was confined inside the 164-ft isobath (i.e., sea floor contour at around 164-ft below the water surface), within about 4 miles of shore. Based upon Eel River plume studies and current knowledge of northern California oceanographic patterns, the fine sediment discharged to the Pacific Ocean nearshore environment under the Proposed Project would likely be delivered to the ocean in a buoyant river plume that hugs the shoreline as it is transported northward. However, since the flushing of sediments from behind the dams would occur over a number of weeks to months (and perhaps to some degree over 1–2 years), the plume carrying reservoir sediments would likely be influenced by a range of meteorological and ocean conditions (e.g., storm and non-storm periods, differing storm directions). Therefore, some of the time the plume would likely be constrained to shallower nearshore waters, while at other times it would likely extend farther offshore and spread more widely, including within some or all of the Klamath River Management Zone. While elevated SSCs (i.e., 10–100 mg/L) created in the nearshore plume would affect physical water quality characteristics specified in the Ocean Plan (i.e., visible floating particulates, natural light attenuation, the deposition rate of inert solids), the effects are likely to be within the range of concentrations and duration caused by historical storm events.

River plumes and the associated habitat conditions they create are considered to be areas of high productivity for marine organisms (Grimes and Funucane 1991, Morgan et al. 2005), and create abrupt changes in marine water quality conditions (e.g., water temperature, salinity, sediment) that support salmonids (Schabetsberger et al. 2003, De Robertis et al. 2005). Due to the relatively small magnitude of SSCs released to the nearshore environment, the anticipated rapid dilution of the sediment plume as it expands in the ocean, and the relatively low rate of deposition of sediments to the Pacific Ocean nearshore environment bottom substrates, any SSCs elevations associated with the Proposed Project are not anticipated to have effects on species distinguishable from existing conditions.

3.3.5.2 Bed Elevation and Grain Size Distribution

The potential effects of increased bedload supply and transport on channel bed elevations and grain size under the Proposed Project are described in Appendix F and summarized in Section 3.11.5.4 *Channel Morphology and Substrate*. As a result of the Proposed Project, the bedload transport processes that salmon evolved with and depend upon to provide substrate suitable for spawning and early rearing in streams and rivers (that are currently interrupted by the Lower Klamath Project dams) would be restored to a more natural condition.

3.3.5.3 Water Quality

Upper Klamath River and Connected Waterbodies

Dam removal activities under the Proposed Project would not affect water quality in the following areas of the Upper Klamath Basin: Wood, Williamson, and Sprague Rivers, Upper Klamath Lake, and Link River to the upstream end of J.C. Boyle Reservoir.

However, existing water quality problems have the potential to negatively impact anadromous salmonids' ability to access waters upstream of the Hydroelectric Reach under the Proposed Project. Water quality problems (e.g., excessive water temperatures and low dissolved oxygen) in the Keno Impoundment/Lake Ewauna during late spring, summer, and early autumn, led NMFS and USFWS to prescribe interim trap-and-haul measures in their Section 18 Prescriptions for the Klamath Hydroelectric Project (DOI 2006) to transport primarily adult fall-run Chinook salmon past Keno Impoundment/Lake Ewauna during periods when conditions would be harmful to salmonids. This would entail seasonal, upstream trap and haul for primarily fall-run adult Chinook salmon around the Keno Impoundment/Lake Ewauna when dissolved oxygen and water temperatures do not meet the applicable criteria (i.e., typically during July through October), since migrating salmonids would have access to this reach of the Klamath River. In the downstream Keno Impoundment/Lake Ewauna, dissolved oxygen reaches very low levels (less than 1 to 2 mg/L) during July through October of most years as algae transported from Upper Klamath Lake settle out of the water and decay (see Figure 3.4-9 in Appendix C.4.1.1). During most years, the Keno Impoundment/Lake Ewauna reach of the Klamath River (Link River Dam to Keno Dam) maintains dissolved oxygen concentrations greater than 6 mg/L from mid-November through mid-June (Appendix C.4.1.1). These dissolved oxygen concentrations are generally acceptable for migrating adult anadromous salmonids (USEPA 1986) for these months and are typically above the ODEQ water quality objective for cool water aquatic life (6.5 mg/L minimum, see Section 3.2.2.5 *Dissolved Oxygen*). Under KHSA Section 7.5.1, the Secretary of the Interior shall initiate a study to evaluate disposition of Keno Dam, including fish passage. Eventual attainment of the Oregon (ODEQ 2002, 2010) and California (USEPA 2008) TMDLs for dissolved oxygen (and other water quality parameters that would improve dissolved oxygen [i.e., pH, chlorophyll-*a*]) would improve water quality in the Keno Impoundment/Lake Ewauna and potentially eliminate water quality as a potential limitation to fall Chinook migration, and therefore the need for trap and haul activities around these waterbodies. However, full TMDL compliance does not reflect the existing condition and it would be speculative at this point to identify either the mechanisms necessary to implement the TMDLs or the timing required to achieve full compliance.

Upper Klamath River - Hydroelectric Reach

As described in Potential Impact 3.2-9, dam removal would result in short-term increases in oxygen demand and corresponding reductions in dissolved oxygen within the Hydroelectric Reach, with anoxia (0 mg/L) possible during reservoir drawdown periods when suspended sediment concentrations are at their peak (January to March of dam removal year 2). This would be a significant and unavoidable impact. In the long term, the Proposed Project would result in somewhat reduced daily fluctuations in dissolved oxygen in the Peaking Reach from the Oregon-California state line to Copco No. 1 Reservoir, which may be due to elimination of hydropower peaking operations (Potential Impact 3.2-10). Dissolved oxygen in the free-flowing river reaches replacing the reservoirs would no longer experience the extreme conditions of super-saturation (i.e., greater than 100 percent saturation) in surface waters and hypolimnetic oxygen depletion in bottom waters of Copco No. 1 and Iron Gate reservoirs during the April/May through October/November period, which would be generally beneficial.

Under the Proposed Project, pH in the Hydroelectric Reach would no longer experience high levels (pH greater than 9) during seasonal algal blooms in the surface waters of Copco No. 1 and Iron Gate reservoirs (Potential Impact 3.2-11). pH in the free-flowing reaches of the river replacing the reservoirs would not exhibit such high levels, instead possessing a more typical riverine signal. While daily fluctuations in pH could occur due to periphyton growth in the river reaches previously occupied by Lower Klamath Project reservoirs, the increases are expected to consistently meet water quality objectives to support beneficial uses and would therefore be beneficial.

Middle and Lower Klamath River

Sediment release associated with dam removal under the Proposed Project would cause short-term increases in oxygen demand and corresponding reductions in dissolved oxygen (Potential Impact 3.2-9) in the Middle Klamath River. During reservoir drawdown periods when suspended sediment concentrations are at their peak (January to March of dam removal year 2), dissolved oxygen concentrations would drop to very low levels (potentially 0 mg/L) immediately downstream from Iron Gate Dam and, depending on background conditions at the time of reservoir drawdown, would remain below 5 mg/L until approximately the confluence with the Shasta River (RM 179.5), or as far downstream as RM 121.7 (approximately 10 miles downstream of Seiad Valley [RM 132]). Recovery to the North Coast Basin Plan water quality objective of 90 percent saturation (i.e., 10–11 mg/L) is anticipated to occur in the reach from Seiad Valley to the mainstem confluence with Salmon River (RM 66), and would therefore not affect dissolved oxygen in the Lower Klamath River, the Klamath River Estuary or the Pacific Ocean nearshore environment.

Removal of the Lower Klamath Project dams under the Proposed Project and conversion of the reservoir reaches to a free-flowing river would result in long-term seasonal (July through November) increases in dissolved oxygen for the reach immediately downstream from Iron Gate Dam (Potential Impact 3.2-10), which would be beneficial relative to existing conditions. Increased diel (i.e., 24-hour period) variability in dissolved oxygen would also occur in the reach immediately downstream of Iron Gate Dam to approximately Seiad Valley (RM 132.7), with modeled concentrations consistently in compliance with the Basin Plan water quality objective of 85 percent saturation. Long-term effects of dam removal on dissolved oxygen would diminish with distance downstream from Iron Gate Dam, with similar or the same predicted dissolved oxygen concentrations and similar magnitude and duration of diel fluctuations by Seiad Valley (RM 132.7) and no differences by the confluence with the Trinity River (RM 43.3).

Under the Proposed Project, pH in the Middle Klamath River downstream from Iron Gate Dam (particularly upstream of the Shasta River confluence [RM 179.5]) during late-summer and early-fall months (August–September) would experience generally high pH (8 to slightly greater than 9 s.u.) and large daily variations in pH during periods of high photosynthesis (Potential Impact 3.2-11). The magnitude of photosynthesis and community respiration from periphyton growth in the Middle Klamath River under the Proposed Project is not entirely certain, but differences in pH between the Klamath TMDL model "TMDL dams-in" (T4BSRN) and "TMDL dams-out" (TOD2RN) scenarios decrease in magnitude with distance downstream from Iron Gate Dam, and are considerably dampened by the Scott River confluence (RM 145.1).

3.3.5.4 Water Temperature

Upper Klamath River – Hydroelectric Reach

Under the Proposed Project, the Hydroelectric Reach would no longer be dominated by hydropower peaking events and flows would more closely mimic the natural hydrograph. Elimination of peaking operations at J.C. Boyle Powerhouse would result in water temperatures in the J.C. Boyle Peaking Reach at the Oregon-California state line (RM 214.1) that exhibit slightly lower daily maximum values (0.0–3.6°F) and lower diel (i.e., 24-hour period) water temperature variation during June through September as compared to a "dams-in" condition, with temperatures moving toward the natural thermal regime (see also Potential Impact 3.2-1).

In the absence of the Lower Klamath Project reservoirs, hydraulic residence time in this reach would likely decrease from several weeks to less than a day, and water temperature suitability for native aquatic species would be improved (Hamilton et al. 2011). Removal of the Lower Klamath Project reservoirs would result in a slight increase in flow as the evaporative losses would be reduced. Evaporation from the surface of the reservoirs is currently about 11,000 acre-feet/year and after dam removal the evapotranspiration in the same reaches is expected to be approximately 4,800 acre-feet/year, potentially resulting in a gain in flow to the Klamath River of up to approximately 6,200 acre-feet/year (USBR 2011). Whether this increase would contribute to increased instream flows or be used upstream to supplement irrigation deliveries is uncertain, so this EIR discloses the potential increase but does not rely on it for conclusions (see also Section 3.8.4 *[Water Supply/Water Rights] Impacts Analysis Approach*). The reservoir drawdowns would allow tributaries and springs such as Fall, Shovel, and Spencer creeks and Big Springs to flow directly into the mainstem Klamath River, creating patches of cooler water 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). To assess whether hot springs near the Shovel Creek confluence with the Klamath River heat the water to an extent that it would be necessary to assess impacts to fisheries, water temperatures were recorded in Shovel Creek on November 1, 2017, and were 3.3°F cooler than in the mainstem Klamath River (46°F in Shovel Creek), and 0.6°F cooler on December 5, 2017 (39.9°F in Shovel Creek) (KRRC 2018). On the same dates, water temperature data was collected both upstream and downstream of the Klamath Hot Springs, located in the

Klamath River downstream of the confluence with Shovel Creek. Water temperatures on November 1, 2017 were 1.4°F warmer downstream of the hot springs, and 0.2°F cooler on December 5, 2017; no evidence of appreciable warming as a result of the hot springs was observed on these dates (KRRC 2018).

Temperature conditions would also improve farther downstream in the Hydroelectric Reach. From Copco No. 1 Reservoir to Iron Gate Reservoir, removal of the Lower Klamath Project reservoirs would result in a decrease in water temperatures during the fall and spring (discussed in detail in Potential Impact 3.2-1). The effects of changes in temperature regimes within this reach would be similar to those discussed in detail below for the Middle and Lower Klamath River.

Removing the Lower Klamath Project dams would allow access to tributaries upstream of Iron Gate Dam that could provide additional habitat for anadromous fish (DOI 2007), including groundwater-fed areas resistant to water temperature increases caused by changes in climate (Hamilton et al. 2011). In addition, the mainstem downstream from Iron Gate Dam would reflect natural temperature regimes (Hamilton et al. 2011). The conversion of an additional 22 miles of reservoir habitat to riverine and riparian habitat (Cunanan 2009) would improve water quality by restoring the nutrient cycling and aeration processes provided by a natural channel. These improvements resulting from implementing the Proposed Project would likely moderate the anticipated stream temperature increases resulting from climate change (see Potential Impact 3.2-1).

Middle and Lower Klamath River

The thermal lag caused by water storage in Lower Klamath Project reservoirs and the associated increased thermal mass would be eliminated in the Lower Klamath River under the Proposed Project (see Potential Impact 3.2-1). This elimination would cause water temperatures to become more in sync with historical 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).

Under the Proposed Project, warmer springtime temperatures would result in fry emerging earlier (Sykes et al. 2009), encountering favorable temperatures for growth sooner than under existing conditions (Figure 3.3-2), which could support higher growth rates and encourage earlier outmigration downstream similar to what likely occurred under historical conditions, and reducing stress and disease (Bartholow et al. 2005, FERC 2007). A predicted earlier outmigration in response to elevated water temperatures in the spring is also supported by a vast body of literature relating to increased growth rates and thermal response of outmigrating salmonids (as reviewed by Hoar 1988). In addition, fall-run Chinook salmon spawning in the mainstem during fall would no longer be delayed (reducing pre-spawn mortality) (Figure 3.3-3), and adult migration would occur in more favorable water temperatures than under existing conditions (Figure 3.3-3). Overall, these changes would result in water temperatures more favorable for salmonids in the mainstem Klamath River downstream from Iron Gate Dam.

The elimination of the thermal lag would also cause water temperatures to have natural diel variations (Figure 3.3-3) similar to what would have occurred historically in the Klamath River. This effect would be most pronounced downstream from Iron Gate Dam, would decline with distance downstream, and by the confluence of the Salmon River (RM 66) would exhibit no difference between the Proposed Project and existing conditions. The highest temperatures experienced by aquatic species would increase during summer (June through August), which could increase physiological stress, reduce growth rates, and increase susceptibility to disease during summer (Figure 3.3-3).

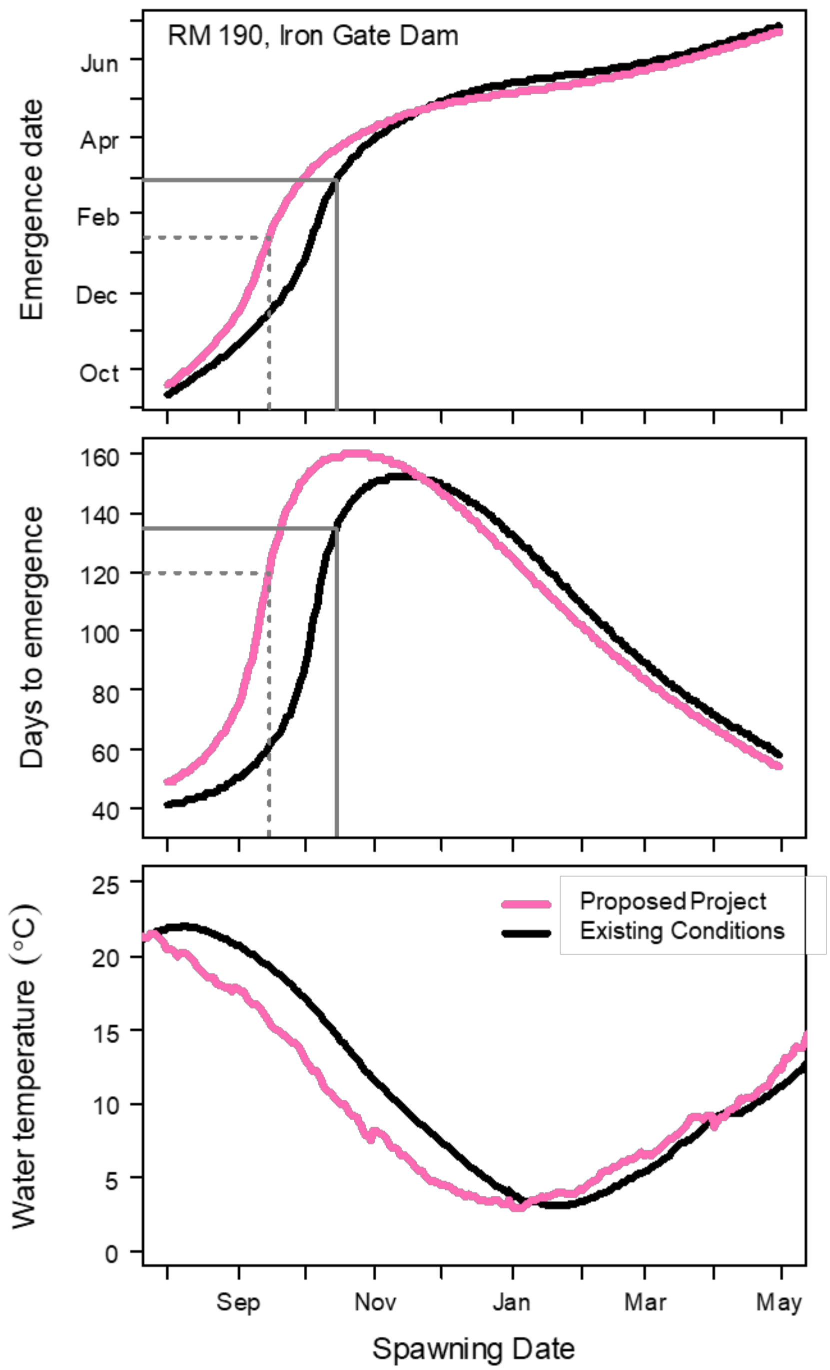


Figure 3.3-4. Perry et al. (2011) Modeled Time Series of Average Daily Mean Water Temperature (lower panel) Predicted at Iron Gate Dam (RM 193.1) Under the Proposed Project and Existing Conditions. Days to emergence (middle panel) and date of emergence (upper panel) for fall-run Chinook salmon was estimated as a function of spawning date assuming that emergence would occur at 889 degree days (accumulated heat related to development) after spawning (Perry et al. 2011).

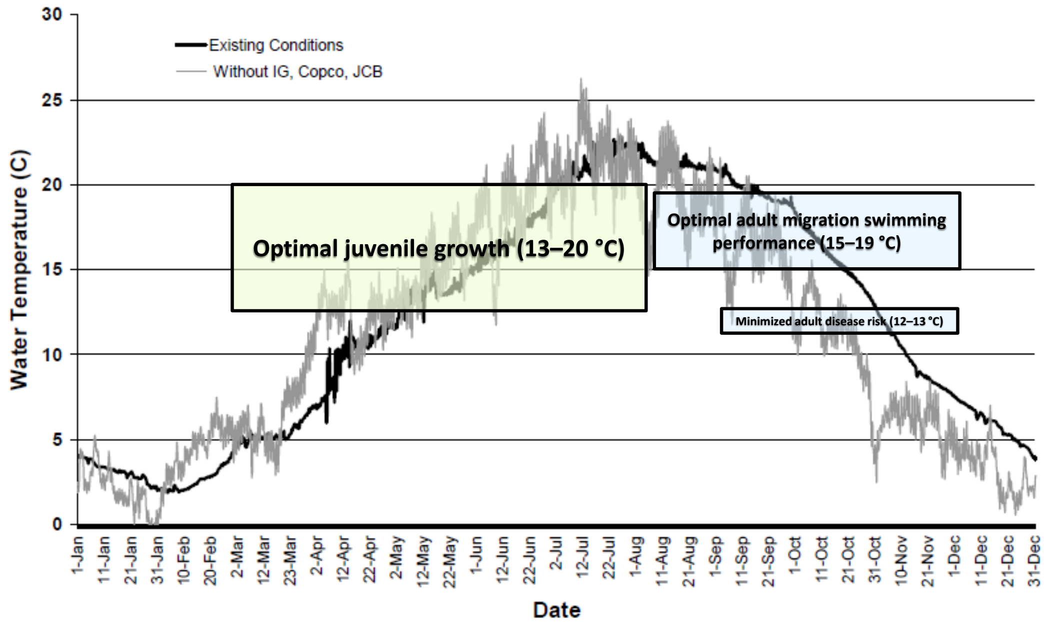


Figure 3.3-5. PacifiCorp (2005) Simulated hourly water temperatures below Iron Gate Dam based on a dry water year (WY 2002) for existing conditions compared to the Proposed Project (without Lower Klamath Project dams), and USEPA (2003) water temperature criteria for salmonid growth and migration.

However, the FERC EIS (2007) states that the increase in average and maximum daily temperatures may be compensated for by lower temperatures at night, which NRC (2004) concludes may allow rearing fish to move out of temperature refugia to forage at night, allowing growth to occur even when ambient day time temperatures are above optimal. Foott et al. (2012) observed positive growth and no apparent effect of elevated temperature on immune function or fitness in Klamath River juvenile Chinook salmon held over a 23-day period under conditions in the laboratory that simulated fluctuating water temperature profiles similar to what would be observed in the Klamath River under the Proposed Project. Salmonids in the Klamath River have been observed to use cooler hours to migrate between thermal refugia (Belchik 2003), and the decrease in minimum temperatures during the spring, summer, and fall under the Proposed Project would be beneficial for fish (Figure 3.3-3). Increased nighttime cooling of water temperatures is important to salmonids in warm systems, providing regular thermal relief, time for repair of proteins damaged by thermal stress, and significant bioenergetic benefits that help fish persist under marginal conditions (Schrank et al. 2003, NRC 2004). In addition, Dunsmoor and Huntington (2006) suggest that lower nighttime temperatures with dam removal would allow fish to leave thermal refugia in the Klamath River to forage and thereby allow more effective use of the available refugia habitat. Overall, the Proposed Project reductions in minimum daily temperatures below those under existing conditions would benefit salmonids in the Klamath River mainstem, helping them to tolerate the warmer periods of the year when dwelling in the mainstem, but also allowing feeding excursions when confined to refugia during the warmer times of the day.

Simulations of water temperatures without the Lower Klamath Project reservoirs (as discussed in Hamilton et al. 2011) show that the temperature difference with and without dams would be greatest directly downstream from Iron Gate Dam, but could extend an additional 120 to 130 river miles downstream. Estimated decreases in stream temperature with dam removal relative to existing conditions are likely to be smaller with continued climate change; however, temperature conditions for aquatic resources would be much improved under the Proposed Project as compared to existing conditions (see Potential Impact 3.2-1).

Klamath River Estuary and Pacific Ocean Nearshore Environment

The influence of the Proposed Project on water temperature would likely decrease with distance downstream from Iron Gate Dam, and it is unlikely that dam removal under the Proposed Project would have detectable effects on water temperatures in the Klamath River Estuary and Pacific Ocean nearshore environment (see Potential Impact 3.2-1).

3.3.5.5 Fish Disease and Parasites

The Proposed Project would be expected to reduce impacts on salmon from fish disease. As discussed in detail in Section 3.3.2.3 *Habitat Attributes Expected to be Affected by the Proposed Project*, currently the greatest disease-related mortality is for juvenile salmonids due to *C. shasta* and *P. minibicornis* in the Middle Klamath River downstream from Iron Gate Dam. Among all of the salmon life stages, juvenile salmon tend to be most susceptible to *P. minibicornis* and *C. shasta*, particularly during their outmigration in the spring months (Beeman et al. 2008). The main factors contributing to risk of juvenile salmonid infection by *C. shasta* and *P. minibicornis* include availability of habitat (pools, eddies, and sediment) for the polychaete worm intermediate host *(Manayunkia speciose)*; microhabitat characteristics (static flows and low velocities); congregations of spawned adult salmon with high spore; polychaete proximity to spawning areas; planktonic food sources for polychaete from Lower Klamath Project reservoirs; and water temperatures greater than 59°F (Bartholomew and Foott 2010). For adult salmon, Ich and columnaris have occasionally resulted in substantial mortality, particularly when habitat conditions include exceptionally low flows, high water temperatures, and high densities of fish (such as adult Chinook salmon migrating upstream in the fall and holding at high densities in pools). This section addresses changes to these disease factors anticipated under the Proposed Project, and predicted affects for juvenile and adult salmonid life stages.

Removal of Iron Gate Dam and the three upstream facilities would reduce the concentration of adult salmon and carcasses that presently occurs downstream of Iron Gate Dam. Greater dispersal of spawning adult salmon would reduce their proximity to existing dense populations of polychaetes. FERC's analysis (FERC 2007) concluded that restoring access to reaches upstream of Iron Gate Dam for anadromous fish would allow adult fall-run Chinook salmon to distribute over a greater length of the river, reducing crowding and the concentration of disease pathogens that currently occur in the reach between Iron Gate Dam and the Shasta River.

Under the Proposed Project, sediment bedload transport rates would increase downstream from the current location of Iron Gate Dam which currently includes habitats with large populations of polychaetes. Under existing conditions, actinospores released from this portion of the Klamath River pass downstream and infect juvenile salmon in the current infectious zone downstream from the Shasta River to Seiad (RM 132.7)

(Bartholomew and Foott 2010). In addition, while the area of significant sediment deposition under the Proposed Project is located upstream of Cottonwood Creek, sediment transport rates would also increase downstream from Cottonwood Creek (Appendix F). This increased movement and transport of sediment (sand, silt, and clay) is anticipated to disrupt polychaete habitat from the current location of Iron Gate Dam to downstream from Shasta River, resulting in reduced actinospore releases.

Warm water temperatures increase risk of disease transmission. Dam removal would mean cooler temperatures in the late summer and fall, but slightly warmer temperatures during spring and early summer. FERC (2007) concluded that dam removal would enhance water quality and reduce the cumulative effects on water quality and habitat that contribute to disease-induced salmon die-offs in the Klamath River downstream from Iron Gate Dam. In turn, this would benefit salmon outmigrants from tributaries downstream from Iron Gate Dam, such as the Shasta and Scott rivers. Based on existing data it appears that a reduction in temperature during late summer and fall would have the effect of reducing disease rates (Bartholomew and Foott 2010). Reduced disease in the mainstem is anticipated to benefit outmigrating smolts that are currently exposed at high rates in disease hotspots.

FERC (2007) concluded that more rapid cooling of river temperatures in the fall with the Lower Klamath Project dams removed may also allow for fall Chinook salmon spawning to occur earlier in the fall. Bartholow et al. (2005) and FERC (2007) also suggest that earlier warming of the river system could trigger juvenile salmonids to out migrate earlier. This is consistent with findings that the cumulative exposure of temperature is more important predictors of migration of juvenile Chinook salmon than flow or length-of-day (Sykes et al. 2009). As previously described, increased water temperatures in the spring would likely result in earlier emergence and growth, and encourage earlier migration downstream. In addition, a slight increase in the rate at which water temperatures increase in the spring would be likely to improve the growth rates of newly emerged fall Chinook salmon fry (FERC 2007). Earlier migration downstream and improved growth would likely mean most outmigrants would avoid periods of high disease infection of juvenile salmon (Bartholow et al. 2005).

Flows also play an important role in the regulation of disease in the Klamath River. Elimination of Lower Klamath Project reservoirs under the Proposed Project would not result in major flow alterations as flows in the Klamath River are regulated through mandatory federal conditions imposed on the Klamath Irrigation Project located upstream of J.C. Boyle, but elimination of the Lower Klamath Project would create more flow variability due to peak flows from storm events no longer being retained in Lower Klamath Project reservoirs as well as a loss of flow variability in the portion of the Lower Klamath River below J.C. Boyle due to cessation of peaking operations. As described in Section 3.1.6 *Summary of Available Hydrology Information for the Proposed Project*, 2017 court-ordered flushing flows have been required in 2017 and 2018, with the intent of reducing disease in the Lower Klamath River by mobilizing bedload sediments to disrupt the periphyton intermediate host (discussed below). In addition, court ordered dilution flows were required in 2018. Flushing and dilution flows are not modeled as part of existing conditions hydrology under the Proposed Project. As described in Section 3.1.6, the 2017 court-ordered flows include a requirement to ensure that certain high flows are reached each winter, and also include an emergency dilution requirement if juvenile fish disease reaches high levels in the infection nidus. The emergency dilution flows were used in 2018. While there has not been sufficient time to collect sufficient data on the efficacy of the flushing flows, the necessity to use the emergency dilution flows in 2018 suggest that the addition of the flushing flows is insufficient on its own to resolve the issue of fish disease downstream of Iron Gate Dam. Because polychaete populations are located outside of the main flow along the margins of the river (Bartholomew and Foott 2010), variable flows disrupt this habitat. Therefore, removal of the Lower Klamath Project dams would disrupt microhabitat conditions and is expected to reduce polychaete populations (Stocking and Bartholomew 2007, Bartholomew and Foott 2010) and presumably, reduce infection rates within polychaete populations both in the short and long term (Hetrick et al. 2009).

Periphyton (attached algae) provides habitat for the intermediate host of *C. shasta* and *P. minibicornis*, and would also affect disease in the Klamath River. Some of the Project's anticipated effects would tend to support increased periphytic algal growth, while others would tend to reduce it from existing conditions. Under the Proposed Project additional periphytic growth including *Cladophora* is anticipated within the Hydroelectric Reach In the long term, which could provide habitat for the intermediate host of *C. shasta* and *P. minibicornis*. The existing reservoirs foster growth of phytoplankton algae. Under a riverine system, phytoplankton's ecological advantage is reduced, and attached aquatic vegetation would tend to increase. In the absence of other factors, this could possibly increase the prevalence of the intermediate host for *C. shasta* and *P. minibicornis*. However, dam removal would also create other conditions that tend to offset the growth of aquatic vegetation. These conditions include a restoration of bedload sediment transport, increased flow variability, and a more normal (and variable), riverine temperature regime with substantially cooler fall water temperatures. FERC (2007) concluded that restoring natural sediment transport processes would likely contribute to the scour of (attached algae) downstream from the current site of Iron Gate Dam, and deposited gravel and sand would provide a less favorable substrate for periphyton because of its greater mobility during high flow events than the existing armored substrate (see also Section 3.4.5.2 *Periphyton*).

The current infectious nidus (reach with high infectivity) for *C. shasta* and *P. minibicornis* is located in the Klamath River downstream of Iron Gate Dam, where returning adult spawners congregate. Removal of the Lower Klamath Project dams would allow anadromous salmonids to move upstream in the mainstem Klamath River and tributaries upstream of Iron Gate Dam. Currently, with Iron Gate Dam blocking upstream fish passage and trapping sediment, 2017 court-ordered flushing flows are released from Iron Gate Dam for the purpose of disrupting the nidus downstream of Iron Gate Dam and reducing disease risk, although, as described above, the change in flow regime has not, in isolation, been successful in avoiding high disease concentrations. Under the Proposed Project, it is anticipated that the nidus would no longer form downstream of Iron Gate Dam, and the risk of a new nidus forming upstream is low, in the absence of the 2017 flow requirements for the reasons described above. Because the 2017 flow requirements ensure a minimum level of bedload-sediment movement in winter to disrupt the disease cycle, the likelihood of reduction in disease risk would be enhanced by including the 2017 flow requirements.

Although the conditions leading to the nidus forming downstream of Iron Gate Dam would be ameliorated, some disease factors would continue under the Proposed Project, including eight years of additional Iron Gate Hatchery operations that would potentially result in continued (through post-dam removal year 10) congregations of mostly adult fall-run Chinook salmon in the reach from Iron Gate Dam downstream to Seiad Valley

(Section 3.3.5.6 *Fish Hatcheries*). Under the Proposed Project, if a nidus were to remain in the vicinity of Iron Gate Hatchery, or theoretically were to form within newly accessible upstream habitat (however unlikely), flushing and emergency dilution flow releases as required by the 2017 court order may be required from a new upstream location to achieve the same ecological benefits (i.e., disruption of nidus).

It is unlikely that a new infectious nidus would be re-created upstream. The current infectious zone and high parasite loads below Iron Gate Dam are the result of a synergistic effect of numerous factors that occur within the current disease zone in the Klamath River from the reach from Shasta River downstream to Seiad Valley (FERC 2007, Hamilton et al. 2011, Bartholomew and Foott 2010). These factors include: (1) close proximity of myxospore-shedding carcasses (concentration of carcasses); (2) abundant polychaete populations that are found in atypically stable habitats; (3) suitable water temperatures (greater than 59°F) during periods when juvenile salmonids are present; and 4) low flow variability (Bartholomew and Foott 2010). This synergy would be unlikely in the Upper Klamath River (Hamilton et al. 2011). The likelihood of those synergistic factors developing upstream of Iron Gate Dam would be reduced as carcasses would likely be more dispersed in the watershed than occurs in the restricted habitat downstream of Iron Gate Dam (Foott et al. 2012). Iron Gate Dam is both the limit of anadromy, and the site of the current fish hatchery that accounts for a substantial proportion of all adult returning fish annually. As discussed under Section 3.3.5.3 *Water Quality*, the Keno Impoundment/Lake Ewuana has the potential to be a habitat barrier during most years for fall-run Chinook due to poor water quality during the late summer, and therefore NMFS and USFWS have prescribed fish passage measures for the Keno Impoundment/Lake Ewuana to be used during periods of poor water quality (DOI 2007). If fish passage were not provided at Keno Impoundment/Lake Ewuana, few fall-run Chinook salmon would migrate past this location, few smolts would be produced, and therefore congregations of adult fall-run Chinook salmon would be unlikely to occur since few returning adults would have a natal cue to migrate past this location. In contrast, downstream of Iron Gate Dam thousands of adults have a natal que to return to the hatchery, and congregations regular occur during the fall. Under the Proposed Project, those conditions that are believed to result in development of an infectious nidus below Iron Gate Dam or could result in development of a potential infectious nidus upstream of Iron Gate Dam, are unlikely to occur.

Historically, it appears spawning concentrations of Upper Klamath Basin Chinook salmon were located primarily in the Sprague River (Lane and Lane Associates 1981). However, there is no information indicating that high densities of polychaetes occur in the Sprague River (Foott et al. 2012). Thus, the synergistic factors that contribute to an infectious nidus for emigrants below Iron Gate Dam and near the Iron Gate Hatchery are unlikely to occur at this location under the Proposed Project either.

There is some concern regarding a disease zone in the lower Williamson River downstream from the confluence with the Sprague River, where there are currently high parasite densities observed (Hurst et al. 2012). However, there is no reason to anticipate congregations of adult migrants at this location. In addition, maximum temperatures in the Williamson River do not exceed the disease threshold of 59°F in all years (Bartholomew and Foott 2010, Hamilton et al. 2011). Overall, the risk of a juvenile salmon disease response in the Williamson River would be lower than existing conditions in the Middle Klamath River, but not negligible in all water years (S. Foott, USFWS, pers. comm., 2012).

Removal of the Lower Klamath Project dams would allow anadromous salmonids to move upstream in the mainstem Klamath River and tributaries upstream of Iron Gate Dam, altering disease dynamics between anadromous salmonids and resident species upstream of Iron Gate Dam. However, available information indicates that fish passage would not increase the risk of disease for resident species that occur upstream of Iron Gate Dam (NMFS 2006a). Pathogens (e.g., *C. shasta* and *P. minibicornis)* exist throughout the Klamath River System in both the Upper and Lower Basins, so migration of wild anadromous fish upstream and downstream from Iron Gate Dam would not increase the risk of introducing new pathogens to resident trout residing upstream of Iron Gate Dam (NMFS 2006a). In addition, native Klamath River trout are generally resistant to *C. shasta*. Recently several new *C. shasta* genotypes have been discovered in the Klamath River (described in Section 3.3.2.3 *Habitat Attributes Expected to be Affected by the Proposed Project*). Disease risk is related to host genotype specificity (Atkinson and Bartholomew 2010). It is not expected that introduction of *C. shasta* genotypes upstream would be deleterious because fish in the upstream Basin have shown resistance to the downstream genotypes. Redband trout would presumably have been exposed to genotypes of *C. shasta* during the pre-dam period, and their populations were abundant. Because the salmonid species in the Klamath Basin already co-occur with the genotype of *C. shasta* to which they are susceptible, and the salmonid species are less susceptible to other genotypes of *C. shasta*, expanding the distribution of the different genotypes of *C. shasta* would be unlikely to be deleterious to salmonids. In addition, The Chinook Salmon Expert Panel convened to attempt to answer specific questions related to the Proposed Project compared with existing conditions (Goodman et al. 2011), concluded that the Proposed Project offers greater potential than the existing conditions in reducing disease-related mortality in Klamath River Chinook salmon. Overall, movement of anadromous salmonids into the Upper Klamath Basin presents a relatively low risk of introducing pathogens to resident fish (NMFS 2006a, USFWS/NOAA Fisheries Service Issue 2(B)).

3.3.5.6 Fish Hatcheries

As described under Section 2.7.6 *Hatchery Operations*, under the Proposed Project, the Fall Creek Hatchery would be reopened, and both the Iron Gate Hatchery and Fall Creek Hatchery would continue to operate for a period of eight years following dam removal (through post-dam removal year 7, Table 3.3-11), with the following production goals (Appendix B: *Definite Plan – Section 7.8.3*):

- 3,400,000 fall-run Chinook salmon age 0 smolts at Iron Gate Hatchery (released in spring)
- 1,000,000 fall-run Chinook salmon age 1 yearling smolts at Fall Creek Hatchery (released in fall)
- 75,000 age 1 yearling coho salmon smolts at Fall Creek Hatchery (released in spring)

Although the ability to meet the production goals varies annually based on adult returns and hatchery performance, since 2005 the current fall-run Chinook salmon yearling smolt goals, and current coho salmon yearling smolt goals have been achieved on average, whereas fall-run Chinook salmon age 0 smolts are typically about a million smolts shy of current production goals (K. Pomeroy, CDFW, pers. comm., 2018). Considering actual production achieved, hatchery operations under the Proposed

Project would constitute a reduction in production goals from existing conditions of around 87 percent for yearling fall-run Chinook salmon smolts, 20 percent for fall-run Chinook salmon age 0 smolts, 100 percent for steelhead (although no steelhead have been released since 2012), and no change in production goals for coho salmon smolts. Moving production and releases from Iron Gate Hatchery to Fall Creek Hatchery is not anticipated to have a discernable effect on aquatic resources.

A Hatchery Genetic Management Plan (HGMP) for the Iron Gate Hatchery (CDFW 2014) recently redefined the operation of this hatchery from a mitigation hatchery to one now operated to protect and conserve the genetic resources of the Upper Klamath population unit of the SONCC coho salmon ESU. Included in the HGMP are defined monitoring and evaluation activities to evaluate effects of the hatchery activities on the abundance, productivity, spatial structure, and diversity of the SONCC coho salmon and the magnitude or relative impact of the hatchery program on other actions that influence SONCC coho salmon. Operation of the Fall Creek Hatchery would therefore be managed with a particular focus on supporting recolonization of coho salmon in newly accessible habitat.

For the first eight years following dam removal, the effect of hatchery production on aquatic resources would be similar to existing conditions, as described in Section 3.3.2.3 *Habitat Attributes Expected to be Affected by the Proposed Project*. The continuation of production (albeit reduced) would affect adult returns for fall-run Chinook and coho salmon, as described for species specific aquatic resource impacts in Section 3.3.5.9 *Aquatic Resource Impacts*.

The elimination of hatchery production eight years after Lower Klamath Project dam removals under the Proposed Project would affect aquatic resources in the Area of Analysis. When production is ceased (post-dam removal year 7), adult coho salmon progeny of hatchery releases would potentially continue to return through post-dam removal year 9 (three-year old returns released as age 1), and hatchery adult fall-run Chinook salmon through post-dam removal year 10 (four-year old returns released in post-dam removal year 7) (Table 3.3-11). After post-dam removal year 3, fewer coho and Chinook salmon adults would possess a natal cue to return to the location of Iron Gate Hatchery (and none after post-dam removal year 10), because there would be fewer smolts released there starting in dam removal year 2, and no artificial supplementation of the population from that location after post-dam removal year 7. In addition, during post-dam removal years 7 through 10 for fall-run Chinook salmon and dam removal years 7 through 9 for coho salmon hatchery adults would continue to return to Iron Gate or Fall Creek hatcheries (natal cue) but would not be collected. For this three to four-year period, straying of hatchery adults into areas of natural spawning may increase. Straying has the potential to reduce the reproductive success of natural salmonid populations (Mclean et al. 2003, Chilcote 2003, Araki et al*.* 2007) and negatively affect the genetic diversity of the populations (Reisenbichler and Rubin 1999). Based on the current low numbers of adult returns of coho salmon, increased straying into Fall Creek for a few years is unlikely to have a substantial effect. Fall-run Chinook salmon adults straying into Bogus Creek and Fall Creek may be high during this period, but there would also be greater access to newly available habitat, likely dispersing adults over a greater area and reducing potential impacts.

The current infectious nidus for salmonid smolts (i.e., reach with highest infectivity) for *C. shasta* and *P. minibicornis* appears to be the result of the synergistic effect high spore input from heavily infected, spawned adult salmon that congregate downstream from Iron Gate Dam and Iron Gate Hatchery and the proximity to dense populations of polychaetes (Bartholomew et al. 2007). Juveniles released from Iron Gate Hatchery may also contribute to the infectious nidus (Som et al. 2016a), as hatchery-released juvenile fish that become infected and experience mortality further downstream in the Klamath River and potentially become another source of myxospores threatening aquatic resources in the Lower Klamath River. The greater dispersal of release locations of smolts (Iron Gate Hatchery and Fall Creek Hatchery) starting in post-dam removal year 1 would reduce density of juveniles in that year, and reduce congregations of adults by post-dam removal year 3, and therefore reduce the risk of the infectious nidus forming in the Middle Klamath River in the short-and long-term.

Table 3.3-11. Hatchery releases and adult returns under the Proposed Project.

Species		Dam Removal Year		Post-dam Removal Year							
		1	2[a]	1	2	3	4	5–7[b]	8	9	10
Chinook salmon	Produced	N smolts from existing habitat and existing H smolts (age 0 in spring and age 1 in fall)	N smolts from existing habitat and reduced H smolts	N smolts from new habitat and reduced H smolts	N and reduced H smolts	N and reduced H smolts	N and reduced H smolts	N and reduced H smolts	N smolts	N smolts	N smolts
	Returning	N and H adults (age 3–4) downstream of Iron Gate Dam	N and H adults access new habitat	N and H adults	N and H adults	N adults from new habitat (progeny of post-dam removal year 1 outmigration) and reduced H adults	N and reduced H adults	N and reduced H adults	N and reduced H adults	N and reduced H adults	N adults and last H adults (age 4, progeny of post-dam removal year 7 outmigration)
Coho salmon	Produced	N smolts from existing habitat and H smolts (age 1)	N smolts from existing habitat and H smolts	N smolts from new habitat and H smolts from Fall Creek	N and H smolts	N and H smolts	N and H smolts	N and H smolts	N smolts	N Smolts	N smolts
	Returning	N and H (age 3) downstream of Iron Gate Dam	N and H adults access new habitat	N and H adults	N and H adults	N adults from new habitat (progeny of post-dam removal year 1 outmigration) and H adults	N and H adults	N and H adults	N and H adults	N and last H adults (progeny of post-dam removal year 7 outmigration)	N adults

[a] Early drawdown of Copco No. 1 begins in dam removal year 1. Drawdown of all reservoirs occurs and dams are removed in dam removal year 2 (see Table 2.7-1). Reduced hatchery releases begin in dam removal year 2 and continue for eight years until post-dam removal year 7.
[b] Final year of hatchery releases occurs in post-dam removal year 7.
H smolt from hatchery releases or adult progeny of hatchery release
N smolt from natural spawning or adult progeny of natural spawning

Overall, dispersing hatchery operations in the short term and discontinuing hatchery operations after eight years following Lower Klamath Project dams removal would reduce the risk of nidus forming in the mainstem Klamath River in the short- and long-term. In addition, hatchery juveniles would no longer be released after post-dam removal year 7 during natural smolt outmigration. Therefore, it is anticipated that the Proposed Project would result in reduced impacts to aquatic resources due to fish disease and parasites in the short- and long-term. Population and other impacts of altered hatchery operations vary for aquatic species and are discussed for specific impacts below.

3.3.5.7 Algal Toxins

The removal of the Lower Klamath Project reservoirs, particularly the larger Copco No. 1 and Iron Gate reservoirs, would decrease or eliminate excessive growth of phytoplankton, and in particular large seasonal blooms of blue-green algae and associated toxins (e.g., microcystin), by eliminating large areas of quiescent habitat where these phytoplankton species currently thrive. In the nutrient-rich Klamath River system, the elevated water temperatures and increased light levels that occur during the summer and early fall under existing conditions result in seasonal blue-green algae blooms in the phytoplankton and periphyton Area of Analysis, and especially the Hydroelectric Reach (Section 3.4.2.3 *Hydroelectric Reach*). As analyzed in Potential Impact 3.4-2, the Proposed Project would dramatically decrease the amount of optimal (calm, slow-moving reservoir) habitat available to support nuisance and/or noxious phytoplankton species, resulting in a corresponding decrease in phytoplankton blooms, alleviating high seasonal concentrations of algal toxins and associated bioaccumulation of microcystin in fish and freshwater mollusk tissue for species downstream of the Lower Klamath Project reservoirs.

While some microcystin may be transported to downstream reaches of the Klamath River from large blooms occurring in Upper Klamath Lake, the levels would not be nearly as high as those experienced under existing conditions, because seasonal blooms in Copco No. 1 and Iron Gate reservoirs are the primary source of *Microcystis aeruginosa* to the Middle and Lower Klamath River (see Section 3.4.2 *Phytoplankton*). Overall, bioaccumulation of algal toxins in freshwater mollusk and fish tissue would be expected to decrease in the mainstem Klamath River from the Hydroelectric Reach to the Klamath River Estuary.

3.3.5.8 Aquatic Habitat

As described in Section 2.1 *Project Objectives*, a primary purpose of the Proposed Project is to increase habitat availability for anadromous salmonids in the Klamath River, for the benefit of the salmonid populations and the recreational, commercial, and cultural uses related to the health of the salmon fishery. The Proposed Project is intended to increase the amount of aquatic habitat by removing migration barriers, and also to improve the quality of the habitat, as related to the operation of the existing hydroelectric facilities. There is some disagreement among experts as to the amount of habitat that Chinook salmon and steelhead would be able to reach, based primarily[90] on the impact of water quality problems in the Lake Ewauna/Keno Reservoir reach and in Upper

[90] Both dams that would remain under the Proposed Project (Keno Dam and Link River Dam), have fish passage facilities.

Klamath Lake, discussed in greater detail in Upper Klamath River and Connected Waterbodies, immediately below. Because coho salmon are not expected to migrate to these reaches, the same concern does not affect estimates of additional coho habitat.

It is worth noting that based on comments received during the public scoping process (Appendix A), it appears that there is concern from some about the historic distribution of salmonids in the Klamath River Basin, with individuals asserting that historical geomorphic features or water quality may have limited upstream migration prior to dam construction (see below paragraph). However, as this document is an analysis of habitat availability upon implementation of the Proposed Project, including consideration of existing and projected future river conditions, this EIR does not further address questions of the historic distribution of salmonids in the Klamath River Basin.

A few commenters (Appendix A) have suggested that a reef existed at the location of Copco No. 1 Dam that would have limited anadromous salmon passage. Boyle (1976) describes an andesite "reef" at the location of Copco No. 1 Dam prior to dam construction and reservoir inundation. He observed evidence of a historical lake formed by this reef that extended approximately five river miles upstream. While the reef may have been a barrier to migration of Chinook salmon when it was originally formed, Boyle is clear that the reef was one of the oldest exposed formations found in the Siskiyou Mountains, and that this barrier and lake existed in the geologic history. At the time of Copco No. 1 Dam construction, no impediments to upstream Chinook salmon migration were described by Boyle. Boyle (1976) describes large runs of salmon at the site of Copco No. 1 in the early 1900's, and details that a fish ladder was considered for construction at Copco No. 1 Dam, but in coordination with California Fish and Game Commission a fish hatchery was proposed for Fall Creek in lieu of passage. Further, historical records reviewed by Hamilton et al. (2005) and Hamilton et al. (2016), and genetic information obtained from archaeological sites analyzed by Butler et al. (2010), indicate that prior to the construction of Copco No. 1 Dam, Chinook salmon (fall- and spring-run based on observed and documented timing) were abundant in, and spawned in, tributaries of the Upper Klamath Basin (i.e., upstream of the described reef and eventual location of Copco No. 1 Dam), Shovel and Spencer creeks, as well as the Sprague, Williamson, and Wood rivers. This conclusion was further recognized in a trial-type hearing concerning federal fisheries requirements in *Klamath Hydroelectric Project* (FERC Project No. 2082, Docket # 2006-NMFS-0001) (Sept. 29, 2006) (hereinafter "NMFS 2006a"). Thus, it appears that there was no "reef" forming a barrier to fish migration at the time Copco No. 1 was built.

The habitat quantity and quality that would be accessible under the Proposed Project within the Area of Analysis are described below for each of the key reaches.

<u>Upper Klamath River and Connected Waterbodies</u>

Removal of the four hydroelectric dams eliminates all of the impassable dams that prevent salmon from accessing an estimated 360 miles of potential anadromous fish habitat upstream of Upper Klamath Lake and Keno Impoundment/Lake Ewauna, with key habitat tributaries being the Woods, Williamson and Sprague rivers (Huntington 2006, DOI 2007, NMFS 2007b). However, FERC's (2007) analysis of habitat access for anadromous fish with fish passage excluded these 360 miles of anadromous fish habitat based upon poor water quality conditions in Upper Klamath Lake and Keno Impoundment/Lake Ewauna during summer months. The Chinook Salmon Expert Panel (Goodman et al. 2011) also concluded that substantial gains in Chinook salmon abundance for areas upstream of Keno Impoundment/Lake Ewauna would be contingent upon successfully resolving limitations associated with poor water quality problems in Upper Klamath Lake and Keno Impoundment/Lake Ewauna. The Coho Salmon and Steelhead Expert Panel (Dunne et al. 2011) stated that poor water quality in Keno Impoundment/Lake Ewauna and in Upper Klamath Lake, and the possibility of difficult passage at Keno Dam, could impede steelhead from reaching improved habitat in the Upper Klamath River. Note that as discussed above (Section 3.3.2.2 *Physical Habitat Descriptions*), fish passage at Keno Dam is in the process of being improved by the USBR.

These concerns for anadromous salmonid migration and spawning overstate the seasonal habitat limitations of Keno Impoundment/Lake Ewauna and Upper Klamath Lake because of the manner in which the seasonal water quality impairments intersect with steelhead, spring-run Chinook, and certain fall-run Chinook life histories.

Regarding Upper Klamath Lake's availability as habitat/migration corridor, a study by Maule et al. (2009) strongly suggests that Upper Klamath Lake habitat can support salmonids, except during the summer (June through September). Maule et al. (2009) examined the response of salmon to Upper Klamath Lake under existing conditions. Iron Gate Hatchery Chinook salmon were tested in the lake and the lower Williamson River to assess whether existing conditions would physiologically impair salmon reintroduced into the Upper Klamath Basin. Juvenile Chinook salmon were tested in cages in 2005 and 2006. These juveniles showed normal development as smolts in Upper Klamath Lake and survived well in both locations (Maule et al. 2009). Maule et al. (2009) concluded that there was little evidence of physiological impairment or significant vulnerability to *C. shasta* that would preclude this stock from being reintroduced into the Upper Klamath Basin. In addition, the dominant life history of fall-run Chinook salmon (Type I) outmigrate to the ocean in spring and would not rear during the stressful summer period in the Upper Klamath Basin. Type II and Type III life history would rear during summer and outmigrate during either fall (Type II) or spring (Type III). Thus, conditions for juvenile fall-run Chinook emigration through Upper Klamath Lake appear favorable. Due to the spring migration period for adult and juvenile spring-run Chinook salmon and steelhead, the migratory life stages would generally avoid the period of poor water quality in Upper Klamath Lake as well. Cool groundwater spring inputs in the Williamson River and on the west side of Upper Klamath Lake would likely provide thermal refugia for the non-migratory juvenile salmonid rearing life stages.

Similar to the severe water quality impairments in Upper Klamath Lake, the serious water quality issues in Keno Impoundment/Lake Ewauna are not year round. Both DOI and NMFS have long recognized the issue of seasonally poor water quality typically between June 15 and November 15 in Keno Impoundment/Lake Ewauna. This is a time period when nearly all adult fall- and some (later portion) spring-run Chinook salmon would be migrating upstream. When water quality is poor both DOI and NMFS prescribed the transfer of primarily adult fall-run Chinook salmon upstream of the Keno Impoundment/Lake Ewauna for the purposes of restoration and safe, effective, and timely passage (DOI 2007, NMFS 2007b). If fish passage were not provided, upstream migrating adults would presumably locate spawning habitat downstream.

Upper Klamath River – Hydroelectric Reach

This reach would be fundamentally altered under the Proposed Project, with the removal of the dams and associated reservoirs, and the restoration of riverine systems and habitat connectivity. Under the Proposed Project anadromous fish (Chinook salmon, steelhead, coho salmon, and Pacific lamprey) access would be restored to an estimated 80 miles of habitat within the mainstem Klamath River and tributaries upstream of Iron Gate Dam and downstream of Keno Dam (DOI 2007, Cunanan 2009). Primary tributary habitat that would be available for salmonids includes Fall, Jenny, Shovel, and Spencer creeks. In addition to the tributaries and the current reaches of the mainstem, the 80 miles of habitat includes restoration of 21.2 miles of currently inundated mainstem and tributary riverine habitat (Cunanan 2009) for resident and anadromous fish. The current reservoirs inundate sections of the river that had high sinuosity and complex channels that historically provided high quality salmonid spawning and rearing habitats (Hetrick et al. 2009). Modeling indicates that the river would return to a similar channel morphology following dam removal, ad discussed in Appendix F. In addition, proposed habitat restoration within the reservoir areas (described in Section 2.7.4 *Restoration Within the Reservoir Footprint*) is designed to slow water velocities along the bank and thus has the potential to create backwater and rearing habitat for coho salmon. Proposed habitat restoration components include manually creating connectivity to tributaries, incorporating floodplain habitat features (e.g., side channels), creating bank-line complexity to slow water velocities, and placing large wood habitat features (Appendix B: *Definite Plan*).

Under the Proposed Project, short-term alterations to the hydrograph would result from the release of water stored in the Lower Klamath Project reservoirs. Based on modeling results, this release is expected to last about three months, from January 1 into mid-March of dam removal year 2, but could vary depending on hydrologic conditions (USBR 2012), increasing the magnitude of flows downstream from the dams during the drawdown period. River flows would be expected to remain below the 10-year flood event.

In the long term flows would increase not only in the bypass reaches, but also in all other mainstem reaches due to changes in operations and the absence of reservoir evaporation. Hydrology in the J.C. Boyle Peaking Reach would follow the natural hydrograph more closely, including increased duration and magnitude of high flows, and cessation of daily extreme flow fluctuations (characteristic of hydroelectric peaking operations).

Increases in flows resulting from changes in peaking operations at J.C. Boyle Dam would provide more habitat than under existing conditions for redband/rainbow trout and other resident riverine species, as well as anadromous fish or lamprey that reestablish in this area. These flows are expected to meet channel maintenance needs to route coarse sediments, build bars, erode banks, flush fine sediments, scour vegetation and undercut and topple large woody riparian vegetation (NRC 2008). The removal of Lower Klamath Project dams would reestablish geomorphic and vegetative processes that form channels that provide fish habitat and spawning gravels in this reach, especially in the former bypassed reaches (FERC 2007). In addition, the impacts associated with daily extreme flow fluctuations resulting from hydroelectric peaking operations (e.g., stranding, displacement, reduced food production, and increased stress) would no longer occur.

Middle and Lower Klamath River

As described above, reservoir drawdown under the Proposed Project would result in increased flows for about four months once drawdown begins. Over the long term, the Proposed Project would alter the hydrograph so that the duration, timing, and magnitude of flows would be more similar to the unregulated conditions under which the native fish community evolved (Hetrick et al. 2009). While mean annual flows would not substantially change from existing flows due to the lack of active reservoir storage (Stillwater Sciences 2009b, USBR 2012), daily, seasonal, and annual flow variability would increase. It is anticipated that restoration of the hydrologic function of the river system under the Proposed Project would support the creation of habitat diversity and maintain biophysical attributes of the Klamath River (Stanford et al. 1996, Poff et al. 1997).

The Proposed Project would substantially decrease the transit time of water in the Hydroelectric Reach, because it would no longer be impounded by the reservoirs, resulting in a shift in the timing of the occurrence of low flow periods to earlier in summer than currently occurs (Balance Hydrologics Inc. 1996, NRC 2004). These hydrologic effects would likely be more important in upstream areas (directly downstream from Iron Gate Dam) than downstream areas (downstream from the confluence of the Scott River) due to the substantial flow contribution of tributaries to the Klamath River (USBR 2012). In addition, these hydraulic changes would result in changes to water quality, water temperatures, sediment transport, and riparian habitat, as described in subsequent sections.

Klamath River Estuary and Pacific Ocean Nearshore Environment

Hydrologic and hydraulic modeling results (described in Section 3.6.2.3 *Flood Hydrology*) indicate that because of the influence of the tributaries entering the Klamath River downstream from Iron Gate Dam, the flow changes for the Proposed Project would not substantially affect the flows entering the estuary. Specifically, Potential Impact 3.6-1 and Potential Impact 3.6-3 provide further discussion and information on this effect. Therefore, the Proposed Project would not affect flow-related fisheries habitat in the estuary or the Pacific Ocean.

3.3.5.9 Aquatic Resource Impacts

Potential Impact 3.3-1 Effects on coho salmon critical habitat quality and quantity due to short-term sediment releases and long-term changes in habitat quality and quantity due to dam removal.

In the short term, under the Proposed Project, designated critical habitat supporting SONCC coho salmon would be degraded from elevated SSCs and sediment deposition downstream of Iron Gate Dam (see Section 3.3.5.1 *Suspended Sediment* and Appendix E of this EIR, and Section 3.3.5.2 *Bed Elevation and Grain Size Distribution* and Appendix F of this EIR). The specific features of critical habitat and designated PCEs considered essential for the conservation of the SONCC ESU that would be adversely impacted in the short term include spawning substrate, water quality, and safe passage conditions. Quality of spawning substrate for coho salmon downstream of Iron Gate Dam would be substantially degraded during the spawning season following dam removal, while most of the spawning habitat occurring in tributaries would remain unaltered by the Proposed Project (Appendix E). Water quality in the mainstem Klamath River downstream of Iron Gate Dam would be substantially degraded in the short term from increased suspended sediment and decreased dissolved oxygen, resulting in a substantial reduction in rearing and migration habitat suitability for juvenile and smolt coho salmon during the winter and spring following dam removal (Appendix E). Passage conditions would be impaired for adult upstream migrants during the fall and winter of dam removal from both increased suspended sediment, and the risk of sediment deposits at tributary confluences (Appendices E and F). Passage conditions would be impaired for coho salmon smolts during spring following dam removal from increased suspended sediment (Appendix E). Based on the substantial short-term decrease in quality of the features of critical habitat and PCEs supporting SONCC coho salmon, there would be a significant impact to coho salmon critical habitat under the Proposed Project in the short term.

However, the Proposed Project includes aquatic resource measures AR-1 (Mainstem Spawning) and AR-2 (Juvenile Outmigration) to reduce the short-term effects of SSCs on coho salmon PCEs of critical habitat. In addition, mitigation measures AQR-1 and AQR-2 (described below), would be required to increase certainty of the effectiveness of the aquatic resource measures AR-1 and AR-2 and to reduce the short-term significant adverse impacts of the Proposed Project on coho salmon critical habitat. Aquatic resource measures submitted as part of the Proposed Project are summarized in Section 2.7.8.1 *Aquatic Resource Measures* and detailed in Appendix B: *Definite Plan − Appendix I*. AR-1 includes the development and implementation of a monitoring and adaptive management plan to offset the impacts of Lower Klamath Project dam removal on mainstem spawning habitat. 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. Monitoring would occur periodically for the two years following dam removal. Additionally, any 5-year flow event of 10,895 cfs or greater on the Klamath River recorded at the USGS Klamath River Below Iron Gate Dam CA gage (No. 11516530) within the first two years following reservoir drawdown would trigger a monitoring effort. Mitigation Measure AQR-1 Mainstem Spawning (detailed below) further specifies that monitoring shall also be conducted following a significant flow event, even if that flow event occurs more than two years following dam removal. Aquatic Resource Measure AR-1 also includes a spawning habitat evaluation on the Klamath River and tributaries in the Hydroelectric Reach. Most coho salmon spawning occurs in tributaries, and very few coho salmon have been observed spawning in the mainstem Klamath River. Therefore, the spawning habitat actions of AR-1 are focused on offsetting impacts of the Proposed Project on Chinook salmon and steelhead. However, due to the similar spawning habitat requirements of coho salmon to both species, these actions would benefit coho salmon as well. If spawning habitat conditions following dam removal do not meet target metrics[91] developed to offset the anticipated loss of Chinook salmon and steelhead redds due to the Proposed Project, AR-1 specifies that spawning gravel augmentation would be completed within the mainstem, with additional spawning habitat actions within tributaries. These tributary spawning habitat restoration actions would be completed in Jenny Creek, Shovel Creek, Fall Creek, and/or Spencer Creek and could include removal of artificial fish passage barriers, or placement of large woody debris to trap and retain spawning gravels. Mitigation Measure AQR-1 Mainstem Spawning (detailed below) further specifies the range of actions that shall be conducted in tributaries to offset impacts to critical habitat. Implementation of the Proposed Aquatic Resource Measure AR-1 along with Mitigation Measure AQR-1 would reduce the short-term

[91] Spawning gravel in the amount of 44,100 yd^2 for fall Chinook salmon and 4,700 yd^2 for steelhead

potential impacts of SSCs on coho salmon spawning habitat in dam removal year 2 by improving access to tributary habitat where impacts from SSC on habitat in the mainstem can be avoided, and by augmenting spawning gravel, ensuring that suitable spawning habitat in mainstem and tributaries is available following dam removal. Given implementation of AR-1 and AQR-1, suitable coho salmon spawning habitat quality and quantity would not be substantially reduced as a result of the Proposed Project.

Proposed Aquatic Resource Measure AR-2 includes three primary actions: 1) salvaging mainstem overwintering juvenile salmonids prior to reservoir drawdown; 2) maintaining tributary-mainstem connectivity to ensure volitional fish passage between tributaries and the Klamath River; and 3) developing a water quality monitoring network, trigger thresholds, and plan for salvaging and relocating juvenile fish from tributary confluence areas to cold water tributaries or nearby off-channel ponds. Implementation of proposed Aquatic Resource Measure AR-2 would reduce the short-term effects of SSCs on rearing habitat for coho salmon juveniles in the mainstem during dam removal by actively transporting up to 500 juvenile coho salmon from vulnerable mainstem areas to off-channel ponds protected from the effects of the Proposed Project, thus offsetting water quality impacts to critical habitat. Other native fish captured during the seining and trapping effort, such as juvenile steelhead and juvenile Chinook salmon would be relocated into tributary streams adjacent to the salvage locations. Proposed Aquatic Resource Measure AR-2 would also reduce the potential short-term effects of SSCs to migratory habitat for coho salmon smolts by maintaining tributary-mainstem connectivity to ensure volitional fish passage between tributaries and the Klamath River. Monitoring would occur regularly for the two years following dam removal. Additionally, any 5-year flow event of 10,895 cfs or greater on the Klamath River recorded at the USGS Klamath River Below Iron Gate Dam CA gage (No.11516530) within the first two years following reservoir drawdown would trigger a monitoring effort. Mitigation Measure AQR-2 Juvenile Outmigration (detailed below) further specifies that monitoring shall also be conducted following a significant flow event, even if that flow event occurs more than two years following dam removal. In addition, proposed Aquatic Resource Measure AR-2 would reduce the potential short-term effects of SSCs to migratory habitat for coho salmon smolts by rescuing and transporting smolts if mainstem SSC are high, and water temperatures within tributaries are too poor to provide safe refuge (a decision to be made in regular consultation with the Aquatic Technical Work Group [ATWG[92]]). These measures would effectively provide juvenile coho salmon short-term refuge in suitable habitat as an alternative to exposure to temporarily degraded critical habitat from periods of high SSC in the mainstem habitat following dam removal.

Based on the wide distribution of coho salmon critical habitat within tributaries, implementation of the KRRC's proposed aquatic resource measures (AR-1 and AR-2), and implementation of the mitigation measures (AQR-1 and AQR-2) developed for this EIR (where both sets of measures were designed to offset short-term impacts to PCEs of critical habitat), there would not be a substantial decrease in the quality of a substantial proportion of habitat for coho salmon critical habitat in the short term. Therefore, the Proposed Project would have no significant impact on coho salmon critical habitat in the short term.

[92] The ATWG would be comprised of agency and tribal fisheries scientists to review the aquatic resource (AR) mitigation measures included in the Proposed Project.

In the long term, the Proposed Project would increase the amount of habitat available to coho salmon upstream of currently designated critical habitat and improve water quality and bedload characteristics in the mainstem Klamath River within current critical habitat.

The Proposed Project would restore access for Upper Klamath River coho salmon populations to the Hydroelectric Reach. The 2006 administrative trial-type hearings evaluating fish passage mandatory conditions found that the record of evidence is inconclusive as to whether coho salmon's historical distribution extended upstream as far as Spencer Creek, but that the evidence definitively shows that based on historical records and tribal accounts coho salmon used habitat as far upstream as Fall Creek (NMFS 2006a). Based on Hamilton et al. (2005), the Proposed Project would expand coho salmon distribution to include historical high-quality spawning and rearing habitat along the mainstem Klamath River and all tributaries upstream at least as far as Spencer Creek, including in Jenny, Shovel, and Fall creeks. Together, this compromises around 80 miles of suitable potential habitat within the Hydroelectric Reach (DOI 2007, Cunanan 2009). Access to suitable habitat upstream of Iron Gate Dam would increase the availability of spawning sites, result in additional food resources, and provide access to areas of better water quality.

NMFS may consider whether to designate the newly available habitat as critical habitat as part of its five-year status review or as a separate reconsideration of the critical habitat designation for the species (J. Simondet, NMFS, pers. comm., 2011). But, it is speculative at this point to prejudge the outcome of any such consideration, so the EIR does not find that the anticipated coho habitat expansion would necessarily result in an increased in the amount of designated critical habitat.

As discussed in detail in Potential Impact 3.2-1, the thermal lag formerly caused by water storage in reservoirs and the associated increased thermal mass would be eliminated in the Lower Klamath River. This would result in Klamath River water temperatures that exhibit more natural diel (i.e., 24-hour period) variation and are more in sync with historical migration and spawning periods. These changes would result in water temperatures that are more favorable for salmonids in the mainstem Klamath River in the long term, thus improving the water quality PCE of critical habitat. Removal of the Lower Klamath Project dams and associated facilities would also increase dissolved oxygen concentrations and eliminate reservoir habitat that creates the conditions necessary for the growth of blue-green algae and other phytoplankton. Under the Proposed Project, increased bedload supply and transport following dam removal would increase the supply of gravel downstream from the removed dams as far downstream as Cottonwood Creek (see Appendix F). In the long term this would likely improve critical habitat for coho salmon by reducing median substrate to a size more favorable for spawning (USBR 2012).

Overall, these changes would be a substantial increase in the quality and quantity of coho salmon critical habitat in the long term. Therefore, the Proposed Project would be beneficial for coho salmon critical habitat in the long term.

Mitigation Measure AQR-1 – Mainstem Spawning.
Implementation of Action 1 of proposed Aquatic Resource Measure AR-1 (tributary-mainstem connectivity) shall be implemented in the tributaries identified in Action 1 of AR-1, as well as all newly created stream channels that were previously inundated by Project reservoirs prior to drawdown. As described in Appendix B: *Definite Plan –*

Appendix I, implementation of Action 1 of proposed Aquatic Resource Measure AR-1 would be conducted for at least two years following dam removal, including following a 5-year flow event if the event were to occur within that two years. This mitigation measure (AQR-1) ensures that in addition to the monitoring that shall be conducted as described for AR-1, monitoring shall also be conducted within one month following a 5-year flow event regardless of how many years since dam removal have passed, and if fish passage obstructions are identified, they shall be removed as described in AR-1 (Appendix B: *Definite Plan − Appendix I*). In addition, implementation of Action 1 of proposed Aquatic Resource Measure AR-1 shall include an evaluation and proposal of other actions to improve spawning and rearing habitat in tributaries to the Klamath River that meet the spawning targets identified in AR-1, which may include: installation of large woody material, riparian planting for shade coverage, wetland construction or enhancement, and cattle exclusion fencing.

Mitigation Measure AQR-2 – Juvenile Outmigration.
Implementation of Action 2 of proposed Aquatic Resource Measure AR-2 (tributary-mainstem connectivity monitoring) shall be implemented in the tributaries identified in Action 2 of AR-2 as well as all newly created stream channels that were previously inundated by Lower Klamath Project reservoirs prior to drawdown. As described in Appendix B: *Definite Plan − Appendix I*, implementation of Action 2 of AR-2 would be conducted for at least two years following dam removal, including following a 5-year flow event, if the event were to occur within that two years. This mitigation measure (AQR-2) ensures that in addition to monitoring described under AR-2, monitoring shall also be conducted within one month following a 5-year flow event regardless of how many years since dam removal have passed, and requires that if fish passage obstructions are identified in relation to the Proposed Project, they shall be removed as described in AR-2 (Appendix B: *Definite Plan − Appendix I*).

Significance
No significant impact with mitigation to coho salmon critical habitat in the short term

Beneficial for coho salmon critical habitat in the long term

Potential Impact 3.3-2 Effects on Southern Resident Killer Whale critical habitat quality due to short-term and long-term alterations to salmon populations due to dam removal.
The Klamath River contributes to critical habitat for Southern Resident Killer Whales through its contribution of salmon to their food supply (included as a PCE). The Proposed Project would not affect the geographic extent of critical habitat for this species, as it is located in the state of Washington. In the short term, salmon population abundance is anticipated to reduce under the Proposed Project, as described in Potential Impacts 3.3-7, 3.3-8, and 3.3-9. In the long term, the Proposed Project is expected to increase salmon populations (as described in Potential Impacts 3.3-7, 3.3-8, and 3.3-9), which could increase food supply for Southern Resident Killer Whales. However, data on the Southern Resident Killer Whale diet indicate that based on the migratory range and behavior of the population, the Klamath River salmon are anticipated to provide less than one percent of the diet of Southern Resident Killer Whales in most months under current and future conditions. While Southern Resident Killer Whales have been shown to consume Klamath River Chinook Salmon, the Klamath River is considered by NMFS and WDFW tenth out of the top ten priority Chinook Salmon populations for Southern Resident Killer Whales (NMFS 2018b, NMFS

and WDFW 2018). Because of the low proportion of the Sothern Resident Killer Whale diet being composed of salmon from the Klamath River, the Proposed Project would not be likely to substantially impact the habitat quality (i.e., food supply) of Southern Resident Killer Whales in the short term or long term. Therefore, the Proposed Project would have no significant impact to Southern Resident Killer Whale critical habitat in the short term and long term.

Significance

No significant impact to Southern Resident Killer Whale critical habitat in the short term

No significant impact to Southern Resident Killer Whale critical habitat in the long term

Potential Impact 3.3-3 Effects on eulachon critical habitat quality due to short-term sediment releases due to dam removal.

In the short term, under the Proposed Project, PCEs of critical habitat supporting eulachon would be degraded, including short-term adverse effects of suspended sediment (see Section 3.3.5.1 *Suspended Sediment* and Appendix E) primarily on spawning and egg incubation habitat, and adult and larval migration habitat (NMFS 2011) during eulachon spawning, and adult and larval migration period (primarily January through April). Eulachon are highly adapted to migrating and spawning during periods of increases suspended sediment, and suspended sediment released under the Proposed Project is predicted to be at levels similar to what occurs under existing conditions within the Klamath River Estuary, at least during infrequent storm events.

Critical habitat for the Southern DPS eulachon includes approximately 539 miles of riverine and estuarine habitat in California, Oregon, and Washington, of which the Klamath River Estuary is a small proportion (less than two percent). Although the Proposed Project could result in short-term reductions in habitat quality detrimental to PCEs (potentially spawning substrate composition during the year of dam removal) under a worst impacts on fish scenario, a negligible amount (less than two percent) of eulachon critical habitat would be effected for a short duration. Therefore, impacts to eulachon critical habitat would not be significant in the short term.

In the long term, SSCs would be similar to those under existing conditions. Natural bedload transport processes would resume, as the dams would no longer trap sediment supplied from areas upstream of Iron Gate Dam (see Appendix F). Channel bed elevations and grains size in the estuary and ocean would not be appreciably affected, because of the small contribution of the area upstream of Iron Gate Dam to the total bedload in the system. Water quality benefits resulting from the Proposed Project would largely have dissipated upstream of the estuary, and therefore, water quality in the estuary would be expected to remain un-altered in the long term (WQST 2011). Therefore, there would be no impact to eulachon critical habitat in the long term.

Significance

No significant impact to eulachon critical habitat in the short term

No significant impact to eulachon critical habitat in the long term

Potential Impact 3.3-4 Effects on Chinook and coho salmon Essential Fish Habitat (EFH) quality and quantity due to short-term sediment releases and long-term changes in habitat quality and quantity due to dam removal.

In the short term, under the Proposed Project, Chinook and coho salmon Essential Fish Habitat (EFH) is identical for both species and would be degraded from elevated SSCs and sediment deposition downstream of Iron Gate Dam (see Section 3.3.5.1 *Suspended Sediment* and Appendix E of this EIR, and Section 3.3.5.2 *Bed Elevation and Grain Size Distribution* and Appendix F of this EIR). The specific features of EFH that would be adversely impacted in the short term include water quality necessary for successful adult migration and holding, spawning, egg-to-fry survival, fry rearing, smolt migration, and estuarine rearing of juvenile Chinook and coho salmon. Water quality in the mainstem Klamath River downstream of Iron Gate Dam would be substantially degraded in the short term from increased suspended sediment and decreased dissolved oxygen, resulting in a substantial reduction in rearing and migration habitat suitability for juvenile and smolt Chinook and coho salmon during the winter and spring following dam removal (Appendix E). Passage conditions would be impaired for adult upstream Chinook and coho salmon migrants during the fall and winter of dam removal from both increased suspended sediment, and the risk of sediment deposits at tributary confluences (Appendices E and F). Quality of spawning substrate for Chinook and coho salmon downstream of Iron Gate Dam would be substantially degraded during the spawning season following dam removal, while most of the spawning habitat occurring in tributaries would remain unaltered by the Proposed Project (Appendix E). Passage conditions would be impaired for Chinook and coho salmon smolts during spring following dam removal from increased suspended sediment (Appendix E). Based on the substantial short-term decrease in quality of EFH for Chinook and coho salmon, there would be a significant impact to Chinook and coho salmon EFH under the Proposed Project in the short term.

However, the Proposed Project includes aquatic resource measures AR-1 (Mainstem Spawning) and AR-2 (Juvenile Outmigration) to reduce the short-term effects of SSCs on Chinook and coho salmon EFH. In addition, mitigation measures AQR-1 and AQR-2 (described above for Potential Impact 3.3-1), would be required to increase certainty of the effectiveness of the aquatic resource measures AR-1 and AR-2 and reduce the potential for short-term significant adverse impacts of the Proposed Project on Chinook and coho salmon EFH. Aquatic resource measures are summarized in Section 2.7.8.1 *Aquatic Resource Measures* and detailed in Appendix B: *Definite Plan − Appendix I*. Proposed Aquatic Resource Measure AR-1 includes the development and implementation of a monitoring and adaptive management plan to offset the impacts of Lower Klamath Project dam removal on mainstem spawning habitat. Proposed Aquatic Resource Measure 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. Monitoring would occur regularly for the two years following dam removal. Additionally, any 5-year flow event of 10,895 cfs or greater on the Klamath River recorded at the USGS Klamath River Below Iron Gate Dam CA gage (No. 11516530) within the first two years following reservoir drawdown would trigger a monitoring effort. Mitigation Measure AQR-1 Mainstem Spawning (described in detail in Potential Impact 3.3-1), developed for this EIR, further specifies that monitoring shall also be conducted following a significant flow event, even if that flow event occurs more than two years following dam removal. Proposed Aquatic Resource Measure AR-1 also includes a spawning habitat evaluation on the Klamath River and tributaries in the Hydroelectric Reach. If spawning habitat conditions following dam removal do not meet target metrics[93] developed to offset the anticipated loss of Chinook salmon and steelhead redds due to the Proposed Project, spawning gravel augmentation would be completed within the mainstem, with additional spawning habitat actions within tributaries. 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. Mitigation Measure AQR-1 Mainstem Spawning further specifies the range of actions that shall be conducted in tributaries to offset impacts to EFH. Implementation of proposed Aquatic Resource Measure AR-1 and Mitigation Measure AQR-1 would reduce the short-term impacts of SSCs on Chinook and coho salmon EFH in dam removal year 2 by improving access to tributary habitat where impacts from SSC on habitat in the mainstem can be avoided, and by augmenting spawning gravel to ensure that an equivalent amount of spawning habitat is available following dam removal. Therefore, it is anticipated that, in the short term, fewer Chinook and coho salmon would spawn in the mainstem prior to and following the dam removal, and suitable spawning gravel access would be maintained.

Proposed Aquatic Resource Measure AR-2 includes three primary actions: (1) salvaging mainstem overwintering juvenile salmonids prior to reservoir drawdown; (2) maintaining tributary-mainstem connectivity to ensure volitional fish passage between tributaries and the Klamath River; and (3) developing a water quality monitoring network, trigger thresholds, and plan for salvaging and relocating juvenile fish from tributary confluence areas to cold water tributaries or nearby off-channel ponds. Implementation of proposed Aquatic Resource Measure AR-2 would reduce the short-term effects of SSCs on Chinook and coho salmon EFH in the mainstem during dam removal by actively transporting up to 500 juvenile coho salmon from vulnerable mainstem areas to off-channel ponds protected from the effects of the Proposed Project. Other native fish captured during the seining and trapping effort, such as juvenile Chinook salmon would also be relocated into tributary streams adjacent to the salvage locations, thus off-setting water quality impacts to Chinook and coho salmon EFH. In addition, proposed Aquatic Resource Measure AR-2 would reduce the short-term effects of SSCs to migratory Chinook and coho salmon EFH by rescuing and transporting smolts if mainstem SSC are high, and water quality conditions within tributaries are too poor to provide safe refuge (a decision to be made in regular consultation with the ATWG). Proposed Aquatic Resource Measure AR-2 would also reduce the potential short-term effects of SSCs to migratory habitat for Chinook and coho salmon smolts by maintaining tributary-mainstem connectivity to ensure volitional fish passage between tributaries and the Klamath River. Monitoring would occur regularly for the two years following dam removal. Additionally, any 5-year flow event of 10,895 cfs or greater on the Klamath River recorded at the USGS Klamath River Below Iron Gate Dam CA gage (No.11516530) within the first two years following reservoir drawdown would trigger a monitoring effort. Mitigation Measure AQR-2 Mainstem Spawning (described in detail in Potential Impact 3.3-1) further specifies that monitoring shall also be conducted following a 5-year flow event, even if that flow event occurs more than two years following dam removal. These actions would effectively reduce the number of salmon juveniles and smolts potentially exposed to periods of high SSC in the mainstem habitat following dam removal, and therefore reduce the proportion of the population experiencing sub-lethal effects or mortality in temporarily degraded habitat.

[93] Spawning gravel in the amount of 44,100 yd^2 for fall Chinook salmon and 4,700 yd^2 for steelhead

Based on the wide distribution and use of tributaries by both juvenile and adult Chinook and coho salmon, implementation of the KRRC's proposed aquatic resource measures (AR-1 and AR-2), and implementation of mitigation measures (AQR-1 and AQR-2) developed for this EIR (where both sets of measures were designed to offset short-term impacts to Chinook and coho salmon EFH), there would not be a substantial decrease in the quality of a large proportion of Chinook and coho salmon EFH in the short term. Therefore, the Proposed Project would have no significant impact on Chinook and coho salmon EFH in the short term.

In the long term, bedload supply and transport following dam removal would increase supply of gravel downstream from the dam as far downstream as Cottonwood Creek (see Appendix F). This would potentially improve EFH for Chinook and coho salmon by reducing median substrate to a size more favorable for spawning (USBR 2012). In the long term, the Proposed Project would also increase habitat for Chinook and coho salmon (upstream of currently designated EFH) by providing access to habitats upstream of Iron Gate Dam. EFH quality would be affected by improved water quality, and decreased prevalence of disease, as described above for coho salmon critical habitat. Improved access to habitats (upstream of currently designated EFH), improved water quality, increased sediment transport, and decreased prevalence of disease, would be beneficial to EFH for Chinook and coho salmon in the long term.

Significance

No significant impact with mitigation to Chinook and coho salmon EFH in the short term

Beneficial for Chinook and coho salmon EFH in the long term

Potential Impact 3.3-5 Effects on groundfish Essential Fish Habitat (EFH) quality due to short-term sediment releases and long-term changes in habitat quality due to dam removal.

EFH for Pacific Coast groundfish includes all waters and substrate within areas with a depth less than or equal to 3,500 meters (1,914 fathoms [ftm]) shoreward to the mean high-water level or the upriver extent of saltwater intrusion. Within the Area of Analysis for aquatic resources, this includes the Klamath River Estuary and Pacific Ocean nearshore environment.

In the short term, under the Proposed Project, impacts to the nearshore environment are not anticipated to be distinguishable from existing conditions, based on a relatively small magnitude of SSCs released to the nearshore environment, an anticipated rapid dilution of the sediment plume as it expands in the ocean, and a relatively low rate of deposition of sediments to the Pacific Ocean nearshore environment bottom substrates (Section 3.3.5.1 *Suspended Sediment*). EFH in the Klamath River Estuary could be affected by elevated SSCs for about four months during the winter following dam removal, during which time many groundfish species could be spawning. After this time, SSCs would return to levels similar to existing conditions. SSCs in the estuary would be less than 40 percent of the peak concentrations that are anticipated to occur immediately downstream from Iron Gate Dam. These peaks (potentially > 1,000 mg/L) downstream from Iron Gate Dam would still be substantial and would be higher than the extreme values estimated by the sediment transport model for existing conditions (see Section 3.3.5.1 *Suspended Sediment*). However, increased suspended sediment is not anticipated to substantially decrease the quality of groundfish EFH, which is adapted to periodic pulses of high sediment. In addition, the area of EFH for groundfish affected by the Proposed Project within the Klamath River Estuary is a very small proportion (<1 percent) of the total EFH designated for groundfish along the Pacific Coast. Therefore, impacts to groundfish EFH from the Proposed Project would have no significant impact in the short term.

In the long term, SSCs would be similar to those under existing conditions. Water quality benefits resulting from the Proposed Project would largely have dissipated upstream of the estuary, and therefore, water quality in the estuary would be expected to remain similar to existing conditions. Therefore, there would no impact to groundfish EFH from the Proposed Project in the long term.

Significance

No significant impact to groundfish EFH in the short term

No significant impact to groundfish EFH in the long term

Potential Impact 3.3-6 Effects on pelagic fish Essential Fish Habitat (EFH) quality due to short-term sediment releases and long-term changes in habitat quality due to dam removal.

EFH for coastal pelagic species occurs from the shorelines of California, Oregon, and Washington westward to the exclusive economic zone and above the thermocline where sea surface temperatures range from 50 to 78.8°F. Within the Area of Analysis for aquatic resources, this includes the Pacific Ocean nearshore environment. Substantial dilution of the mainstem river SSCs is expected to occur in the nearshore under the Proposed Project, and therefore the SSCs in the nearshore ocean would be expected to be similar to what would occur during existing extreme conditions. Pelagic fish are highly adapted to periods of increased suspended sediment and have the ability to swim away from areas of temporary poor habitat quality. In addition, the area for EFH for pelagic fish affected by the Proposed Project within the near-shore environment is a very small proportion (less than one percent) of the total EFH designated for pelagic species along the Pacific Coast. Overall, there would be no substantial reduction in the quality of pelagic fish EFH, and thus there would be no significant impact to pelagic fish EFH from the Proposed Project in the short term or long term.

Significance

No significant impact to pelagic fish EFH in the short term

No significant impact to pelagic fish EFH in the long term

Potential Impact 3.3-7 Effects on the fall-run Chinook salmon population due to short-term sediment releases and long-term changes in habitat quality, habitat quantity, and hatchery operations due to dam removal.

The potential for the Proposed Project to significantly increase the salmonid population in the Klamath River, including the fall-run Chinook salmon population, is an underlying purpose for the Proposed Project (KHSA 2016, Appendix B: *Definite Plan*). Therefore, as described in Section 2.7 *Proposed Project*, the drawdown timing for J.C. Boyle, Copco No. 1, and Iron Gate reservoirs under the Proposed Project was selected to minimize impacts from sediment release following dam removal under the Proposed Project to aquatic species, including fall-run Chinook salmon. Based on the distribution and life-history timing of fall-run Chinook salmon in the Klamath Basin, only a portion of

Chinook salmon adults, juveniles, and smolts are likely to be present in the mainstem Klamath River during the periods of greatest sediment transport between January and March. Most individuals are in tributaries, or further downstream during this time where concentrations would be diluted by tributary inflows. Additionally, the timing of drawdown coincides with periods of naturally high suspended sediment in the Klamath River, to which fall-run Chinook salmon have adapted by avoiding and tolerating.

This potential impact section begins with a summary of the available analysis predicting the response of the fall-run Chinook salmon population to the Proposed Action in the short- and long-term. The section then discusses in detail the potential short-term and long-term changes from the Proposed Project in each of the five study reaches within the Area of Analysis.

Quantitative modeling of fall-run Chinook salmon populations predict that the Proposed Project would increase Chinook salmon abundance. Modeling of dam removal and existing conditions by Oosterhout (2005) suggests that dam removal would substantially increase Chinook full-run spawners over a 50-year period relative to other management scenarios. Additional population capacity and modeling efforts support this conclusion (Huntington 2006, Dunsmoor and Huntington 2006, Hendrix 2011, Lindley and Davis 2011). Of these, the Hendrix (2011) life-cycle model (Evaluation of Dam Removal and Restoration of Anadromy, EDRRA) approach is considered the most intensive and robust conducted to date, because it explicitly addressed the Proposed Project, used stock-recruitment data from the Klamath River, explicitly incorporated variability in watershed and ocean conditions, and presented variance estimates of uncertainty.

Hendrix (2011) applied EDRRA to forecast the abundance of Chinook salmon (Type I and Type II life history strategies) for both the Proposed Project and continuation of existing conditions for the years 2012 to 2061. The EDDRA model did not incorporate potential climate change effects. The EDRRA Chinook salmon life cycle model assumes that current management rules (fishery control rule) established by the Pacific Fishery Management Council (PFMC) for management of Klamath River Chinook salmon would remain in place throughout the 50-year period of analysis. The PFMC has regulatory jurisdiction over salmon fishing within the 317,690-square mile exclusive economic zone from three miles to 200 miles off the coast of Washington, Oregon, and California. Since the management of salmon considers many factors that can fluctuate greatly from year to year (population abundance and environmental conditions) it is impossible to predict how future management decisions regarding the specific harvest of Klamath Basin salmon might change as a result of the Proposed Project. As stated in Hendrix (2011) “this rule is based on an optimal (i.e., escapement that produces maximum sustainable yield) escapement target after harvest of 40,700 (PFMC 2005).” The analysis uses the same escapement target (40,700 fish) for both alternatives despite the fact that Klamath Basin spawning distribution would be extended by hundreds of miles under the Proposed Project (as described below) and would therefore presumably have a higher escapement target. Therefore, in the EDRRA model, harvest and escapement targets to sustain the population are being managed optimally under existing conditions, whereas under the Proposed Project the escapement target is likely lower than would be required to fill newly accessible habitat. If the PFMC changes management under the Proposed Project based on additional access to spawning and rearing habitat, the harvest and escapement targets could be higher than predicted by the EDRRA model.

The EDRRA model assumes a flow regime under the Proposed Project based on the 2010 BiOp flows (NMFS 2010a), and implicitly incorporates water quality and disease by modeling a smolt survival rate that varies based on flows. The model assumes habitat restoration actions in the Upper- and Mid-Klamath basins, and it further assumes that these actions would take time to become effective. This EIR's analysis selectively uses the EDRRA modeling results that characterize conditions prior to habitat restoration because habitat restoration in the Upper- and Mid-Klamath basins is not included as part of the Proposed Project (aside from habitat restoration in Lower Klamath Project reservoirs). The EDDRA model also assumes active reintroduction efforts described in Hooton and Smith (2008), which would fully seed available fry habitats upstream of Iron Gate Dam, including the Upper Klamath Basin upstream of Upper Klamath Lake, prior to dam removal. Active reintroduction of fall-run Chinook salmon is not currently planned following dam removal under the Proposed Project. Instead, natural volitional reintroduction is anticipated under the Proposed Project and would require a longer time to meet the production levels predicted by the EDRRA model and reported by Hendrix (2011).

The EDRRA model assumes that Iron Gate Hatchery production does not occur under the Proposed Project. Therefore, the eight years of hatchery releases of Chinook salmon, after Lower Klamath Project dams removal, albeit at reduced production goals compared with existing conditions (43 percent decrease in Chinook age 0 and age 1 smolt release goals compared with current releases), would somewhat offset the lack of active reintroduction included in the EDRRA model.

From 1978 through 2016, returns of fall-run Chinook salmon adults to the Iron Gate Hatchery have ranged from 2,558 (in 1980) to 72,474 (in 2001), and averaged 16,559 (CDFW 2016b). During the same period, natural returns in the Klamath River (excluding Trinity River returns) ranged from 6,957 to 91,757 fall-run Chinook salmon, with an average of 31,379 fish (CDFW 2016a). While natural returns typically outnumber hatchery returns, the proportion of the Chinook salmon escapement composed of Iron Gate Hatchery returns has historically been substantial (approximately 35 percent of age 3 adults, KRTT 2011, 2013, 2015). Assuming a 43 percent decrease in smolt production relative to current (2005 through 2018) releases would result in a similar reduction in adult returns; it is possible that between post-dam removal years 3 and 10 (Table 3.3-11) an average of 7,120 fewer fish could return on an annual basis due to reduced hatchery releases. The elimination of the goal of releasing around six million Chinook salmon smolts and yearlings annually after eight years (post-dam removal year 7) would be anticipated to result in a reduction in adult hatchery returns to the Klamath River. Most adult returns are age 3 (around 75 percent), with some age 4 (around 23 percent), and a few age 5 (less than 2 percent) (KRTT 2011, 2013, 2015). As a result, progeny of hatchery releases are anticipated to return as adults continuing mostly through post-dam removal year 10 (four-year old returns, progeny of final releases in post-dam removal year 7). The first adult returns from the progeny of naturally spawning fall-run Chinook salmon in newly accessible habitat upstream of the location of Iron Gate Dam would be expected in post-dam removal year 3 (3-year old returns, progeny of post-dam removal year 1; Table 3.3-3). Therefore, between post-dam removal years 3 and 10, both hatchery returns and returns from newly accessible habitat would occur, potentially increasing the rate of reintroduction comparable to the effect of active reintroduction assumed in the EDRRA model. Impacts associated with hatcheries operations in relation to water diversions and minimum bypass flows for fish passage is discussed in

Potential Impact 3.3-23 (Iron Gate Hatchery) and Potential Impact 3.3-24 (Fall Creek Hatchery).

The amount of time required for the fall-run Chinook salmon population in the Klamath River to reach capacity under the Proposed Project would be a function of adult returns that volitionally recolonize new habitat, although there is no accurate means to predict how much longer it would take to reach full capacity without the active reintroduction modeled using EDRRA. Recolonization success and rate is a function of fish straying into newly available habitats (Pess 2009). For Chinook salmon, stray rates are around six percent (Hendry et al. 2004), and 95 percent of strays migrate less than 20 miles from their natal area (Quinn and Fresh 1984, Quinn et al. 1991). However, following major changes in environmental conditions (e.g., dam removal, high SSC), salmonid stray rates have been observed to increase. For example, Leider (1989) reported steelhead stray rates increasing from 16 percent to 45 percent during recolonization of streams following the Mt. Saint Helens eruption. The time period of colonization (historical or new habitat) has been reported to occur within five to thirty years, with most falling between one to two decades (Withler 1982, Bryant 1999, Burger et al 2000, Glen 2002, Pess et al. 2003, Milner et al. 2008, Kiffney et al. 2009). Rapid (less than one year) recolonization was observed for fall-run Chinook salmon following fish ladder installation at Landsburg Dam on the Cedar River, Washington (Kiffney et al. 2009) and within months of removal of Condit Dam on the White Salmon River, Washington (Allen et al. 2016). Fall-run Chinook salmon were observed to recolonize habitat upstream of the former location of the Elwha Dam within the first year of dam removal, and within five years of dam removal a majority of returning adults were spawning in newly accessible habitat upstream of the former dam location (Weinheimer et al. 2018). A ladder was placed on the Landsburg Dam in 2003, and Chinook salmon immediately (i.e., the first fall following ladder installation) accessed areas upstream of the dam, with juveniles of both species being observed during snorkel surveys the following year. By 2011, Chinook salmon occurred throughout nearly all accessible habitat upstream of the dam.

It is likely that following dam removal under the Proposed Project, recolonization of the 80 miles of habitat downstream of Keno Dam would be rapid, with a longer timeframe for habitat in the Upper Klamath River and connected waterbodies (and contingent on fish passage being provided at Keno Impoundment/Lake Ewauna). The EDRRA model prediction is that with dam removal there would be substantially more (median increase greater than 10,000) returning adult Chinook salmon in the Klamath Basin than without dam removal, where the prediction is based solely on access to habitat between Iron Gate and Keno dams.

Median escapements to the Klamath Basin are predicted to be higher (median increase greater than 30,000) with the Proposed Project than under existing conditions. The potential for ocean harvest is also predicted to be greater with the Proposed Project due to increased Chinook salmon adults in ocean, and the probability of low escapement leading to fishery closures was less under the Proposed Project. Modeling results of Hendrix (2011) indicated uncertainty in Chinook salmon stock recruitment dynamics due to the uncertainty in predicting smolt production based on habitat conditions, as well as uncertainty in escapement and harvest abundance forecasts based on habitat conditions. Despite the uncertainty, the results indicate that the Proposed Project would result in higher relative abundance of Chinook salmon.

In addition to the quantitative EDRRA modeling results, FERC (2007) and Hamilton et al. (2011) synthesized all available information and both concluded that increased habitat access following dam removal would result in an increase in the abundance of fall-run Chinook salmon population in the Klamath Basin.

Further, to help determine if the Proposed Project would advance restoration of the salmonid fisheries of the Klamath Basin, a Chinook Salmon Expert Panel was convened to attempt to answer specific questions that had been formulated by the KHSA (2016) stakeholders to assist with assessing the effects of the KHSA compared with existing conditions (Goodman et al. 2011). The Chinook Salmon Expert Panel concluded that Lower Klamath Project dam removal (and habitat restoration actions associated with the KBRA) would be a major step forward in conserving target fish populations in the Klamath Basin. The Chinook Salmon Expert Panel predicted that, based on the information provided to them, it was possible that Lower Klamath Project dam removal would provide a substantial increase in the abundance of naturally spawned Klamath River Chinook salmon above that expected under existing conditions in the reach between Iron Gate Dam and Keno Dam. In addition, the Chinook Salmon Expert Panel concluded that Lower Klamath Project dam removal offers greater potential than the existing conditions for Chinook salmon to tolerate climate change and changes in marine survival (Goodman et al. 2011). While the Chinook Salmon Expert Panel agreed that there was also evidence for potential dramatic increases in abundance associated with potential fish passage upstream of Keno Dam as well, they cautioned that achieving substantial gains in Chinook salmon abundance and distribution in the Klamath Basin is contingent upon successfully resolving key factors that would continue to affect the population, including water quality in Upper Klamath Lake and Keno Reservoir, disease, colonization of the Upper Klamath River Basin, harvest and escapement, hatchery interactions, predation by resident fish, climate change, instream flows, and impacts from dam removal. The anticipated influence of the Proposed Project on these factors (among others) within specific reaches is described below.

Upper Klamath River and Connected Waterbodies

As discussed above under 3.3.5.8 *Aquatic Habitat*, under the Proposed Project, removal of the Lower Klamath Project dams would allow fall-run Chinook salmon to regain access to around 360 miles within the upper Klamath River upstream of Upper Klamath Lake (DOI 2007, Hamilton et al. 2005, 2016). The access would expand the Chinook salmon's current habitat to include historical habitat along the mainstem Klamath River, upstream to the Sprague, Williamson, and Wood rivers (Hamilton et al. 2005, 2016). This would be a potential increase in access to 49 significant tributaries in the Upper Klamath Basin, comprising hundreds of miles of additional potentially productive habitat upstream of Iron Gate Dam (DOI 2007), including access to groundwater-fed areas with relatively cold water that would be resistant to climate change-induced water temperature increases (Hamilton et al. 2011).

As discussed under Section 3.3.5.3 *Water Quality*, the Keno Impoundment/Lake Ewuana has the potential to be a habitat barrier during most years for fall-run Chinook due to poor water quality during the late summer, and therefore NMFS and USFWS have prescribed fish passage measures for the Keno Impoundment/Lake Ewuana to be used during periods of poor water quality (DOI 2007). If fish passage were not provided, fall-run Chinook salmon would be limited to the additional habitat access in the Hydroelectric Reach, as described in detail below. Over the long term, seasonal dissolved oxygen in the Keno Impoundment/Lake Ewauna would also be expected to improve as TMDL implementation projects continue. While it would be speculative at this point to identify the timing or scope of such improvements, it is reasonable to assume that the multiple water quality improvement projects would work to shorten the season of impairment in the reach (allowing early and/or later migrants to reach upstream spawning habitat) and to reduce the number of years in which Keno Impoundment/Lake Ewauna's poor water quality forms a barrier to migration.

Upper Klamath River - Hydroelectric Reach

The Proposed Project would restore fall-run Chinook salmon access to the Hydroelectric Reach, expanding their distribution to include historical habitat along the mainstem Klamath River and all tributaries upstream at least as far as Spencer Creek; including in Jenny, Shovel, and Fall creeks (Hamilton et al. 2005), totaling around 80 miles of potential habitat within the Hydroelectric Reach, including 21.2 miles of habitat currently inundated by Lower Klamath Project reservoirs (DOI 2007, Cunanan 2009). Historically, Chinook salmon (both fall- and spring-run) spawned and were abundant within this habitat (NMFS 2006a, Hamilton et al. 2016). Prior to construction of Iron Gate Dam, Coots and Wales (1952) observed about 300 Chinook salmon spawning in the Copco No. 2 Bypass Reach at around eight cfs, with additional spawning habitat available at the time of survey.

Adults would be able to access this reach starting in September of dam removal year 2 (Table 2.7-1). By fall of dam removal year 2, elevated SSCs from dam removal would have subsided (USBR 2012). Because of this, fall-run Chinook salmon would not be exposed to the elevated SSCs that would occur during dam removal in this reach. Most of the sediment stored within the river channels currently inundated by Lower Klamath Project reservoirs would likely be eroded by the end of spring of dam-removal year 2. The maximum deposition anticipated is minor (less than 0.5 foot), within pockets of the river reaches between reservoirs, settling into pool and other low-velocity habitats as water velocities decrease. This would constitute a negligible and temporary (less than six months following reservoir drawdown in dam removal year 1) reduction in the quality of habitat and would occur prior to the first adult salmon accessing newly available habitat in post-dam removal year 1.

River channel habitat within the reservoir reaches would be primarily low gradient habitat which is of critical importance for salmon spawning and rearing. For example, FERC (2007) described the Copco No. 2 bypassed reach and reaches inundated by Iron Gate and Copco reservoirs to be low gradient. For these reaches, they estimated that the density of Chinook salmon spawners per mile for mainstem habitat was twice that of high gradient habitat (FERC 2007). These river channels would likely excavate to their pre-dam elevations within six months, and revert to and maintain pool-riffle morphology due to restoration of riverine processes, creating holding, spawning, and rearing habitat for anadromous salmonids.

Modeling (USBR 2012) indicates that after dam removal, spawning gravel in all sections of the Hydroelectric Reach would be within the range usable for fall-run Chinook salmon, but the amount of sand in the bed within former reservoir sections could initially inhibit spawning success. 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). The flushing flow is expected to be at least 6,000 cfs and of several days to weeks to return the bed to a bed dominated by cobble and gravel with a sand content less than 20 percent. After the flushing flow, the bed is expected to maintain fractions of sand, gravel, and cobble which would be expected under natural conditions. Based on the historical record a sufficient flushing flow would likely occur within five years following dam removal (see Section 3.6.5.1 *Flood Hydrology*).

Habitat currently within inundated Lower Klamath Project reservoir that would be exposed following dam removal under the Proposed Project is anticipated to be used during the first spawning migration after dam removal (fall of dam removal year 2). A similar rapid recolonization of formally reservoir inundated habitat was observed at two dam removal sites in southern Oregon. Following removal of Savage Rapids Dam on the Rogue River in 2009, 91 redds from within the bounds of the former reservoir were documented where no redds had existed previously in 2010 (the first fall spawning season following dam removal), and more the following year (ODFW 2011). Following removal of the Gold Ray Dam on the Rogue River in 2010, 37 redds were documented from within the bounds of the former reservoir the fall after dam removal, with over twice that many the following year (ODFW 2011).

The Proposed Project would establish flow and water quality conditions that more closely mimics natural conditions by incorporating more variability in daily flows (described in Section 3.6.5.1 *Flood Hydrology*). The reservoir drawdowns would also allow tributaries and springs such as Fall, Shovel, and Spencer creeks and Big Springs to flow directly into the mainstem Klamath River, creating patches of cooler water 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).

In addition, as described in detail in Section 3.3.5.5 *Fish Disease and Parasites*, it is unlikely that the disease conditions that currently exist downstream of Iron Gate Dam would develop upstream of Iron Gate Dam under the Proposed Project.

Middle and Lower Klamath River

In the short term in this reach, the Proposed Project would decrease dissolved oxygen and release dam-stored sediment downstream to the Lower Klamath River. In the long term, the Proposed Project would restore a flow and sediment regime that more closely mimics natural conditions in the long term. Suspended sediment effects on fall-run Chinook salmon under the Proposed Project are described in detail in Appendix E.3.2.1, and summarized here.

During the fall and winter of dam removal year 1, under the least impacts on fish, most-likely impacts on fish, or worst impacts on fish scenario, no impact from suspended sediment is anticipated for all adult fall-run Chinook salmon migrating or spawning within tributaries to the Klamath River, or for juveniles rearing within tributaries (Appendix E, Table E-8). Under the most-likely impacts on fish or worst impacts on fish scenario, complete loss of eggs from the dam removal year 1 brood year deposited in the mainstem in fall of dam removal year 1 is predicted. Based on redd surveys from 1999 through 2009 (Magneson and Wright 2010), an average of around 2,100 redds could be affected in the mainstem. As described in detail in Appendix E.3.2.1, based on escapement estimates in the Klamath Basin from 2001 through 2009 (CDFG 2010, unpublished data) on average this would be around eight percent of all anticipated fall-run Chinook salmon redds in the Klamath River Basin in the fall spawning of dam removal year 1.

In dam removal year 2 suspended sediment could be high enough for long enough duration to cause moderate physiological stress for returning adults during the fall under a least impacts on fish scenario, impaired homing under a most-likely impacts on fish scenario, and major physiological stress under the worst impacts on fish scenario (Appendix E.3.2.1). For smolts, in dam removal year 2 suspended sediment is anticipated to have sublethal effects on Type I, Type II, and Type III outmigrants (Appendix E.3.2.1) and would not cause substantial reductions in abundance. The Type I smolts affected by increased SSCs during dam removal year 2 would be the progeny of the same cohort[94] of adult spawners potentially affected by dam removal. However, the Type-II and Type-III progeny of that same cohort of adults that successfully spawn in tributaries during dam removal year 2 would produce smolts that would outmigrate to the ocean a year after the spring pulse of suspended sediment in dam removal year 2 and should not be noticeably affected by the Proposed Project.

In the long term (by post-dam removal year 2), SSC in the Middle and Lower Klamath River are predicted to return to similar levels to existing conditions, and no substantial effect on fall-run Chinook salmon is anticipated.

In the short term, a higher proportion of sand in the mainstem channel bed surface may reduce the quality of spawning habitat in the mainstem Klamath River downstream of Iron Gate Dam. As described in detail in Appendix F, the dam removal year 2 fall-run Chinook salmon cohort could be affected by sediment deposits with higher levels of sand than under existing conditions. After a flushing flow of at least 6,000 cfs, the bed is expected to maintain fractions of sand, gravel, and cobble which would be expected under natural conditions, and suitable for fall-run Chinook salmon. Based on the historical record a sufficient flushing flow would likely occur within five years following dam removal. These effects would be most apparent in successive median or dry years following dam removal, but less apparent in successive wet years (Appendix F). Increased proportion of sand in the spawning substrate could reduce embryo survival-to-emergence (Chapman 1988) for fall-run Chinook salmon spawning during fall of dam removal year 1 (affecting fry that would emerge and smolt during dam removal year 2). Changes in bedload would be limited to the reach from Iron Gate Dam to Cottonwood Creek, a length of eight miles, or 4 percent of the channel length of the mainstem Klamath River downstream from Iron Gate Dam. The most severe effects would also be limited to a small proportion of the total channel length (0.5 miles, or less than one percent of the channel downstream from Iron Gate Dam), as sediment deposition would lessen downstream from Bogus Creek to Cottonwood Creek. At most, around eight percent of fall-run Chinook salmon in the Klamath Basin are expected to spawn in the mainstem downstream of Iron Gate Dam prior to dam removal, with an even smaller percentage expected to spawn within the 8-mile affected reach (described in Appendix E.3.2.1).

In the long term, the river would eventually exhibit enhanced habitat complexity due to increased sediment supply, a more natural flow regime, greater sediment transport rates, and more frequent bed mobilization that would increase spawning habitat availability and quality and improve early rearing habitat downstream from Iron Gate

[94] Cohort is a group of fish born during the same year.

Dam (see Appendix F). Bedload sediment movement and transport are vital to create and maintain functional aquatic habitat. An increased supply of gravel from upstream sources is predicted to improve spawning gravel quality and increase the amount of fall-run Chinook salmon spawning habitat downstream from Iron Gate Dam by decreasing the median substrate size to 1.5 to 2.4 in (USBR 2012), within the observed range for Chinook salmon spawning (0.6 to 2.8 in [Kondolf and Wolman 1993]). 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.

Short-term (less than two months) reductions in dissolved oxygen are anticipated to occur as a result of high organic SSCs following dam removal, as described in detail in Potential Impact 3.2-9. Despite predicted short-term increases in oxygen demand under the Proposed Project, dissolved oxygen concentrations would generally remain above the minimum acceptable level (5 mg/L) for salmonids of all life stages in this reach. Exceptions to this would occur four to eight weeks following drawdown of J.C. Boyle and Iron Gate reservoirs (i.e., in February dam removal year 2), when dissolved oxygen would remain below 5 mg/L for a distance approximately 48–71 miles downstream from Iron Gate Dam (approximately RM 145 to RM 122). Any incubating fall-Chinook salmon eggs in the river during this time are assumed to have already suffered 100 percent mortality caused by increased SSC during this time, and thus the decrease in dissolved oxygen is not anticipated to have an additional effect. No other life-stages are anticipated to occur in the mainstem Klamath River during this time, and thus no additional effects are expected.

By eliminating peaking flows in the Hydroelectric Reach and removing the Lower Klamath Project reservoirs, the Proposed Project would support a flow regime that more closely mimics natural conditions in the Lower Klamath River. Flows under the Proposed Project are intended to benefit fall-run Chinook salmon and are anticipated to have positive consequences for Chinook salmon given their life cycle in the Klamath River.

As discussed in detail in Section 3.2.5.1 *Water Temperature*, dam removal would also cause water temperatures to become warmer earlier in the spring and early summer and cooler earlier in the late summer and fall and have diurnal variations more synchronized with historical migration and spawning periods (Hamilton et al. 2011). Under the Proposed Project, warmer springtime temperatures would result in fall-run Chinook salmon fry emerging earlier (Sykes et al. 2009), encountering favorable temperatures for growth sooner than under existing conditions (Figure 3.3-5), which could support higher growth rates and encourage earlier migration downstream, thereby reducing stress and disease (Bartholow et al. 2005, FERC 2007). A predicted earlier outmigration in response to elevated water temperatures in the spring is also supported by the scientific literature relating to increased growth rates and thermal response of outmigrating salmonids, as summarized by Hoar (1988). In addition, fall-run Chinook salmon spawning in the mainstem during fall would no longer be delayed by water temperatures (reducing prespawn mortality) (Figure 3.3-4), and adult migration would occur in lower water temperatures than under existing conditions (Figure 3.3-5). Overall, these changes would result in water temperatures more favorable for fall-run Chinook salmon in the mainstem Klamath River downstream from Iron Gate Dam.

As described in Section 3.3.5.5 *Fish Disease and Parasites*, the Proposed Project is expected to disrupt many of the existing congruence of factors that lead to high disease parasite concentrations at locations with multiple water quality stressors for fish and resulting high levels of fish disease.

As described in Section 3.3.5.6 *Fish Hatcheries*, operation of the Iron Gate Hatchery and Fall Creek Hatchery, at a combined reduced capacity for eight years following dam removal, would be likely to reduce hatchery Chinook salmon returns available for ocean or in-river harvest compared with existing conditions. However, naturally-spawning adult returns benefiting from dam removal are predicted to occur beginning in post-dam removal year 3 and the larger returns would begin to offset reductions due to lower hatchery capacity during the first eight years following dam removal and, ultimately, to hatchery closure in post-dam removal year 7.

Also, as described in Section 3.3.5.6 *Fish Hatcheries*, the cessation of juvenile fish releases from Iron Gate Hatchery after eight years may also significantly decrease the amount of competition for food resources and habitat space between hatchery-reared and natural origin smolts and yearlings in the Klamath River. This would result in higher growth rates for natural origin fish (McMichael et al. 1997), and thus larger size at ocean entry beginning in post-dam removal year 8 (first year of no hatchery releases; Table 3.3-11). Smolt size is correlated with increased marine survival for Chinook salmon (Scheuerell et al. 2009, Feldhaus et al. 2016) which, in conjunction with reduced competition with hatchery smolts in the marine environment (Sweeting et al. 2003), is anticipated to result in increased adult returns as soon as post-dam removal year 10 (three-year-old adult returns). In addition, incidences of disease are expected to be reduced by ending hatchery operations after eight years.

Klamath River Estuary and Pacific Ocean Nearshore Environment

Under the Proposed Project, habitat in the Klamath River Estuary and the Pacific Ocean nearshore environment could be affected by sediment releases during dam removal for approximately three months (January through March) under all scenarios. After this time, SSCs would return to levels similar to existing conditions (see Appendix E). SSCs in the Klamath River Estuary would be less than 40 percent of the peak concentrations that are anticipated to occur immediately downstream from Iron Gate Dam. These peaks would still be substantial, and would be higher than the extreme values estimated by the sediment transport model for existing conditions (see Section 3.2.5.2 *Suspended Sediments*). However, the increased SSCs predicted to occur in the estuary would not be of sufficient magnitude or duration to result in substantial sublethal or lethal effects on fall-run Chinook salmon individuals (Appendix E.3.2.1). While the magnitude of SSCs released to the Pacific Ocean nearshore environment would be within the range of natural conditions, the duration of elevated SSCs (i.e., weeks) would be greater than would occur under natural (i.e., storm) conditions (i.e., days). Therefore, there also would be elevated SSCs in the Pacific Ocean nearshore environment relative to existing conditions (see Section 3.2.5.2 *Suspended Sediments*). However, no Chinook salmon adults or juveniles are anticipated to occur within the nearshore environment during this period.

Summary

In the short term, reservoir drawdown under the Proposed Project would result in elevated SSCs, low dissolved oxygen, and altered sand and finer bedload sediment transport and deposition, and would adversely impact fall-run Chinook salmon primarily in the Middle Klamath River downstream of Iron Gate Dam. Fall-run Chinook salmon use the mainstem Klamath River for spawning, rearing, and as a migratory corridor. Direct mortality is predicted for a proportion of fall-run Chinook salmon redds. However, the effect of SSCs from the Proposed Project on the fall-run Chinook salmon population, under all scenarios, is not expected to substantially reduce the population because of variable life histories, the timing of SSC pulses to avoid the most vulnerable fall-run Chinook life stages, the comparatively small number of fall-run Chinook salmon that spawn in the mainstem, 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 outmigrate to the mainstem come from lower-Basin tributaries (e.g., Salmon and Trinity rivers) and thus would be subject only to conditions in the Lower Klamath River, where SSCs resulting from the Proposed Project are expected to be lower due to dilution from tributaries (USBR 2012). Based on no predicted substantial short-term decrease in fall-run Chinook salmon abundance of a year class, or substantial decrease in habitat quality or quantity, there would not be a significant impact to fall-run Chinook salmon under the Proposed Project in the short term.

Although this EIR finds no significant impact on fall-run Chinook salmon In the short term, the KRRC proposes aquatic resource measures AR-1 (Mainstem Spawning) and AR-2 (Juvenile Outmigration) which would further reduce the potential for short-term effects of SSCs on salmonid juveniles, smolts, and eggs, including fall-run Chinook salmon. In addition, although CEQA Guidelines Section 15126.4(a)(3) states that mitigation measures are not required for effects which are not found to be significant, mitigation measures AQR-1 and AQR-2, which would be implemented as a result of significant adverse impacts described for Potential Impact 3.3-1 and Potential Impact 3.3-4, would even further reduce the less than significant short-term effects of the Proposed Project on fall-run Chinook salmon by increasing certainty regarding the effectiveness of the KRRC's proposed aquatic resource measures. Aquatic resource measures are summarized in Section 2.7.8.1 *Aquatic Resource Measures* and detailed in Appendix B: *Definite Plan − Appendix I*. Proposed Aquatic Resource Measure AR-1 includes the development and implementation of a monitoring and adaptive management plan to offset the impacts of Lower Klamath Project dam removal on mainstem spawning. Proposed Aquatic Resource Measure 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. Monitoring would occur regularly for the two years following dam removal. Additionally, any 5-year flow event of 10,895 cfs or greater on the Klamath River recorded at the USGS Klamath River Below Iron Gate Dam CA gage (No. 11516530) within the first two years following reservoir drawdown would trigger a monitoring effort. Mitigation Measure AQR-1 Mainstem Spawning (detailed above), developed for this EIR, further specifies that monitoring shall also be conducted following a significant flow event, even if that flow event occurs more than two years following dam removal. Proposed Aquatic Resource Measure AR-1 also includes a spawning habitat evaluation on the Klamath River and tributaries in the Hydroelectric Reach. The spawning habitat actions of AR-1 are focused on offsetting impacts of the Proposed Project on Chinook salmon and steelhead. If spawning habitat conditions following dam removal do not meet target metrics[95] developed to offset the anticipated loss of Chinook salmon and steelhead redds due to the Proposed Project, spawning gravel augmentation would be

[95] Spawning gravel in the amount of 44,100 yd^2 for fall Chinook salmon and 4,700 yd^2 for steelhead

completed within the mainstem, with additional spawning habitat actions within tributaries. 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. Mitigation Measure AQR-1 Mainstem Spawning (detailed above) further specifies the range of actions that shall be conducted in tributaries to offset impacts to Chinook salmon spawning. Proposed Aquatic Resource Measure AR-1 and Mitigation Measure AQR-1 would reduce the less than significant short-term impacts of SSCs on fall-run Chinook salmon spawning in dam removal year 1 by improving access to tributary habitat where impacts from SSCs in the mainstem can be avoided, and by augmenting spawning gravel ensuring that suitable spawning habitat in mainstem and tributaries is available following dam removal.

Proposed Aquatic Resource Measure AR-2 includes three primary actions: (1) salvaging mainstem overwintering juvenile salmonids prior to reservoir drawdown; (2) maintaining tributary-mainstem connectivity to ensure volitional fish passage between tributaries and the Klamath River; and (3) developing a water quality monitoring network, trigger thresholds, and plan for salvaging and relocating juvenile fish from tributary confluence areas to cold water tributaries or nearby off-channel ponds. Implementation of proposed Aquatic Resource Measure AR-2 would reduce the short-term effects of SSCs to fall-run Chinook salmon juveniles rearing in the mainstem during dam removal by actively transporting juveniles from vulnerable mainstem areas to off-channel ponds protected from the effects of the Proposed Project, thus offsetting water quality impacts to juvenile Chinook salmon. Seining efforts would be focused on coho salmon, but all captured juvenile Chinook salmon would also be relocated into tributary streams adjacent to the salvage locations. Proposed Aquatic Resource Measure AR-2 would also reduce the potential short-term effects of SSCs to fall-run Chinook salmon smolts by maintaining tributary-mainstem connectivity to ensure volitional fish passage between tributaries and the Klamath River. Monitoring would occur regularly for the two years following dam removal. Additionally, any 5-year flow event of 10,895 cfs or greater on the Klamath River recorded at the USGS Klamath River Below Iron Gate Dam CA gage (No. 11516530) within the first two years following reservoir drawdown would trigger a monitoring effort. Mitigation Measure AQR-2 Juvenile Outmigration (detailed below) developed for this EIR, further specifies that monitoring shall also be conducted following a significant flow event, even if that flow event occurs more than two years following dam removal. In addition, proposed Aquatic Resource Measure AR-2 would reduce the less than significant short-term effects of SSCs to migratory Chinook salmon smolts by rescuing and transporting smolts if mainstem SSC are high, and water temperatures within tributaries are too poor to provide safe refuge (a decision to be made in regular consultation with the ATWG).

These actions would effectively reduce the number of fall-run Chinook salmon juveniles and smolts potentially exposed to periods of high SSC in the mainstem following dam removal, and therefore off-set short-term impacts to the proportion of the population experiencing sub-lethal effects or mortality.

In the long term, removal of the Lower Klamath Project dams under the Proposed Project would increase habitat availability, restore a more natural flow regime by eliminating peaking flows in the Hydroelectric Reach and removing the Lower Klamath Project reservoirs, restoring more natural seasonal water temperature variation, improve water quality, and reduce the likelihood of fish disease, all of which would be beneficial for fall-run Chinook salmon. As stated above, dam removal would also restore connectivity to hundreds of miles of potentially usable habitat in the Upper Klamath Basin and would create additional spawning and rearing habitat within the Hydroelectric Reach. It is anticipated that the Proposed Project would increase the abundance, productivity, population spatial structure, and genetic diversity of fall-run Chinook salmon in the Klamath Basin (Hendrix 2011). In general, free-flowing river conditions created by the Proposed Project would likely increase adult migration rate, decrease outmigrant delay, and increase adult escapement (Buchanan et al. 2011b). As discussed in detail above, dam removal would also cause water temperatures to become warmer earlier in the spring and early summer and cooler earlier in the late summer and fall, and have diurnal variations more in sync with historical migration and spawning periods (Hamilton et al. 2011). These changes would result in water temperature more favorable for salmonids in the mainstem. In addition, under the Proposed Project diminished disease conditions and improved water quality in the mainstem Klamath River would likely improve the survival of smolts outmigrating from tributaries downstream from Iron Gate Dam (e.g., Scott and Shasta rivers). Finally, the loss of hatchery production following the closure of Iron Gate Hatchery and Fall Creek Hatchery following eight years of operation is anticipated to be offset by the increase in natural production from habitat upstream of Iron Gate Dam. If fish passage is not provided a Keno Impoundment/Lake Ewuana, restored habitat access to the Hydroelectric Reach and the multiple benefits of the Proposed Project would be beneficial for fall-run Chinook salmon in the long term. If fish passage were provided (per DOI [2007] fish passage prescriptions), an even greater magnitude of restored habitat access to the Upper Klamath River Basin and the multiple benefits of the Proposed Project would be beneficial for fall-run Chinook salmon in the long term.

Significance

No significant impact for fall-run Chinook salmon populations in the short term

Beneficial for fall-run Chinook salmon populations in the long term

Potential Impact 3.3-8 Effects on the spring-run Chinook salmon population due to short-term sediment releases and long-term changes in habitat quality, habitat quantity, and hatchery operations due to dam removal.

As discussed above for fall-run Chinook salmon, a Chinook Salmon Expert Panel was convened to attempt to answer specific questions that had been formulated by the project stakeholders to assist with assessing the effects of the Proposed Project compared with existing conditions (Goodman et al. 2011). While noting uncertainties based on existing data, the panel concluded that the prospects for the Proposed Project to provide a substantial positive effect for spring-run Chinook salmon were less certain than for fall-run Chinook salmon. The primary concern of the panel was that low abundance and productivity (return per spawner) of spring-run Chinook salmon could limit recolonization of habitats upstream of Iron Gate Dam.

There are a few basic mechanisms by which spring-run Chinook salmon could recolonize newly accessible habitat, including (1) straying of adults returning to the Salmon River, (2) adaptation of fall-run Chinook salmon to an early spring-run Chinook salmon life history, or (3) active reintroduction of spring-run Chinook salmon from another population. There are many examples of fall-run Chinook salmon rapidly recolonizing newly accessible habitat discussed in Potential Impact 3.3-7 above, and spring-run Chinook salmon were observed recolonizing habitat in the White Salmon

River, Washington, following removal of Condit Dam (Allen et al. 2016). Following the removal of Condit Dam most of the observed spring-run Chinook salmon spawning was upstream of the location of the former Condit Dam. The current spring-run Chinook salmon abundance in the Salmon River is low (Table 3.3-10), and the rate of recolonization could be slow as a result. However, under the Proposed Project water temperatures and instream flows in the Klamath River upstream of the confluence with the Salmon River are predicted to mimic more natural conditions, which could encourage increased straying into upstream habitat.

The potential for adaptation of fall-run Chinook salmon to a spring-run Chinook salmon life history was assessed by Thompson et al. (2018), and they concluded that based on the genetics of the fall-run Chinook salmon currently downstream of Iron Gate Dam, it was unlikely that this would occur. Active reintroduction of Chinook salmon with genetics suited to adapt to an early spring-run Chinook salmon life history may be successful strategy for recolonization (Thompson et al. 2018). The Proposed Project does not include an active reintroduction plan, although ODFW has been considering implementing active reintroduction of spring-run Chinook salmon following dam removal (T. Wise, ODFW, pers. comm., 2018).

Under the Proposed Project, steelhead, coho, and fall-run Chinook salmon yearlings and smolts would no longer be released from hatcheries in the Klamath River following post-dam removal year 7. Currently there are no releases of spring-run Chinook salmon from hatcheries into the Klamath River. Therefore, the closure of hatcheries eight years following dam removal is not anticipated to result in a decline in adult returns for spring-run Chinook. Impacts associated with hatcheries operations in relation to water diversions and minimum bypass flows for fish passage is discussed in Potential Impact 3.3-23 (Iron Gate Hatchery) and Potential Impact 3.3-24 (Fall Creek Hatchery).

The expected influence of the Proposed Project within specific reaches is described below.

Upper Klamath River and Connected Waterbodies

The Proposed Project would not result in changes to suspended or bedload sediment, flow-related habitat, or algal toxins in this reach. Under the Proposed Project, dam removal would allow spring-run Chinook salmon to regain access to the Upper Klamath River upstream of J.C. Boyle Reservoir (FERC 2007). The access would expand the Chinook salmon's current habitat to include historical habitat along the mainstem Klamath River and upstream to the Sprague, Williamson, and Wood rivers (Hamilton et al. 2005). This would be a potential increase in access to 49 significant tributaries in the Upper Klamath Basin, comprising hundreds of miles of additional potentially productive habitat (DOI 2007), including access to important thermal refugia within areas influenced by groundwater exchange that are more resistant to climate change (Hamilton et al. 2011). Some of these areas, such as the lower Williamson River, have habitat that would provide substantial holding areas for spring-run Chinook salmon (Hamilton et al. 2011). Other holding areas with suitable temperatures upstream of J.C. Boyle Reservoir include groundwater influenced areas on the west side of Upper Klamath Lake, and the Wood River (Gannett et al. 2007). Warmer winter water temperatures associated with groundwater input to the river would also be conducive to the growth of salmonids (Hamilton et al. 2011).

Poor water quality (e.g., severe hypoxia, temperatures exceeding 77°F, high pH) in the reach from Keno Dam to Link Dam might impede volitional fish passage at any time from late June through mid-November (Sullivan et al. 2009, USGS 2010; both as cited in Hamilton et al. 2011). However, available information indicates that Upper Klamath Lake habitat is presently suitable to support Chinook salmon for at least the period from October through May (Maule et al. 2009). Currently, adult spring-run Chinook migration takes place in approximately April through June. Historically, adult spring-run Chinook salmon migrated upstream of the current location of Iron Gate Dam perhaps as early as February and March (Fortune et al. 1966) and likely held over in large holding pools in the mainstem in tributaries fed by cool water, and in thermal refuge habitat upstream of Upper Klamath Lake (Snyder 1931, CDFG 1990c, Moyle 2002). One benefit of such early migration (similar to the spring-run Chinook salmon migration timing currently observed in the Klamath Basin) would be the avoidance of periods of poor water quality in the vicinity of Keno Impoundment/Lake Ewuana. The restored water temperature regime under the Proposed Project may restore the natural upstream migration timing of adult spring-run Chinook salmon because of the shift in water temperatures downstream from Iron Gate Dam (Bartholow et al. 2005). Either under the current migration timing or under a shift towards earlier migration, most or all of the spring-run Chinook salmon migrants would be able to pass upstream through the Keno Impoundment/Lake Ewuana area before seasonal water quality reductions would make passage restricted.

Huntington (2006) reasoned that spring-run Chinook salmon likely accounted for the majority of the Upper Klamath Basin's actual salmon production under historical conditions. Huntington (2006) cautioned that while access to the Upper Klamath Basin provides considerable promise of increasing spring-run abundance, the existing potential for Chinook salmon production within the basin upstream of Upper Klamath Lake is clearly much lower than his estimate of historical potential. However, Huntington (2006) did not fully account for the historical (and unknown) production potential of Upper Klamath Lake itself, which could have been considerable, as suggested by a recent experimental reintroduction into Upper Klamath Lake (Maule et al. 2009).

Upper Klamath River - Hydroelectric Reach

The Proposed Project would restore spring-run Chinook salmon access to the Hydroelectric Reach, including include historical habitat along the mainstem Klamath River and all tributaries upstream at least as far as Spencer Creek; including in Jenny, Shovel, and Fall creeks (Hamilton et al. 2005), comprising around 80 miles of potential habitat within the Hydroelectric Reach (DOI 2007, Cunanan 2009). Chinook salmon (both fall- and spring-run) historically spawned and were abundant within this habitat (NMFS 2006a, Hamilton et al. 2016). Adults would be able to access this reach beginning in spring of dam removal year 2 (Table 2.7-1); thus, short-term gains in flow-related habitat or habitat expansion may be limited to later cohorts. Elevated SSCs and bedload movement from dam removal may not have sufficiently dissipated in time for the first potential migrants, but by the second adult migrant season in post-dam removal year 1, would return to background levels similar to those under existing conditions and would not be expected to affect spring-run Chinook salmon using this area. Adult spring-run Chinook salmon do not currently occur upstream of the Salmon River, and would not be expected to be able to use the mainstem Klamath River upstream of Iron Gate Dam until conditions in the Hydroelectric Reach are suitable.

The Proposed Project would establish flow and water quality conditions that more closely mimics natural conditions by eliminating peaking flows, removing Lower Klamath

Project reservoirs, and incorporating more variability in daily flows. The removal of the reservoirs would allow Fall, Shovel, and Spencer creeks to flow directly into the mainstem Klamath River, along with Big Springs (in the J.C. Boyle Bypass Reach) and additional springs, which would provide fish with patches of cooler water as refugia during summer and fall, as well as providing slightly warmer winter water temperatures conducive to the growth of salmonids (Hamilton et al. 2011).

As described in detail in Section 3.3.5.5 *Fish Disease and Parasites*, it is unlikely that the disease conditions that currently exist downstream of Iron Gate Dam would develop upstream of Iron Gate Dam under the Proposed Project.

Middle and Lower Klamath River

The Proposed Project would release dam-stored sediment downstream to the Lower Klamath River Reach in the short term and would establish a flow and sediment regime that more closely mimics natural conditions in the Middle Klamath River in the long term.

Short-term effects of elevated SSCs on spring-run Chinook salmon under the Proposed Project are described in detail in Appendix E.3.2.2 and summarized here. Spring-run Chinook salmon are primarily distributed in the Salmon River and other tributaries downstream with limits their exposure to temporarily elevated concentrations of suspended sediment that would occur in the mainstem Klamath River under the Proposed Project. Under all scenarios, no impact from suspended sediment is anticipated for all spring-run Chinook salmon spawning and rearing, which occurs primarily within tributaries (Table E-9). Suspended sediment is anticipated to have sublethal effects on adult migration, primarily for those adults returning to the Salmon River (around five percent of all spring-run migrants). All outmigrating spring-run Chinook salmon smolts enter the Klamath River at the confluence with the Salmon River, where SSC are predicted to be much lower than further upstream, and where SSCs under existing conditions can be high from tributary contributions of suspended sediment. Therefore, only sublethal effects on outmigrants are predicted (Appendix E, Table E-9), which is similar to existing conditions (Appendix E, Table E-3).

Short- and long-term changes in channel bed elevations and grain size in response to increased bedload supply would be limited to the reach from Iron Gate Dam to Cottonwood Creek, a length of eight miles, or four percent of the mainstem Klamath River channel downstream from Iron Gate Dam (see Appendix F for details). The most severe effects would also be limited to a small proportion of the total channel length (0.5 miles, or less than one percent of the channel downstream from Iron Gate Dam), as sediment deposition would lessen downstream from Bogus Creek to Cottonwood Creek and, thus, would not affect the area currently used by spring-run Chinook salmon. Within one year (i.e., by spring of post-dam removal year 1), SSCs would have returned to existing conditions and the channel would likely have reverted to its previous pool-riffle morphology (Stillwater Sciences 2008).

By eliminating peaking flows in the Hydroelectric Reach and removing the Lower Klamath Project reservoirs, the Proposed Project would support a flow regime that more closely mimics natural conditions in the Lower Klamath River, mostly upstream of the confluence of Scott Creek. Dam removal would cause water temperatures upstream of the Salmon River confluence to warm earlier in the spring and early summer and cool earlier in the late summer and fall and have diurnal variations more in sync with historical migration and spawning periods (Hamilton et al. 2011). These changes would result in water temperatures that are more favorable for salmonids in the mainstem upstream of the Salmon River confluence (Section 3.3.5.4 *Water Temperature*). Therefore, in the long term it is anticipated that improved mainstem migration conditions may increase migration of spring-run Chinook salmon upstream of the Salmon River towards newly accessible habitat.

Although disease incidence is predicted to decrease (resulting in increased salmonid smolt survival) under the Proposed Project (see Section 3.3.5.5 *Fish Disease*), these benefits would be most noticeable upstream of the confluence with the Salmon River, and thus are anticipated to have less of benefit for spring-run Chinook salmon than other salmonids in comparison with existing conditions.

Klamath River Estuary and Pacific Ocean Nearshore Environment

Under the Proposed Project, habitat in the Klamath River Estuary could be affected by elevated sediment releases during dam removal for about three months (January through March) when spring-run Chinook salmon smolts could be within the estuary (see Section 3.3.5.1 *Suspended Sediment* and Appendix E). After this time, SSCs would return to levels similar to existing conditions. SSCs in the estuary would be less than 40 percent of the peak concentrations that are anticipated to occur immediately downstream from Iron Gate Dam. These peaks would still be substantial, and would be higher than the extreme values estimated by the sediment transport model for existing conditions (see Section 3.3.2.3 *Habitat Attributes Expected to be Affected by the Proposed Project* and Appendix E). However, the increased SSCs predicted to occur in the Klamath River Estuary would not be of sufficient magnitude or duration to result in substantial sublethal or lethal effects on spring-run Chinook salmon individuals (Appendix E.3.2.2). While the magnitude of SSCs released to the Pacific Ocean nearshore environment would be within the range of natural conditions, the duration of elevated SSCs (i.e., weeks) would be greater than would occur under natural (i.e., storm) conditions (i.e., days). Therefore, there also would be elevated SSCs in the Pacific Ocean nearshore environment relative to existing conditions (see Section 3.2.5.2 *Suspended Sediments*). However, no Chinook salmon adults or juveniles are anticipated to occur within the nearshore environment during this period.

Summary

In the short term, reservoir drawdown associated with dam removal under the Proposed Project would alter SSCs and bedload sediment transport and bedload deposition. The overall effect of suspended sediment from the Proposed Project on the spring-run Chinook salmon population is not anticipated to differ substantially from existing conditions. Suspended sediment conditions experienced by adult migrants would result in minor and only sublethal impacts. No impacts are anticipated for the spawning, incubation, and fry stages because they do not occur in the mainstem. Type I, II, and III outmigrants are expected to experience similar conditions under the Proposed Project as under existing conditions. Based on no predicted substantial short-term decrease in spring-run Chinook salmon abundance of a year class, or substantial decrease in habitat quality or quantity, there would not be a significant impact to spring-run Chinook salmon under the Proposed Project in the short term.

Although this EIR finds no significant impact on spring-run Chinook salmon In the short term, the KRRC proposes Aquatic Resource Measures AR-2 (Juvenile Outmigration) which would further reduce the potential for short-term effects of SSCs on salmonid juveniles and smolts, including spring-run Chinook salmon. In addition, although CEQA

Guidelines Section 15126.4(a)(3) states that mitigation measures are not required for effects which are not found to be significant, Mitigation Measure AQR-2, which would be implemented as a result of significant adverse impacts described for Potential Impact 3.3-1 and Potential Impact 3.3-4, would even further reduce the potential for short-term, less than significant effects of the Proposed Project on spring-run Chinook salmon by increasing certainty regarding the effectiveness of the KRRC's proposed aquatic resource measure.

Aquatic resource measures are summarized in Section 2.7.8.1 and detailed in Appendix B: *Definite Plan − Appendix I*. AR-2 includes three primary actions: (1) salvaging mainstem overwintering juvenile salmonids prior to reservoir drawdown; (2) maintaining tributary-mainstem connectivity to ensure volitional fish passage between tributaries and the Klamath River; and (3) developing a water quality monitoring network, trigger thresholds, and plan for salvaging and relocating juvenile fish from tributary confluence areas to cold water tributaries or nearby off-channel ponds. Implementation of AR-2 would reduce the short-term effects of SSCs to outmigrating juvenile spring-run Chinook salmon smolts by rescuing and transporting smolts if mainstem SSC are high, and water quality conditions within tributaries do not allow safe refuge. This action would effectively reduce the number of spring-run Chinook salmon smolts potentially exposed to periods of high SSC in the mainstem following dam removal, and therefore reduce the proportion of the population experiencing sub-lethal effects.

In the long term, removal of the Lower Klamath Project dams under the Proposed Project would increase habitat availability, restore a more natural temperature regime, improve water quality, and reduce the likelihood of fish disease, all of which would be beneficial for spring-run Chinook salmon. Dam removal would restore connectivity to hundreds of miles of potentially usable habitat in the Upper Klamath Basin, including additional habitat within the Hydroelectric Reach. Access to additional habitat would provide a long-term benefit to spring-run Chinook salmon populations. The expansion of habitat opportunities would allow increased expression of life-history variation and the restoration of an additional population of spring-run Chinook salmon to strengthen resiliency in the Klamath Basin, particularly because passage upstream of Iron Gate Dam would provide access to groundwater-fed thermal refugia during summer and fall, as well as providing slightly warmer winter water temperatures conducive to the growth of salmonids (Hamilton et al. 2011). By providing an unimpeded migration corridor, the Proposed Project would provide the greatest possible benefit related to fish passage, hence, the highest survival and reproductive success (Buchanan et al. 2011b). As discussed in detail above, dam removal would also cause water temperatures to become warmer earlier in the spring and early summer and cooler earlier in the late summer and fall, and have diurnal variations more in sync with historical migration and spawning periods in the mainstem upstream of the confluence with the Salmon River (Hamilton et al. 2011). These changes would result in water temperatures more favorable for spring-run Chinook salmon in the mainstem, supporting any portion of the population that recolonizes Klamath River Basin habitat upstream of the Salmon River. It is anticipated that, as a result of the Proposed Project, the spring-run Chinook salmon population within the Klamath Basin would have an opportunity to increase in abundance, and would have increased productivity, population spatial structure, and genetic diversity. Implementation of the Proposed Project would be beneficial for spring-run Chinook salmon in the long term.

Significance

No significant impact for spring-run Chinook salmon populations in the short term

Beneficial for spring-run Chinook salmon populations in the long term

Potential Impact 3.3-9 Effects on coho salmon populations due to short-term sediment releases and long-term changes in habitat quality, habitat quantity, and hatchery operations due to dam removal.

The Coho Salmon and Steelhead Expert Panel was convened and charged with answering specific questions that had been formulated to assist with assessing the effects of the Proposed Project on coho salmon (Dunne et al. 2011). While noting the constraints of the Coho Salmon and Steelhead Expert Panel to arrive at conclusions within a short time, and without adequate quantitative or synthesized information, the conclusion of the Coho Salmon and Steelhead Expert Panel was that, in the short term, the difference between the Proposed Project and existing conditions is expected to be small. The Coho Salmon and Steelhead Expert Panel stated that larger (moderate) increases in abundance are possible under the Proposed Project if additional restoration actions are implemented, and mortality caused by the pathogen *C. shasta* is reduced. The Coho Salmon and Steelhead Expert Panel predicted a small increase in the population from a modest increase in habitat area usable by coho salmon, small changes in conditions in the mainstem, and positive but un-quantified changes in tributary habitats where most coho spawn and rear. The Coho Salmon and Steelhead Expert Panel also noted the potential for increased disease risk and low ocean survival to offset gains in production in the new habitat, although no evidence for either increased disease risk or reduced ocean survival was presented.

Under the Proposed Project, hatchery coho salmon smolts would be released from Fall Creek Hatchery into the Klamath River at current (75,000 smolts annually) production goals for eight years following dam removal. During that eight-year period no change to the coho salmon population resulting from hatchery operations relative to existing conditions is anticipated. Eight years following dam removal, all hatchery coho salmon releases would cease (final releases would occur in dam removal year 7). Based on production goals, ceasing operations after eight years would likely result in a reduction of up to 75,000 coho salmon smolts per year beginning in post-dam removal year 8 (Table 3.3-11). Based on the current low abundance of coho salmon in the upper Klamath River population unit, a conservation focus for the coho salmon hatchery program has been deemed necessary to protect the remaining genetic resources of that population unit (CDFW 2014). Coho salmon adult returns to Iron Gate Hatchery have significantly and steadily declined from a high of 2,466 adults in the 2001/2002 return year to 38 in the 2015/2016 return year, with an average of 866 annually (CDFW 2016b). Assuming smolts are released for the last time in post-dam removal year 7, adults of hatchery progeny would continue to return through post-dam removal year 9 (as age 3 adults). Based on the average coho salmon smolt-to-adult survival ratio of 0.99 percent estimated for current coho salmon Iron Gate Hatchery operations (CDFW 2014), a reduction in the release of 75,000 coho salmon smolts following closure of Fall Creek Hatchery could result in a decline of around 743 adult returns on average annually starting in post-dam removal year 10. These adults would return to the Fall Creek Hatchery, but also stray and spawn naturally. Between 2004 and 2011 an average of 46 coho salmon hatchery adults per year strayed into Bogus Creek (CDFW 2014). Impacts associated with hatcheries operations in relation to water diversions and minimum bypass flows for fish passage is discussed in Potential Impact 3.3-23 (Iron Gate Hatchery) and Potential Impact 3.3-24 (Fall Creek Hatchery).

As described in Section 3.3.5.6 *Fish Hatcheries* and summarized in CDFW (2014), there are potential adverse hatchery-related effects on the coho salmon population, including straying of hatchery fish into important tributaries such as Bogus Creek (first three years) and Fall Creek (years four through ten) with the potential to reduce the reproductive success of the natural population (Mclean et al. 2003, Chilcote 2003, Araki et al. 2007) and negatively affect the diversity of the Klamath River coho salmon populations via outbreeding depression[96] (Reisenbichler and Rubin 1999). The current Hatchery Genetic Management Plan for Iron Gate Hatchery coho salmon (HGMP, CDFW 2014) operates to assist in the basin's coho salmon recovery efforts by conserving a full range of the existing genetic, phenotypic, behavioral, life history, and ecological diversity of the run. The intent of this program is to use genetic analysis in brood stock selection and rearing and release techniques improve fitness and reduce straying of hatchery fish to natural spawning areas.

Under the Proposed Project, dam removal and the associated habitat improvements are anticipated to result in an increase in coho salmon abundance. The first adults that could potentially access newly available habitat upstream of Iron Gate Dam would be in dam removal year 2 (Table 3.3-11) and produce age 1 smolts benefiting from improved river function (e.g., reduced disease in the Middle Klamath River). Therefore, the first adult returns that could reflect improved conditions would be in post-dam removal year 4 (as age 3 adults). Under existing conditions, CDFW (2014) estimates that greater than 30 percent of the total adult returns to the upper Klamath River are of hatchery origin, including greater than 70 percent of returns to the hatchery, around 34 percent of returns to Bogus Creek, and around 16 percent of returns to tributaries such as the Shasta and Scott rivers. Between post-dam removal years 4 and 10, both hatchery returns and returns from newly accessible habitat, would occur (Table 3.3-11) providing a likelihood of increased abundance and recolonization of the newly accessible habitat.

As described in Section 3.3.5.6 *Fish Hatcheries*, outmigrant smolt mortality from disease would be reduced under the Proposed Project starting in post-dam removal year 8 with the end of Chinook and coho salmon hatchery releases. The cessation of juvenile fish releases may also significantly decrease the amount of competition for food resources and habitat space between hatchery-reared and natural origin smolts in the Klamath River. This would result in higher growth rates for natural origin fish (McMichael et al. 1997), and thus larger size at ocean entry beginning in dam removal year 8. Smolt size is correlated with increased marine survival for coho salmon (Holtby et al. 1990), which in conjunction with reduced competition with hatchery smolts in the marine environment (Sweeting et al. 2003) is anticipated to result in increased adult returns as soon as post-dam removal year 10 (3-year-old adult returns). Although existing data are not available for a quantitative prediction, it is anticipated that benefits from dam removal and cessation of hatchery operations would increase adult returns by more than the loss of hatchery progeny.

Upper Klamath River and Connected Waterbodies

Available data suggests that coho salmon were in both mainstem and tributary reaches of the Klamath River upstream to and including Spencer Creek at RM 232.6 (Figure 3.3-

[96] Outbreeding depression is progeny that are less adapted to the environment than parents.

1, NRC 2004, as cited in NMFS 2007a, Hamilton et al. 2005). It is not anticipated that under the Proposed Project coho salmon would begin to occupy habitat within the Upper Klamath River and connected waterbodies, and therefore this reach is not analyzed for effects on coho salmon.

Upper Klamath River – Hydroelectric Reach

The Proposed Project would restore access for the Upper Klamath River Population coho salmon to the Hydroelectric Reach, expanding their distribution to include historical habitat along the mainstem Klamath River and all tributaries upstream at least as far as Spencer Creek; including in Jenny, Shovel, and Fall creeks (Hamilton et al. 2005), comprising around 80 miles of potential habitat within the Hydroelectric Reach (DOI 2007, Cunanan 2009). Coho salmon downstream from Iron Gate Dam belonging to the Upper Klamath River Population Unit would migrate upstream of the dam if access was provided (NMFS 2006a). Over time, access to habitat upstream of Iron Gate Dam would benefit the Upper Klamath River Population Unit by: a) extending the range and distribution of the species thereby increasing the coho salmon's reproductive potential; b) increasing genetic diversity in the coho stocks; and c) reducing the species' vulnerability to the impacts of degradation. These benefits would cumulatively result in an increase in the abundance of the coho salmon population (NMFS 2006a). The National Research Council (NRC) of the National Academy of Sciences reviewed causes of decline and strategies for recovery of endangered and threatened fishes of the Klamath Basin. The NRC concluded that "removal of Iron Gate Dam...could open new habitat, especially by making available tributaries that are now completely blocked to coho" (NRC 2004). Coho salmon recolonization of newly accessible habitat was observed following fish ladder installation at Landsburg Dam on the Cedar River, Washington (Kiffney et al. 2009), and following removal of Condit Dam on the White Salmon River, Washington (Allen et al. 2016). The Landsburg Dam was laddered in 2003, and coho salmon were observed within areas upstream of the dam within the first year. By 2011 salmon (with coho salmon being most abundant) occurred within nearly all of the accessible habitat upstream of the dam. Pess (et al. 2011) predicted that within the habitat upstream of Landsburg Dam juvenile coho salmon would establish a population that outnumbered resident salmonid species (e.g., rainbow trout, cutthroat trout) by 40 percent within five years of colonization, suggesting a strong ability of coho salmon to successfully occupy newly accessible habitat.

By eliminating peaking flows in the Hydroelectric Reach and removing the Lower Klamath Project reservoirs, the Proposed Project would support a flow regime that more closely mimics natural conditions in the Lower Klamath River. The reservoir drawdowns would also allow tributaries and springs such as Fall, Shovel, and Spencer creeks and Big Springs to flow directly into the mainstem Klamath River, creating patches of cooler water 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). As described in Section 3.3.5.5 *Fish Disease and Parasites*, risk of fish disease and parasites for coho salmon would decrease.

Adults would be able to access the Hydroelectric Reach beginning in fall of dam removal year 2. By this time, elevated SSCs from dam removal would likely have dissipated, returning to background levels similar to those of existing conditions. Most sediment released from the reservoirs would likely be eroded within the first six months after dam removal (by June of dam removal year 2), returning sections of river currently inundated by the Lower Klamath Project reservoirs and riverine sections between reservoirs to pool-riffle morphology. Within this reach, coho salmon would generally spawn in tributaries and not within the mainstem Klamath River, but might rear in and migrate through the Hydroelectric Reach. Dam removal would result in the provision of suitable rearing habitat for juveniles and spawning habitat for the few individual coho that might spawn in the mainstem Klamath River. Access to the cooler waters associated with spring inputs in the Hydroelectric Reach would benefit coho salmon rearing in the mainstem (Hamilton et al. 2011). Removal of the Lower Klamath Project reservoirs would result in more favorable water temperature for coho salmon adult migrants, juveniles, and smolts. As described in detail in Section 3.3.5.5 *Fish Disease and Parasites*, it is unlikely that the disease conditions that currently exist downstream of Iron Gate Dam would develop upstream of Iron Gate Dam under the Proposed Project. Access to this reach and the habitat conditions within it would benefit the Upper Klamath River coho salmon population.

Middle and Lower Klamath River

The Proposed Project would release dam-stored sediment downstream to the Lower Klamath River Reach in the short term and would establish a flow and sediment regime that more closely mimics natural conditions in the long term. Suspended sediment effects on coho salmon under the Proposed Project are described in detail in Appendix E.3.2.3, and summarized here.

There are nine coho salmon population units in the Klamath Basin (see the coho salmon subsection of Section 3.3.2.1 *Aquatic Species*). Only negligible effects from suspended sediment would be expected on the three population units in the Trinity River, and on the Lower Klamath River Population Unit. Effects on the Salmon River Population Unit are anticipated to remain similar to existing condition (SEV ranging from 5.4 to 8.4 with sublethal physiological stress) even under a worst impacts on fish scenario (Appendix E.3.2.3, Table E-10), due to dilution of suspended sediment from tributaries in the Middle Klamath River. Effects on the Upper Klamath River, Mid-Klamath River, Shasta River, and Scott River population units under all scenarios are anticipated to be sublethal on most life-stages (Appendix E.3.2.3). Under all scenarios, the small proportion of coho salmon from the Upper Klamath River Population Unit that spawn in the mainstem, as well as their progeny, would suffer 60 to 80 percent mortality due to the effects of suspended sediment on these life stages. This compares to existing conditions high rate of mortality for this small proportion of mainstem spawners predicted to be from 20 to 60 percent depending on severity of conditions (Appendix E.3.1.3). It is believed by experts in the watershed that progeny of mainstem spawning coho salmon experience reduced survival compared to fish produced from tributary spawners (Simondet 2006), since rearing and growth conditions within tributaries are more favorable than in the mainstem. Based on spawning surveys conducted from 2001 through 2017 (Magneson and Gough 2006, Hentz and Wickman 2016, Dennis et al. 2017), from 0 to 13 redds could be affected in dam removal year 1 during the Proposed Project. Many of these redds are thought to be from returning hatchery fish (NMFS 2010a), and thus may be only selecting this habitat after failing to locate the hatchery collection site. Based on the range of escapement estimates of Ackerman et al. (2006), 13 redds (the highest number observed) would be much less than one percent of the natural and hatchery returns to the Klamath River Basin. The Upper Klamath River Population Unit would be expected to recover from these losses in the long term, given the benefits to the population.

Coho salmon smolts from the dam removal year 1 cohort are expected to outmigrate to the ocean beginning in late February, although most natural origin smolts outmigrate to the mainstem Klamath River during April and May (Wallace 2004). Coho smolt releases from Iron Gate Hatchery typically occur in the first three weeks of April (CDFW 2014). Numerous field and laboratory studies have shown that juvenile salmonids actively avoid exposure to high (> 150 mg/L) SSCs, including altering migratory patterns to seek lower turbidity (Bisson and Bilby 1982, Berg and Northcote 1985, Redding et al. 1987, Servizi and Martens 1992, Bash et al. 2001, Carlson et al. 2001, Kemp et al. 2011, Kjelland et al. 2015). Therefore, it is assumed that coho salmon outmigration during the spring of dam removal year 2 would occur within the period of typical outmigration with the lowest predicted SSC. Once in the mainstem Klamath River, coho salmon smolts move downstream fairly quickly (Stutzer et al. 2006). Under the Proposed Project, SSCs would be slightly higher during spring than under existing conditions, and coho salmon smolts are likely to suffer moderate to major stress and reduced feeding depending on scenario (Appendix E.3.2.3, Table E-10).

Under existing conditions, coho salmon smolts outmigrating from the Upper Klamath River, Scott River, and Shasta River populations currently have high mortality rates (35 to 70 percent) presumably as a result of poor water quality and disease (Beeman et al. 2007, 2008), which, in conjunction with physiological stress and reduced growth resulting from the Proposed Project, could result in higher mortality than under existing conditions in the spring of dam removal year 2.

Based on the results of coho salmon outmigrant trapping by the USFWS (2001) on the mainstem Klamath River compared with trapping in the Trinity River from 1997 to 2000 (USFWS 2011), most (greater than 80 percent) coho smolts originate from the Trinity River and Lower Klamath River populations. For the majority of coho salmon smolts, produced from tributaries downstream from Orleans, effects of the Proposed Project would be similar to existing conditions by late April.

The Proposed Project would also result in the release of coarse sediment, as described in Section 3.11 *Geology, Soils, and Mineral Resources* and Appendix F of this EIR. Impacts associated with the release of coarse sediment are expected to affect the same individuals described for suspended sediment above. For example, coarse sediment is predicted to bury redds constructed in fall of dam removal year 1, which are the same redds expected to suffer from suspended sediment (potentially from 0 to 13 redds). In addition, sediment deposition could aggrade pools or overwhelm other habitat features that coho salmon use for adult holding or juvenile rearing. However, the sediment impact on habitat is anticipated to be short term, and pools would likely return to their pre-sediment release depth within one year (USBR 2012).

Additionally, as described in Potential Impact 3.2-1 and Potential Impact 3.2-2, water quality improvements are anticipated to reduce stress to smolts, improving fitness and survival. As discussed in detail in Section 3.2.5.1 *Water Temperature*, dam removal would cause water temperatures to become warmer earlier in the spring and early summer and cooler earlier in the late summer and fall and have diurnal variations more in sync with historical migration and spawning periods (Hamilton et al. 2011). These changes would result in water temperature more favorable for coho salmon and other salmonids in the mainstem. Cooler water temperatures during fall would benefit upstream migrant adults during fall upstream migration and juvenile redistribution to overwintering habitats by providing a broader window of suitable habitat, starting in dam-removal year 2. A predicted earlier outmigration in response to elevated water temperatures in the spring is also supported by of the scientific literature relating to increased growth rates and thermal response of outmigrating salmonids, as summarized by Hoar (1988). Spring outmigrants could therefore begin an earlier outmigration starting in post-dam-removal year 1, potentially reducing their susceptibility to disease. Coincident with increased with SSCs, in the short term, migrating adults and juveniles rearing or migrating in the mainstem would be exposed to reductions in dissolved oxygen due to the Proposed Project. The risk of sublethal physiological stress and avoidance behavior predicted for migrating adults and juveniles rearing or migrating in the mainstem after dam removal resulting from increased suspended sediment is anticipated to be further exacerbated by reductions in dissolved oxygen.

As described in Section 3.3.5.5 *Fish Disease and Parasites*, the Proposed Project is expected to disrupt many of the existing congruence of factors that lead to high disease parasite concentrations at locations with multiple water quality stressors for fish and resulting high levels of fish disease.

Klamath River Estuary and Pacific Ocean Nearshore Environment

Under the Proposed Project, habitat in the Klamath River Estuary could be affected by elevated sediment during dam removal for about three months (January through March) when a low abundance of coho salmon smolts could be within the estuary during their outmigration to the ocean. After this time, SSCs would return to levels similar to existing conditions. SSCs in the estuary would be less than 40 percent of the peak concentrations that are anticipated to occur immediately downstream from Iron Gate Dam. These peaks would still be substantial, and would be higher than the extreme values estimated by the sediment transport model for existing conditions (see Section 3.3.5.1 *Suspended Sediment*). However, the increased SSCs predicted to occur in the estuary would not be of sufficient magnitude or duration to result in substantial sublethal or lethal effects on coho salmon individuals (Appendix E.3.2.3). While the magnitude of SSCs released to the Pacific Ocean nearshore environment would be within the range of natural conditions, the duration of elevated SSCs (i.e., weeks) would be greater than would occur under natural (i.e., storm) conditions (i.e., days). Therefore, there also would be elevated SSCs in the Pacific Ocean nearshore environment relative to existing conditions (see Section 3.2.5.2 *Suspended Sediments*). However, no coho salmon adults or juveniles are anticipated to occur within the nearshore environment during this period.

Summary

In the short term, reservoir drawdown associated with dam removal under the Proposed Project could alter SSCs and bedload sediment transport and deposition, causing both lethal and sub-lethal impacts to coho salmon at all life stages. In general, the wide distribution and use of tributaries by both juvenile and adult coho salmon would likely protect the population from the worst short-term impacts of the Proposed Project. A small amount of direct mortality is anticipated for redds from the Upper Klamath Population Unit, and no mortality is anticipated for the other population units under all scenarios. Based on no predicted substantial short-term decrease in coho salmon abundance of a year class, or substantial decrease in habitat quality or quantity, there would not be a significant impact to coho salmon under the Proposed Project in the short term.

Although this EIR finds no significant impact on coho salmon In the short term, the KRRC proposes aquatic resource measures AR-1 (Mainstem Spawning), AR-2 (Juvenile Outmigration), and AR-4 (Iron Gate Hatchery Management) which would further reduce the potential for short-term effects of SSCs on coho salmon eggs, juveniles, and smolts (natural and hatchery production). In addition, although CEQA Guidelines Section 15126.4(a)(3) states that mitigation measures are not required for effects which are not found to be significant, mitigation measures AQR-1 and AQR-2, which would be implemented as a result of significant adverse impacts described for Potential Impact 3.3-1 and Potential Impact 3.3-4, would even further reduce the potential for short-term effects of the Proposed Project on coho salmon by increasing certainty regarding the effectiveness of the KRRC's proposed aquatic resource measures. Aquatic resource measures are summarized in Section 2.7.8.1 *Aquatic Resource Measures* and detailed in Appendix B: *Definite Plan − Appendix I*. Proposed Aquatic Resource Measure AR-1 includes the development and implementation of a monitoring and adaptive management plan to offset the impacts of Lower Klamath Project dam removal on mainstem spawning. Proposed Aquatic Resource Measure 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. Monitoring would occur regularly for the two years following dam removal. Additionally, any 5-year flow event of 10,895 cfs or greater on the Klamath River recorded at the USGS Klamath River Below Iron Gate Dam CA gage (No. 11516530) within the first two years following reservoir drawdown would trigger a monitoring effort. Mitigation Measure AQR-1 Mainstem Spawning (detailed in Potential Impact 3.3-1 above) further specifies that monitoring shall also be conducted following a significant flow event, even if that flow event occurs more than two years following dam removal. Proposed Aquatic Resource Measure AR-1 also includes a spawning habitat evaluation on the Klamath River and tributaries in the Hydroelectric Reach. Most coho salmon spawning occurs in tributaries, and very few coho salmon have been observed spawning in the mainstem Klamath River. Therefore, the spawning habitat actions of Proposed Aquatic Resource Measure AR-1 are focused on offsetting impacts of the Proposed Project on Chinook salmon and steelhead. However, due to the similar spawning habitat requirements of coho salmon to both species, these actions would benefit them as well. If mainstem spawning habitat conditions following dam removal do not meet target metrics[97] developed to offset the anticipated loss of Chinook salmon and steelhead redds due to the Proposed Project, spawning gravel augmentation would be completed within the mainstem, with additional spawning habitat actions within tributaries. 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. Mitigation Measure AQR-1 Mainstem Spawning (detailed in Potential Impact 3.3-1 above) further specifies the range of actions that shall be conducted in tributaries to offset impacts to coho salmon spawners. Implementation of Proposed Aquatic Resource Measure AR-1 and Mitigation Measure AQR-1 would reduce the short-term potential impacts of SSCs on coho salmon spawning in dam removal year 2 by improving access to tributary habitat where impacts from SSC on habitat in the mainstem can be avoided, and by augmenting spawning gravel ensuring that suitable spawning habitat in mainstem and tributaries is available following dam removal.

Proposed Aquatic Resource Measure AR-2 includes three primary actions: (1) salvaging mainstem overwintering juvenile salmonids prior to reservoir drawdown; (2) maintaining tributary-mainstem connectivity to ensure volitional fish passage between tributaries and

[97] Spawning gravel in the amount of 44,100 yd^2 for fall Chinook salmon and 4,700 yd^2 for steelhead

the Klamath River; and (3) developing a water quality monitoring network, trigger thresholds, and plan for salvaging and relocating juvenile fish from tributary confluence areas to cold water tributaries or nearby off-channel ponds. Implementation of AR-2 would reduce the short-term effects of SSCs to coho salmon juveniles rearing in the mainstem during dam removal by actively transporting up to 500 coho salmon juveniles from vulnerable mainstem areas to off-channel ponds protected from the effects of the Proposed Project, thus offsetting water quality impacts to these coho salmon individuals. Proposed Aquatic Resource Measure AR-2 would also reduce the potential short-term effects of SSCs to migrating coho salmon smolts by maintaining tributary-mainstem connectivity to ensure volitional fish passage between tributaries and the Klamath River. Monitoring would occur regularly for the two years following dam removal. Additionally, any 5-year flow event of 10,895 cfs or greater on the Klamath River recorded at the USGS Klamath River Below Iron Gate Dam CA gage (No. 11516530) within the first two years following reservoir drawdown would trigger a monitoring effort. Mitigation Measure AQR-2 Juvenile Outmigration (detailed in Potential Impact 3.3-1 above) further specifies that monitoring shall also be conducted following a significant flow event, even if that flow event occurs more than two years following dam removal. In addition, proposed Aquatic Resource Measure AR-2 would reduce the potential short-term effects of SSCs to migrating coho salmon smolts by rescuing and transporting smolts if mainstem SSC are high, and water temperatures within tributaries are too poor to provide safe refuge (a decision to be made in regular consultation with the ATWG). These actions would effectively reduce the number of coho salmon juveniles and smolts potentially exposed to periods of high SSC in the mainstem habitat following dam removal, and therefore reduce the proportion of the population experiencing sub-lethal effects or mortality.

The Proposed Project would shift all production of Iron Gate Hatchery coho salmon (75,000 yearling goal) to Fall Creek Hatchery. In the short term, transfer of coho salmon production from Iron Gate Hatchery to Fall Creek Hatchery would have no impact on adult returns. In addition, proposed Aquatic Resource Measure AR-4 proposes that hatchery-reared yearling coho salmon to be released in the spring of dam removal year 2 be held at Iron Gate Hatchery or Fall Creek Hatchery until water quality conditions in the mainstem Klamath River improve to sublethal levels. This would reduce the short-term effects of SSCs to coho salmon smolt released from the hatchery by decreasing the probability that they would be exposed to peak SSC levels, and would increase survival during downstream migration in dam removal year 2.

In the long term, removal of the Lower Klamath Project dams under the Proposed Project would increase habitat availability, restore a more natural flow regime by eliminating peaking flows in the Hydroelectric Reach and removing the Lower Klamath Project reservoirs, restoring more natural seasonal water temperature variation, improve water quality, and reduce the likelihood of fish disease, all of which would be beneficial for coho salmon populations. Substantial declines in abundance resulting from effects of the Proposed Project are not anticipated for more than one year class (i.e., one generation). Dam removal would restore connectivity to habitat on the mainstem Klamath River up to and including Spencer Creek and would create additional habitat within the Hydroelectric Reach. Dam removal would also cause water temperatures to become warmer earlier in the spring and early summer, cooler earlier in the late summer and fall, and have diurnal variations more in sync with historical migration and spawning periods (Hamilton et al. 2011). These changes would result in water temperature more favorable for salmonids in the mainstem.

In the long term, increased adult returns resulting from newly accessible habitat upstream of Iron Gate Dam would offset reductions in adult returns due to cessation of hatchery operations eight years following dam removal. It is anticipated that as a result of the Proposed Project, the coho salmon population would experience an increase in abundance, productivity, population spatial structure, and genetic diversity. In general, free flowing river conditions under the Proposed Project would likely increase adult migration efficiency, decrease outmigrant delay, and increase adult escapement (Buchanan et al. 2011b). The Proposed Project would provide multiple benefits to coho salmon from all Klamath River population units in the long term.

Significance

No significant impact for coho salmon populations in the short term

Beneficial for coho salmon populations in the long term

Potential Impact 3.3-10 Effects on the steelhead population due to short-term sediment releases and long-term changes in habitat quality, habitat quantity, and hatchery operations due to dam removal.

The Coho Salmon and Steelhead Expert Panel was convened and charged with answering specific questions that had been formulated to assist with assessing the effects of the Proposed Project on steelhead (Dunne et al. 2011). The conclusion of the Coho Salmon and Steelhead Expert Panel was that the Proposed Project could increase the spatial distribution and abundance of steelhead. This assessment is based on the observations that steelhead would be able to access a substantial extent of new habitat, steelhead are relatively tolerant to warmer water (compared to coho salmon), steelhead are similar to other species (resident redband/rainbow trout) that are currently thriving in upstream habitats, and that while steelhead are currently at lower abundances than historical values, they currently migrate to habitat directly downstream of Iron Gate Dam (e.g., Bogus Creek), and are not yet rare. It is likely that steelhead recolonization would occur rapidly, as was observed for similar steelhead populations following fish ladder installation at Landsburg Dam on the Cedar River, Washington (Kiffney et al. 2009), and following removal of Condit Dam on the White Salmon River, Washington (Allen et al. 2016). Steelhead recolonization of habitat upstream of Condit Dam was notable, with steelhead spawning observed in upper basin tributaries within five years of dam removal.

Under the Proposed Project, steelhead, coho, and fall-run Chinook salmon yearlings and smolts would no longer be released from hatcheries in the Klamath River following post-dam removal year 7. Currently there are no releases of steelhead from hatcheries into the Klamath River. Therefore, the closure of hatcheries eight years following dam removal is not anticipated to result in a decline in adult returns for steelhead. Impacts associated with hatcheries operations in relation to water diversions and minimum bypass flows for fish passage is discussed in Potential Impact 3.3-23 (Iron Gate Hatchery) and Potential Impact 3.3-24 (Fall Creek Hatchery).

The impacts of the Proposed Project on steelhead populations within specific reaches are described below.

Upper Klamath River and Connected Waterbodies

Under the Proposed Project, dam removal would allow steelhead to regain access to the Upper Klamath River upstream of J.C. Boyle Reservoir. Under the Proposed Project, the population's distribution would likely expand to include historical habitat along the mainstem Klamath River upstream to the Sprague, Williamson, and Wood rivers (Hamilton et al. 2005). As discussed under Section 3.3.5.3 *Water Quality*, in some years poor water quality in the Keno Impoundment/Lake Ewuana reach may prevent the latest migrants of the summer steelhead run and the earlier migrants from the fall run from accessing upstream spawning habitat in these upper reaches. If no upstream trap and haul is provided at Keno, these fish would be likely to spawn in habitat downstream of Keno Dam in the Hydroelectric Reach (described below), or, in the case of fall-run steelhead, hold below the dam until conditions become passable. However, the majority of the summer steelhead adult migration, much of the fall-run adult steelhead migration, and all of the winter adult steelhead migration is anticipated to occur outside the mid-June to mid-November timeframe in which water quality in the Keno Impoundment/Lake Ewuana reach is typically so poor as to present a migration barrier to adult salmonids. Similarly, juvenile outmigration and run-backs also occur outside this timeframe. Under the Proposed Project, there would be a potential increase in access to 49 significant tributaries in the Upper Klamath Basin, comprising around 360 miles of additional potentially productive habitat (Huntington 2006, DOI 2007, NMFS 2007b).

Upper Klamath River - Hydroelectric Reach

In the long term, the Proposed Project would restore steelhead access to habitat upstream of Iron Gate Dam and below J.C. Boyle, including an estimated 80 miles of habitat within the Hydroelectric Reach (DOI 2007, Cunanan 2009). Reaches currently inundated by reservoirs and reaches between reservoirs would likely return to a pool-riffle morphology, which would benefit steelhead.

In the short term, adults could first access this reach in winter (summer steelhead) or fall (winter steelhead) of dam removal year 2. Steelhead could use this reach as a migration corridor, as most sediment released from the reservoirs would likely be eroded within the first six months after reservoir drawdown (by June of dam removal year 2) and would not impede upstream movement. By late spring of removal year 2, elevated SSCs resulting from dam removal would likely have returned to low levels unlikely to impact steelhead.

By eliminating peaking flows in the Hydroelectric Reach and removing the Lower Klamath Project reservoirs, the Proposed Project would support a flow regime that more closely mimics natural conditions in the Lower Klamath River. The reservoir drawdowns would also allow tributaries and springs such as Fall, Shovel, and Spencer creeks and Big Springs to flow directly into the mainstem Klamath River, creating patches of cooler water 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).

Middle and Lower Klamath River

The Proposed Project would release dam-stored sediment downstream to the Lower Klamath River in the short term and restore a flow regime that more closely mimics natural conditions in the long term. Short-term suspended sediment effects on steelhead populations under the Proposed Project are described in detail in Appendix E.3.2.4, and summarized here.

Under all scenarios, sublethal effects from suspended sediment are anticipated for adult migrants, all spawning (which occurs primarily in tributaries), and outmigrating smolts

(Appendix E.3.2.4, Table E-11). As detailed in Appendix E.3.2.4, mortality is anticipated for the following steelhead life-stages:

- Half-pounder adult: Mortality ranging from just under 20 percent of those present in the mainstem under a least impacts on fish or most-likely impacts on fish scenario, to just over 20 percent under a worst impacts on fish scenario (data on half pounder adult abundance is lacking). Majority remain in tributaries and would not be affected. Some would enter tributaries if conditions within the mainstem were adverse.
- Juvenile age 0: No mortality under a least impacts on fish or most-likely impacts to fish scenario, up to 20 percent mortality of those present in the mainstem under a worst impacts on fish scenario (up to 843 juveniles or around 3 percent of population basin-wide age 0 production in a worst impacts on fish scenario).
- Juvenile age 1: 0 to 20 percent of those present in the mainstem under a least impacts on fish scenario, or up to 40 percent mortality under the most-likely impacts to fish or worst impacts on fish scenario (up to 6,314 juveniles or around 11 percent of population basin-wide age 1 production).
- Juvenile age 2: 0 to 20 percent of those present in the mainstem under a least impacts on fish scenario, or up to 40 percent mortality under the most-likely impacts to fish or worst impacts on fish scenario (up to 5,303 juveniles or around 10 percent of population basin-wide age 2 production in a worst impacts on fish scenario).

As described in detail in Section 3.11 *Geology, Soils, and Mineral Resources* and Appendix F, dam-released sediment associated with the Proposed Project might aggrade pools or overwhelm other habitat features currently used for adult holding and juvenile rearing upstream of Cottonwood Creek. The effect would be short term (less than one year), as pools would quickly return to their pre-sediment release depth (USBR 2012). Within six months the river would revert to and maintain the pool-riffle morphology that currently exists. In the long term, under the Proposed Project, bedload sediment transport would restore vital aquatic habitat for steelhead.

As discussed in detail above, dam removal would cause water temperatures to warm earlier in the spring and early summer, cool earlier in the late summer and fall, and have diurnal variations more in sync with historical migration and spawning periods. These changes would result in water temperatures that are more favorable for salmonids occurring in the mainstem. Migrating adults and juveniles rearing or migrating in the mainstem after dam removal would be exposed to low dissolved oxygen due to the Proposed Project, but these effects would be short term and of limited spatial extent, and not likely to be of sufficient magnitude to exacerbate effects substantially beyond those anticipated for increased suspended sediment. Long-term effects of the Proposed Project would benefit steelhead using the Lower Klamath River.

The Iron Gate Hatchery does not currently produce steelhead smolts, and no steelhead releases are included under the Proposed Project. Therefore, discontinuing hatchery operations under the Proposed Project would not have a direct effect on the steelhead population, although it would eliminate the potential for additional hatchery production were sufficient numbers of steelhead to enter the hatchery again. As described in Section 3.3.5.6 *Fish Hatcheries*, and 3.3.5.5 *Fish Disease and Parasites*, incidences of disease are expected to be reduced under the Proposed Project through changes to a number of factors underlying disease prevalence. Reducing polychaete habitat would likely reduce the prevalence of *P. minibicornis* infection, although the benefit to the steelhead would not be as great as for coho and Chinook salmon because they are resistant to *C. shasta*.

Klamath River Estuary and Pacific Nearshore Environment
Under the Proposed Project, habitat in the estuary could be affected by elevated sediment releases during dam removal for about three months (January through March) when a low abundance of steelhead juveniles and smolts could be within the Klamath River Estuary. After this time, SSCs would return to levels similar to existing conditions. SSCs in the estuary would be less than 40 percent of the peak concentrations that are anticipated to occur immediately downstream from Iron Gate Dam. These peaks would still be substantial, and would be higher than the extreme values estimated by the sediment transport model for existing conditions (see Section 3.3.5.1 *Suspended Sediment*). However, the increased SSCs predicted to occur in the estuary would not be of sufficient magnitude or duration to result in substantial sublethal or lethal effects on steelhead salmon individuals (Appendix E.3.2.3). While the magnitude of SSCs released to the Pacific Ocean nearshore environment would be within the range of natural conditions, the duration of elevated SSCs (i.e., weeks) would be greater than would occur under natural (i.e., storm) conditions (i.e., days). Therefore, there also would be elevated SSCs in the Pacific Ocean nearshore environment relative to existing conditions (see Section 3.2.5.2 *Suspended Sediments*). However, no steelhead adults or juveniles are anticipated to occur within the nearshore environment during this period.

Summary
In the short term, reservoir drawdown associated with dam removal under the Proposed Project could alter SSCs and affect steelhead. In general, the short term impacts of suspended sediment resulting from the Proposed Project on steelhead are likely to be substantial for any juveniles rearing in the mainstem. However, there are several aspects of steelhead life history in the Klamath River Watershed that would ameliorate these impacts, and only a limited proportion of the rearing juveniles would be affected. The broad spatial distribution of steelhead in the Klamath Basin and their flexible life history suggests that some juveniles that would otherwise be in the mainstem would avoid the most serious effects of the Proposed Project by: (1) remaining in tributaries for extended rearing, (2) rearing farther downstream where SSC should be lower due to dilution (e.g., the progeny of the adults that spawn in the Trinity River Basin or tributaries downstream from the Trinity River), and/or (3) moving out of the mainstem into tributaries and off-channel habitats during winter. In addition, the life-history variability (e.g., regularly smolting at age 0+, 1+, or 2+) observed in steelhead means that not all individuals in any given year class would smolt during spring of dam removal year 2 and be exposed to the effects of the Proposed Project. Those that do not smolt would remain in tributaries and be unaffected by sediment release. Based on no predicted substantial short-term decrease in steelhead abundance of a year class, or substantial decrease in habitat quality or quantity, there would not be a significant impact to steelhead under the Proposed Project in the short term.

Although this EIR finds no significant impact on steelhead In the short term, the KRRC proposes aquatic resource measures AR-1 (Mainstem Spawning) and AR-2 (Juvenile Outmigration) which would further reduce the potential for short-term effects of SSCs on salmonid juveniles and eggs, including steelhead. In addition, although CEQA Guidelines Section 15126.4(a)(3) states that mitigation measures are not required for effects which are not found to be significant, mitigation measures AQR-1 and AQR-2, which would be implemented as a result of significant adverse impacts described for Potential Impact 3.3-1 and Potential Impact 3.3-4, would even further reduce the potential for short-term effects of the Proposed Project on steelhead by increasing certainty regarding the effectiveness of the KRRC's proposed aquatic resource measures. Aquatic resource measures are summarized in Section 2.7.8.1 *Aquatic Resource Measures* and detailed in Appendix B: *Definite Plan − Appendix I*. Proposed Aquatic Resource Measure AR-1 includes the development and implementation of a monitoring and adaptive management plan to offset the impacts of Lower Klamath Project dam removal on mainstem spawning. Proposed Aquatic Resource Measure 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. Monitoring would occur regularly for the two years following dam removal. Additionally, any 5-year flow event of 10,895 cfs or greater on the Klamath River recorded at the USGS Klamath River Below Iron Gate Dam CA gage (No. 11516530) within the first two years following reservoir drawdown would trigger a monitoring effort. Mitigation Measure AQR-1 Mainstem Spawning (detailed in Potential Impact 3.3-1) further specifies that monitoring shall also be conducted following a significant flow event, even if that flow event occurs more than two years following dam removal. Proposed Aquatic Resource Measure AR-1 also includes a spawning habitat evaluation on the Klamath River and tributaries in the Hydroelectric Reach. If spawning habitat conditions following dam removal do not meet target metrics[98] developed to offset the anticipated loss of Chinook salmon and steelhead redds due to the Proposed Project, spawning gravel augmentation would be completed within the mainstem, with additional spawning habitat actions within tributaries. 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. Mitigation Measure AQR-1 Mainstem Spawning (detailed in Potential Impact 3.3-1) further specifies the range of actions that shall be conducted in tributaries to offset impacts to steelhead spawning. Implementation of proposed Aquatic Resource Measure AR-1 and Mitigation Measure AQR-1 would reduce the short-term potential impacts of SSCs on steelhead spawning habitat in dam removal year 2 by improving access to tributary habitat where impacts from SSC on habitat in the mainstem can be avoided, and by augmenting spawning gravel, ensuring that suitable spawning habitat in mainstem and tributaries is available following dam removal. Therefore, it is anticipated that steelhead spawning would not be substantially reduced as a result of the Proposed Project.

Proposed Aquatic Resource Measure AR-2 includes three primary actions: (1) salvaging mainstem overwintering juvenile salmonids prior to reservoir drawdown; (2) maintaining tributary-mainstem connectivity to ensure volitional fish passage between tributaries and the Klamath River; and (3) developing a water quality monitoring network, trigger thresholds, and plan for salvaging and relocating juvenile fish from tributary confluence areas to cold water tributaries or nearby off-channel ponds. Implementation of Proposed Aquatic Resource Measure AR-2 would reduce the short-term effects of SSCs on juvenile steelhead rearing in the mainstem during dam removal by actively transporting juveniles from vulnerable mainstem areas to off-channel ponds protected from the effects of the Proposed Project. Seining efforts would be focused on coho salmon juveniles, but other native fish captured during the seining and trapping effort, including

[98] Spawning gravel in the amount of 44,100 yd^2 for fall Chinook salmon and 4,700 yd^2 for steelhead

juvenile steelhead, would be relocated into tributary streams adjacent to the salvage locations. Proposed Aquatic Resource Measure AR-2 would also reduce the potential short-term effects of SSCs to steelhead smolts by maintaining tributary-mainstem connectivity to ensure volitional fish passage between tributaries and the Klamath River. Monitoring would occur regularly for the two years following dam removal. Additionally, any 5-year flow event of 10,895 cfs or greater on the Klamath River recorded at the USGS Klamath River Below Iron Gate Dam CA gage (No. 11516530) within the first two years following reservoir drawdown would trigger a monitoring effort. Mitigation Measure AQR-2 Juvenile Outmigration (detailed in Potential Impact 3.3-1) further specifies that monitoring shall also be conducted following a significant flow event, even if that flow event occurs more than two years following dam removal. In addition, Proposed Aquatic Resource Measure AR-2 would reduce the potential short-term effects of SSCs to steelhead smolts by rescuing and transporting smolts if mainstem SSCs are high, and water temperatures within tributaries are too poor to provide safe refuge (a decision to be made in regular consultation with the ATWG). These actions would effectively reduce the number of steelhead juveniles and smolts potentially exposed to periods of high SSC in the mainstem following dam removal, and therefore reduce the proportion of the population experiencing impacts.

In the long term, removal of the Lower Klamath Project dams under the Proposed Project would increase habitat availability, restore a more natural flow regime by eliminating peaking flows in the Hydroelectric Reach and removing the Lower Klamath Project reservoirs, restoring more natural seasonal water temperature variation, improve water quality, and reduce the likelihood of fish disease, all of which would be beneficial for steelhead in the long term. Dam removal would restore connectivity to hundreds of miles of historical habitat in the Upper Klamath Basin and would create additional habitat within the Hydroelectric Reach. FERC (2007) concluded that implementing fish passage would help to reduce adverse effects to steelhead associated with lost access to upstream spawning habitats. Hamilton et al. (2011) also concluded that access to additional habitat in the Upper Klamath Basin would benefit steelhead runs. In general, dam removal would likely result in the restoration of more reproducing populations, increased abundance, higher genetic diversity, the opportunity for variable life histories, and use of new habitats (Hamilton et al. 2011). In general, free flowing conditions would likely increase adult migration rate, decrease outmigrant delay, and increase adult escapement (Buchanan et al. 2011b). As discussed in detail above, dam removal would also cause water temperatures to become warmer earlier in the spring and early summer, cooler earlier in the late summer and fall, and have diurnal variations more in sync with historical migration and spawning periods (Hamilton et al. 2011). These changes would result in water temperature more favorable for salmonids in the mainstem. The multiple benefits of the Proposed Project would be beneficial for steelhead populations in the long term.

Significance

No significant impact for steelhead populations in the short term

Beneficial for steelhead populations in the long term

Potential Impact 3.3-11 Effects on the Pacific lamprey population due to short-term sediment releases and long-term changes in habitat quality and quantity due to dam removal.

The Lamprey Expert Panel (Panel) was convened and charged with answering specific questions that had been formulated to assist with assessing the effects of the Proposed Project on lamprey (Close et al. 2010). The conclusion was that the Proposed Project could increase Pacific lamprey habitat by up to 14 percent with access to habitat upstream of Iron Gate Dam, and even more potential habitat if Pacific lamprey gain access to habitat upstream of Keno Dam. However, the Panel concluded that larval lamprey habitat within much of the newly accessible habitat is of less quality that current larval habitat downstream of Iron Gate Dam, and therefore there might be roughly a total increase of production of outmigrant lamprey (and hence harvest potential) in the range of 1 to 10 percent relative to existing conditions, lower than the percent increase in habitat access. The Panel expects that adult Pacific lamprey would recolonize newly accessible habitat after dam removal, as was observed for Pacific lamprey following fish ladder installation at Landsburg Dam on the Cedar River, Washington (Kiffney et al. 2009), and for Pacific lamprey following removal of Condit Dam on the White Salmon River, Washington (Allen et al. 2016). Larval rearing capacity downstream from Iron Gate Dam is expected to increase after dam removal because a large amount of fine sediment—a major component of larval rearing habitat—would be released through dam removal. The available burrowing habitat for larvae would subsequently decrease over time, but would likely remain higher than under existing conditions because sediment input and transport processes would be restored (Close et al. 2010). In addition, the return to a temperature regime and flows that more closely mimic natural patterns would likely benefit Pacific lamprey, which evolved under those conditions.

Access to habitat would benefit Pacific lamprey by increasing their viability through: (a) extending the range and distribution of the species; (b) providing additional spawning and rearing habitat; (c) increasing the genetic diversity of the species; and (d) increasing the abundance of the Pacific lamprey population (NMFS 2006a). The FERC EIS (2007) concluded that “Removal of Iron Gate Dam provides the greatest potential to expand the range of Pacific lamprey, a species of cultural importance to the tribes, to potential habitat upstream of Iron Gate Dam.”

In a 2015 USFWS regional implementation plan for measures to conserve Pacific lamprey in northern California and the Klamath River Basin, Goodman and Reid (2015) conclude that while there remains some uncertainty about the historical extent of Pacific lamprey in the Upper Klamath Watershed, the removal of the dams and restoration of natural hydrologic flow regimes to the Klamath River would have the greatest positive influence on Pacific Lamprey in the Upper Klamath River. The influence of the Proposed Project on Pacific lamprey populations within specific reaches on the Klamath River is described below.

Upper Klamath River and Connected Waterbodies

Pacific lamprey occurred historically at least to Spencer Creek (Hamilton et al. 2005), and there are no predictions that under the Proposed Project Pacific lamprey would occur in the Upper Klamath River and connected waterbodies.

Upper Klamath River - Hydroelectric Reach

Under the Proposed Project, it is anticipated that Pacific lamprey would migrate upstream of the location of Iron Gate Dam (NMFS 2006a). The Proposed Project would provide Pacific lamprey with access to the Hydroelectric Reach and to the mainstem Klamath River and its tributaries upstream at least as far as Spencer Creek, including Jenny, Shovel, and Fall creeks (Hamilton et al. 2011). Most sediment released from the reservoirs would likely be eroded within the first six months after dam removal (by June of dam removal year 2), returning sections of river currently inundated by reservoirs, and riverine sections between reservoirs, to a pool-riffle morphology. After erosion of dam-stored sediment, the Hydroelectric Reach would likely contain gravel suitable for lamprey spawning.

By eliminating peaking flows in the Hydroelectric Reach and removing the Lower Klamath Project reservoirs, the Proposed Project would support a flow regime that more closely mimics natural conditions. Drawing-down the reservoirs would also allow tributaries and springs such as Fall, Shovel, and Spencer creeks and Big Springs to flow directly into the mainstem Klamath River. These changes would result in more favorable water temperatures for native fishes, and improved water quality. These changes would provide a long-term benefit to Pacific lamprey populations that would occur within the Hydroelectric Reach.

Middle and Lower Klamath River

The Proposed Project would release dam-stored organic sediment and reduce dissolved oxygen downstream to the Lower Klamath River in the short term, and improve water quality and restore a flow regime that more closely mimics natural conditions in the long term. Suspended sediment effects on Pacific lamprey populations under the Proposed Project are described in detail in Appendix E.3.2.5, and summarized here.

Under the most-likely impacts to fish scenario or worst impacts on fish scenario, sub-lethal effects from suspended sediment are anticipated for outmigrants, and for Pacific lamprey migrating to or from the Trinity River or tributaries farther downstream (Appendix E.3.2.5, Table E-13). High rates of mortality are predicted for ammocoetes (lamprey larvae) in the mainstem Klamath River during winter and spring of dam removal year 2. However, there is little information on the effects of suspended sediment on Pacific lamprey. This analysis used the effects of suspended sediment on salmonids to predict effects on Pacific lamprey, with the assumption that effects on Pacific lamprey are equivalent or less severe than on salmonids. In general, most life stages of Pacific lamprey appear more resilient to poor water quality conditions (such as suspended sediment) than salmonids (Zaroban et al. 1999), so this is likely a conservative assessment (an overestimate) of potential effects. In addition, Goodman and Hetrick (2017) report that in a 2008 ammocoete survey within the Klamath Basin no Pacific Lamprey were detected in the reach from Iron Gate Dam downstream to the confluence with the Shasta River (RM 179.5), and the densities did not approach levels observed elsewhere in the watershed until the confluence with the Scott River (RM 145.1). Therefore, the proportion of the Pacific lamprey population in the Klamath River potentially exposed to the highest SSCs during dam removal is low. In addition, recent genetic analysis of Pacific lamprey (Goodman and Reid 2012) indicates a high degree of historical gene flow even across expansive distances of the northern Pacific Rim as a result of low fidelity of Pacific lamprey progeny to their natal stream. This suggests that impacts to Pacific lamprey in the Klamath River are unlikely to affect the metapopulation.

As described for salmonid species above, the Proposed Project would affect spawning and incubation in the short term in the area between Iron Gate Dam and Cottonwood Creek by burying gravel in dam-released sediment and increasing the proportion of sand in the bed. This could reduce the quality of spawning habitat In the short term, but also may increase suitability of habitat for rearing ammocoete (Close et al. 2010). After a flushing flow of at least 6,000 cfs, the bed is expected to maintain fractions of sand, gravel, and cobble which would be expected under natural conditions (suitable for Pacific lamprey spawning). Based on the historical record a sufficient flushing flow would likely occur within five years following dam removal.

The Proposed Project would establish a flow regime that more closely mimics natural conditions in the Lower Klamath River Reach. Dam removal would cause water temperatures to have natural diurnal variations. These changes would result in water temperatures that are more similar to those that Pacific lamprey evolved with and would improve water quality. These long-term changes would likely provide a benefit to Pacific lamprey in the Lower Klamath River.

Klamath River Estuary and Pacific Ocean Nearshore Environment
Under the Proposed Project, habitat in the estuary could be affected by sediment releases during dam removal for about three months (January through March) when a low abundance of Pacific lamprey ammocoetes could be within the estuary during outmigration. After this time, SSCs would return to levels similar to existing conditions. SSCs in the Klamath River Estuary would be less than 40 percent of the peak concentrations that are anticipated to occur immediately downstream from Iron Gate Dam. These peaks would still be substantial and would be higher than the extreme values estimated by the sediment transport model for existing conditions (see Section 3.3.5.1 *Suspended Sediment*). However, the increased SSCs predicted to occur in the estuary would not be of sufficient magnitude or duration to result in substantial sublethal or lethal effects on Pacific lamprey individuals (Appendix E.3.2.5). While the magnitude of SSCs released to the Pacific Ocean nearshore environment would be within the range of natural conditions, the duration of elevated SSCs (i.e., weeks) would be greater than would occur under natural (i.e., storm) conditions (i.e., days). Therefore, there also would be elevated SSCs in the Pacific Ocean nearshore environment relative to existing conditions (see Section 3.2.5.2 *Suspended Sediments*). However, few Pacific lamprey adults (and no juveniles) are anticipated to occur within the nearshore environment during this period.

Summary
In the short term, reservoir drawdown associated with dam removal under the Proposed Project would alter SSCs and bedload sediment transport and deposition and could affect Pacific lamprey. The Proposed Project would have short-term effects related to SSCs, bedload sediment transport and deposition, and water quality (particularly dissolved oxygen). As described in detail in Appendix E.3.2.5, Pacific lamprey use the mainstem Klamath River for several aspects of their life history. Because multiple year classes of Pacific lamprey rear in the mainstem Klamath River at any given time, and since adults would migrate upstream over the entire year, including January of dam removal year 2 when effects from the Proposed Project would be most pronounced, effects on Pacific lamprey adults and ammocoetes could be much higher in the mainstem Klamath River than under existing conditions. However, because of their wide spatial distribution and low observed occurrence downstream of Iron Gate Dam, most of the population would likely avoid the most severe suspended sediment pulses resulting from the Proposed Project and a substantial reduction in abundance is not anticipated. In addition, Pacific lamprey are considered to have low fidelity to their natal streams (FERC 2007), and may not enter the mainstem Klamath River if environmental

conditions are unfavorable in dam removal year 2. Migration into the Trinity River and other Lower Klamath River tributaries may also increase during dam removal year 2 because of poor water quality in the mainstem Klamath River. Low fidelity also increases the potential that Pacific lamprey can recolonize mainstem habitat if ammocoetes rearing there suffer high mortality. In addition, the geographic range of the Pacific lamprey population is very large and disperse (Goodman and Reid 2012), and thus the percentage of adult and larval Pacific lamprey that would be affected by the Proposed Project relative to the population as a whole would be minor (although no data are available to estimate percentage of population affected). Based on no predicted substantial short-term decrease in Pacific lamprey abundance of a year class, or substantial decrease in habitat quality or quantity, there would not be a significant impact to the Pacific lamprey population under the Proposed Project in the short term.

Although this EIR finds no significant impact on Pacific lamprey In the short term, the KRRC proposes aquatic resource measures AR-1 (Mainstem Spawning) which would further reduce the potential for short-term effects of SSCs on Pacific lamprey spawners. In addition, although CEQA Guidelines Section 15126.4(a)(3) states that mitigation measures are not required for effects which are not found to be significant, Mitigation Measures AQR-1, which would be implemented as a result of significant adverse impacts described for Potential Impact 3.3-1 and Potential Impact 3.3-4, would even further reduce the potential for short-term effects of the Proposed Project on Pacific lamprey by increasing certainty regarding the effectiveness of the KRRC's proposed aquatic resource measure. Aquatic resource measures are summarized in Section 2.7.8.1 and detailed in Appendix B: *Definite Plan − Appendix I*. Proposed Aquatic Resource Measure AR-1 includes the development and implementation of a monitoring and adaptive management plan to offset the impacts of Lower Klamath Project dam removal on mainstem spawning. Proposed Aquatic Resource Measure 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. Implementation of AR-1 would reduce the short-term impacts of SSCs on Pacific lamprey spawning in dam removal years 1 and 2 by improving access to tributary habitat where impacts from SSC in the mainstem can be avoided. Therefore, it is anticipated that fewer Pacific lamprey would spawn in the mainstem prior to and following the Proposed Project, further decreasing the proportion of the population exposed to high SSC.

In the long term, the Proposed Project would provide access to habitat upstream of Iron Gate Dam at least as far as Spencer Creek. It is anticipated that as a result of the Proposed Project the Pacific lamprey population within the Klamath Basin would have an increase in abundance and productivity due to increases in habitat availability, and improved flow regime, water quality, and temperature variation. Based on no predicted substantial long-term decrease in Pacific lamprey abundance of a year class, or substantial decrease in habitat quality or quantity, there would not be a significant impact to the Pacific lamprey population under the Proposed Project in the long term. Furthermore, implementation of the Proposed Project would be beneficial for Pacific lamprey in the long term.

Significance

No significant impact for Pacific lamprey populations in the short term

Beneficial for Pacific lamprey populations in the long term

Potential Impact 3.3-12 Effects on the green sturgeon population due to short-term sediment releases and long-term changes in habitat quality due to dam removal.
Southern DPS Green Sturgeon may enter the Klamath River Estuary to forage during the summer months. They would not be present when the most severe effects of dam removal are occurring and are not expected to be affected by the Proposed Project. The remainder of this section focuses on the effects of the Proposed Project on the Northern Green Sturgeon DPS. Northern Green Sturgeon are an anadromous species that enter the Klamath River to spawn from March through July (Table 3.3-9). Green sturgeon spawn primarily in the lower 67 miles of the mainstem Klamath River (downstream from Ishi Pishi Falls), in the Trinity River, and occasionally in the lower Salmon River. Since green sturgeon do not occur upstream of Ishi Pishi Falls, they would only be affected by Proposed Project effects that would extend downstream of these falls.

Middle and Lower Klamath River
The Proposed Project would release dam-stored sediment downstream to the Lower Klamath River in the short term. There is not extensive literature on the effects of suspended sediment on green sturgeon. This analysis is based on available information of the effects of SSC on salmonids, with the assumption that effects of suspended sediment on sturgeon are likely less than or equal to those on salmonids. Suspended sediment effects on Northern Green Sturgeon populations under the Proposed Project are described in detail in Appendix E.3.2.6 and summarized here.

As described in Appendix E.3.2.6, green sturgeon in the Klamath River spawn approximately every four years. The result of this life history pattern is that up to 75 percent of the mature adult green sturgeon population (as well as 100 percent of sub-adults) can be assumed to be in the ocean during dam removal year 2 and avoid effects associated with the Proposed Project. For the 25 percent of the adult population that could be in the Klamath River during dam removal year 2, only slightly higher impacts are predicted for adults than under existing conditions under all scenarios (Appendix E.3.2.6, Table E-14), mostly because Northern Green Sturgeon distribution within the mainstem Klamath River is primarily limited to areas downstream from Orleans, where the effects of SSC resulting from the Proposed Project are more diluted from tributary accretion. Green sturgeon females are broadcast spawners that lay thousands of adhesive eggs that settle into the spaces between cobble substrates. Eggs in the mainstream Klamath River are vulnerable to suspended sediment under existing conditions as a result of the contributions of multiple tributaries in the Middle Klamath River (Appendix E 3.1.6). From 40 to 60 percent mortality is predicted for incubating eggs and larval life stages under all scenarios.

Juvenile green sturgeon typically rear for one year in the Klamath River system (M. Belchik, pers. comm., 2008), but may rear for up to three years before they migrate to the estuary and the ocean, usually during summer and fall. Moderate physiological stress is predicted for rearing juveniles under a least impacts on fish scenario. Under a most-likely impacts to fish or worst impacts on fish scenario major physiological stress is predicted (Appendix E.3.2.6). Around 30 percent of green sturgeon juveniles rear in the Trinity River and would not be exposed to SSC from the Proposed Project.

Bedload sediment effects related to dam-released sediment would not extend as far downstream to Ishi Pishi Falls (USBR 2012) and would not affect Northern Green Sturgeon.

The Proposed Project would improve water quality, and reduce instances of algal toxins. These long-term effects would benefit Northern Green Sturgeon in the Lower Klamath River.

Klamath River Estuary and Pacific Ocean Nearshore Environment

Rearing for more than one year is rarely observed in the mid-Klamath River (M. Belchik, pers. comm., 2008), but juvenile green sturgeon may rear for additional months or years in the estuary before migrating to the ocean. Under the Proposed Project, habitat in the Klamath River Estuary could be affected by elevated suspended sediment during dam removal for about three months during winter, when juvenile green sturgeon could be rearing in the estuary. After this time, SSCs would return to levels similar to existing conditions. SSCs in the estuary would be less than 40 percent of the peak concentrations that are anticipated to occur immediately downstream from Iron Gate Dam. These peaks would still be substantial, and would be higher than the extreme values estimated by the sediment transport model for existing conditions (see Section 3.3.5.1 *Suspended Sediment*). However, the increased SSCs predicted to occur in the estuary would not be of sufficient magnitude or duration to result in substantial sublethal or lethal effects on green sturgeon juveniles (Appendix E.3.2.6). While the magnitude of SSCs released to the Pacific Ocean nearshore environment would be within the range of natural conditions, the duration of elevated SSCs (i.e., weeks) would be greater than would occur under natural (i.e., storm) conditions (i.e., days). Therefore, there also would be elevated SSCs in the Pacific Ocean nearshore environment relative to existing conditions (see Section 3.2.5.2 *Suspended Sediments*). However, few green sturgeon adults or juveniles are anticipated to occur within the nearshore environment during this period.

Summary

In the short term, reservoir drawdown associated with dam removal under the Proposed Project would alter water quality and SSCs and could affect Northern Green Sturgeon. Overall the effects of the Proposed Project are most likely to include physiological stress, inhibited growth, and high mortality for incubating eggs. Northern Green Sturgeon in the Klamath Basin have the following traits likely to enhance the species' resilience to impacts of the Proposed Project:

- Most of the Northern Green Sturgeon population (sub-adult and adult) would be in the ocean during the year of the Proposed Project (dam removal year 2) and would be unaffected (Appendix E.3.2.6).
- Approximately 30 percent of the Northern Green Sturgeon population that spawn and rear in the Trinity River and would be unaffected.
- Much of the spawning and rearing of Northern Green Sturgeon occurs downstream from the Trinity River, where sediment concentrations would be similar to existing conditions.

Northern Green Sturgeon are long-lived (greater than 40 years) and are able to spawn multiple times (approximately 8 times in their lifetime) (Klimley et al. 2007), so effects on the spawning effort of a proportion of adults for one year are anticipated to have little influence on the population as a whole. Because there would be no predicted substantial short-term decrease in green sturgeon abundance of a year class, or substantial decrease in habitat quality or quantity, there would not be a significant impact to the green sturgeon population under the Proposed Project in the short term.

In the long term, suspended sediment levels would return to levels similar to existing conditions, and removal of dams would result in improvements in water quality, temperature variation, and algal toxins which could affect Northern Green Sturgeon. Because there would be no predicted substantial long-term decrease in green sturgeon abundance of a year class, or substantial decrease in habitat quality or quantity, there would not be a significant impact to the green sturgeon population under the Proposed Project in the long term.

Significance

No significant impact for green sturgeon populations in the short term

No significant impact for green sturgeon populations in the long term

Potential Impact 3.3-13 Effects on Lost River and shortnose sucker populations due to short- and long-term changes in habitat quality and quantity due to dam removal.

A Resident Fish Expert Panel (Panel) was convened to compare the potential effects of the Proposed Project and existing conditions on resident fish, including sucker populations (Buchanan et al. 2011a). The Panel noted that the populations of Lost River and shortnose sucker in Upper Klamath lake are currently self-sustaining, whereas the populations in the Hydroelectric Reach (Iron Gate and Copco reservoirs) are not self-sustaining. The Panel concluded that most factors limiting the production of Lost River and shortnose sucker populations occur in Upper Klamath Lake (e.g., poor water quality, nonnative fish predation and competition, lack of emergent vegetation rearing habitat), upstream of the Area of Analysis for aquatic resources.

Upper Klamath River and Connected Waterbodies

The Proposed Project has no elements that would substantially alter habitat conditions for Lost River and shortnose sucker populations in the Upper Klamath River upstream of Keno/Lake Ewuana. Facilitating the movement of anadromous fish presents a relatively low risk of introducing pathogens to sucker species upstream of Iron Gate Dam (NMFS 2006a). Generally, with the exception of *F. columnaris* and Ich, pathogens associated with anadromous fish do not impact non-salmonids (e.g., suckers) (NMFS 2006a). In the most recent review of effects of interactions between reintroduced anadromous fish and federally listed suckers, the USFWS concludes that indirect effects of removal of the Lower Klamath Project dams is “not likely to adversely affect” listed suckers (Roninger 2012).

Upper Klamath River - Hydroelectric Reach

Lost River and shortnose sucker individuals are found within Lower Klamath Project reservoirs in the Hydroelectric Reach (Desjardins and Markle 1999). The Proposed Project would eliminate reservoir habitat, and as dams within the Hydroelectric Reach were removed, sediment would move downstream. However, the Lost River and shortnose suckers in these reservoirs are considered by the USFWS (2013) as “sink populations”, as they are not likely self-sustaining because of low recruitment due to the lack of access to spawning habitats, citing Moyle (2002), and NRC (2004). Buettner et al. (2006) conclude that since little or no reproduction occurs downstream from Keno Dam, and there is no potential for interaction with upstream populations, they are not considered to substantially contribute to the achievement of conservation goals or recovery. This is also consistent with the findings of Hamilton et al. (2011), and NRC

(2004). In addition, Miller and Smith (1981) asserted that sucker hybridization was most pronounced in these reservoirs, prompting Buettner et al. (2006) and others to caution against relocating individuals from Iron Gate and Copco reservoirs into the Upper Klamath Lake population.

Middle and Lower Klamath River, Estuary, and Pacific Ocean Nearshore Environment
No Lost River or shortnose suckers have been documented to occur downstream of Iron Gate Dam and therefore these reaches are not considered in the potential impact analysis for this EIR.

Summary
In the short term, reservoir removal associated with dam removal under the Proposed Project could alter habitat availability and affect Lost River and shortnose suckers in Iron Gate and Copco reservoirs. All individual suckers occurring within these reservoirs would likely be lost within dam removal year 2; however, these individuals are not considered to substantially contribute to the achievement of conservation goals or recovery, since little or no reproduction occurs downstream from Keno Dam (Buettner et al. 2006), and there is no potential for interaction with upstream populations (Hamilton et al. 2011). Although both species are fully protected species under California Fish and Game Code, Assembly Bill Number 2640 (Wood 2018) added Section 2081.11 to the Fish and Game Code to allow the take of both sucker species resulting from impacts attributable to the decommissioning and removal of the Lower Klamath Project facilities, consistent with CDFW take provisions. Based on the best available estimates of Lost River and shortnose sucker abundance in the Lower Klamath Project reservoirs, there are likely fewer than 1,000 adult suckers of both species in all reservoirs combined (USFWS 2012, Desjardins and Markle 1999), with a combined suitable sucker area of less than 2,500 acres. The populations in Upper Klamath Lake are estimated at 50,000 to 100,000 Lost River sucker (USFWS 2013b), and up to 25,000 shortnose suckers (USFWS 2013c), within around 79,000 acres of suitable habitat in Upper Klamath Lake and connected water bodies. Therefore, a loss of the suckers in Lower Klamath Project reservoirs represents around less than 1.5 percent of the total sucker population, and a loss of less than 3.5 percent of the total suitable sucker habitat. Based on no predicted substantial (< 1.5 percent) short-term decrease in Lost River and shortnose suckers' abundance of a year class, or substantial decrease in habitat quality or quantity (<1.5 percent), the Proposed Project would not cause a significant impact to the Lost River and shortnose sucker populations in the short term.

In the long term, reservoir removal associated with dam removal under the Proposed Project would eliminate habitat availability and affect Lost River and shortnose suckers in Lower Klamath Project reservoirs. All individual suckers occurring within these reservoirs would likely be lost within the short term and would not be replaced in the long term. However, as described above, these individuals are not considered to substantially contribute to the achievement of conservation goals or recovery of the populations (Hamilton et al. 2011). In addition, and as described above, the loss of the sucker population and suitable habitat in the Lower Klamath Project reservoirs is a minor proportion of the total sucker population and suitable habitat area. Based on no predicted substantial long-term decrease in Lost River and shortnose suckers' abundance of a year class, or substantial decrease in habitat quality or quantity, the Proposed Project would not cause a significant impact to the Lost River and shortnose sucker populations in the long term.

Although this EIR finds no significant impact on Lost River and shortnose suckers in the short-or long-term, the Proposed Project includes aquatic resource measure AR-6 (Suckers) to reduce the short- and long-term effects of reservoir removal. Aquatic resource measures are summarized in Section 2.7.8.1 *Aquatic Resource Measures* and detailed in Appendix B: *Definite Plan − Appendix I*. AR-6 includes two primary actions including reservoir and river sampling to estimate the abundance of suckers in the Hydroelectric Reach and conduct genetic testing for hybridization, and sucker salvage and release into waterbodies isolated from the Upper Klamath Lake Populations. As discussed above, Section 2081.11 was added to the Fish and Game Code to authorize take of Lost River and shortnose suckers, subject to certain conditions. CDFW (2018b) has reviewed AR-6 and preliminarily agreed that the Proposed Project with implementation of AR-6 potentially meets the standards for take authorization under Fish and Game Code, section 2081.11. The proposed actions are anticipated to increase the survival of individual Lost River and shortnose suckers currently inhabiting the Hydroelectric Reach, without increasing exposure of the Upper Klamath Lake population to adults with a high degree of hybridization. The number of translocated fish would not exceed 3,000 fish, which is the capacity of the currently-identified recipient waterbody (Tule Lake). Tule Lake currently supports both sucker species and has suitable habitat for translocation site. In addition, Tule Lake is isolated from the sucker population in Upper Klamath Lake, and thus this measure would not risk influencing the sucker populations designated as recovery populations in Upper Klamath Lake.

Significance

No significant impact for Lost River and shortnose sucker populations in the short term

No significant impact for Lost River and shortnose sucker populations in the long term

Potential Impact 3.3-14 Effects on the redband trout population due to short-term sediment releases and long-term changes in habitat quality and quantity due to dam removal.

A Resident Fish Expert Panel (Panel) was convened to compare the potential effects of the Proposed Project and existing conditions on resident fish, including redband trout (Buchanan et al. 2011a). The Panel predicted that following the Proposed Project, the abundance of redband trout in the free-flowing reach between Keno Dam and Iron Gate Dam could increase significantly. In addition, the Panel expects the existing trout and colonizing anadromous steelhead to co-exist (or even for the redband to produce anadromous progeny), as they do in other watersheds, although there may be shifts in abundance related to competition for space and food. The effects of implementing the Proposed Project on redband trout populations within specific reaches of the Klamath River are described below.

Upper Klamath River and Connected Waterbodies

Under the Proposed Project, redband trout would be able to migrate more successfully from the Hydroelectric Reach to the Upper Klamath Basin (Hamilton et al. 2011) than under existing conditions. Redband trout could be affected by increased predation from reintroduced anadromous salmonids, but this loss might be offset by an increase in available food sources (e.g., eggs, fry, and juveniles of reintroduced salmonids) (Hamilton et al. 2011). Furthermore, anadromous steelhead trout and resident rainbow/redband trout co-existed and intermingled prior to the construction of Copco No. 1 Dam in 1917. There are many examples from nearby river systems in the Pacific Northwest showing that wild anadromous salmon and resident rainbow/redband trout can co-exist and maintain abundant populations without negative consequences. The Deschutes River in Oregon, the Yakima River in Washington, and the river systems in Idaho are examples (NMFS 2006a).

Facilitating the movement of anadromous fish presents a relatively low risk of introducing pathogens to resident fish upstream of Iron Gate Dam (NMFS 2006a).

Upper Klamath River - Hydroelectric Reach

Under existing conditions, redband trout are found within the California portion of the Area of Analysis within the Hydroelectric Reach, including within all riverine areas and reservoirs. Spawning primarily occurs within Shovel and Spencer creeks. Redband trout are currently prevented from migrating between some tributaries and the reservoirs to complete their life cycle because of poorly functioning fishways at J.C. Boyle Dam (DOI 2007, NMFS 2007b). Under the Proposed Project, redband trout would be able to migrate more successfully than under existing conditions (Hamilton et al. 2011). Approximately 4 mi (6.4 km) of habitat has been adversely affected by the dewatered flows in the Bypass Reach, and 17 mi (27.4 km) of habitat has been adversely affected by the daily fluctuating flows in the Peaking Reach (NMFS 2006a). In addition, the NMFS (2006a) finding regarding J.C. Boyle flow operations stated, “Current Project operations, particularly sediment blockage at the J.C. Boyle Dam, the flow regime, and peaking operations, negatively affect the redband trout fishery.”

Under the Proposed Project, the establishment of a flow regime that more closely mimics natural conditions, eliminates hydroelectric peaking and associated negative aquatic impacts, would benefit the redband trout populations in the Hydroelectric Reach. Redband trout throughout this reach of the mainstem would be affected by high SSCs for a period of three to four months during reservoir drawdown associated with the Proposed Project. Redband trout in riverine reaches between the reservoirs in the Hydroelectric Reach would be vulnerable to effects of sediment released during dam removal and bedload deposition (Newcombe and Jensen 1996, Buchanan et al. 2011a). However, SSCs would be the result of sediment stored in J.C. Boyle and Copco reservoirs, which is relatively small potential impact (USBR 2012), and a large proportion of the adult redband trout population should be already spawning in Spencer or Shovel creeks during the dam removal. Juvenile redband trout outmigrating from Spencer Creek would be expected to recolonize the mainstem by late spring or summer when water conditions become suitable. Those in the affected area could move to tributaries for refuge.

The Proposed Project would eliminate reservoir habitat, returning sections of river currently inundated by reservoirs and riverine sections between reservoirs to a pool-riffle morphology. Although most redband trout are anticipated to continue to spawn in tributaries, modeling data indicate that after dam removal, spawning gravel in all sections of the Hydroelectric Reach would be within the range usable for redband trout, but the amount of sand within the bed within former reservoir sections might inhibit spawning success in the short term. Riverine sections between reservoirs would be expected to contain gravel with very little sand, suggesting high-quality spawning habitat would become available within a few years following dam removal. The initial movement of coarse and fine sediment after drawdown would likely create unfavorable conditions for redband trout within the mainstem Klamath River, but these conditions would be short term. Buchanan et al. (2011a) estimate that 43 miles of additional riverine habitat would be available to resident redband trout as a result of the Proposed Project. The adfluvial individuals within this reach would likely adopt a fluvial[99] life history, which is unlikely to affect the sustainability of the population. Overall migratory opportunities would increase for redband trout, increasing resiliency to disturbance over the short and long-term. The Proposed Project would also increase the number of thermal refugia available to redband trout as they would have access to more tributaries, as well as to the cold water areas near the mouths of tributaries and the many springs in this reach.

Middle and Lower Klamath River
No redband trout occur downstream of Iron Gate Dam, and therefore these reaches are not considered in the potential impact analysis for this EIR. However, in the long term redband trout would have access to habitat in the Middle Klamath River, and they are anticipated to use cold-water tributaries and portion of the mainstem river. The resident trout currently within the Middle Klamath River (rainbow trout) are genetically very similar to the redband trout currently present upstream of Iron Gate Dam; these two populations that are currently isolated would revert to a connected and sustainable population (Buchanan et al. 2011a).

Summary
In the short term, the Proposed Project would have impacts related to SSCs and bedload movement. However, very little sediment is stored in J.C. Boyle Reservoir, and only a small proportion of the redband population is expected to be exposed to short-term effects. Based on no predicted substantial short-term decrease in redband trout abundance of a year class, or substantial decrease in habitat quality or quantity, there would not be a significant impact to the redband trout population under the Proposed Project in the short term.

In the long term, dam removal would restore connectivity among the Middle Klamath Basin, the Hydroelectric Reach and its tributaries, and the Upper Klamath Basin, and would rehabilitate and increase availability of riverine habitat within the Hydroelectric Reach. Based on a long-term substantial increase in redband trout habitat quality and quantity, the Proposed Project would be beneficial for redband trout in the long term.

Significance
No significant impact for redband trout population in the short term

Beneficial for redband trout population in the long term

Potential Impact 3.3-15 Effects on the eulachon population due to short-term sediment releases and long-term changes in habitat quality due to dam removal.
The Proposed Project would release dam-stored sediment downstream to the Lower Klamath River and Estuary. SSCs in the estuary would be less than 40 percent of the peak concentrations that are anticipated to occur immediately downstream from Iron Gate Dam. These peaks would still be substantial (>500 mg/L) and would be higher than the extreme values estimated by the sediment transport model for existing conditions. Predicted increases in SSCs under the most-likely impacts to fish scenario are within the range of existing extreme conditions (Appendix E.4). Under a worst impacts on fish scenario SSCs could be higher than typically occur within the estuary (>1,000 mg/L) for a period of weeks. Adult eulachon entering the Klamath River in the

[99] Fluvial life history is resident trout spawning in tributaries and maturing within a larger mainstem river.

winter and spring of dam removal year 2 may be exposed to high SSCs for a portion of their migration period. Although no analysis of the effects of SSCs on eulachon is available, based on application of the Newcombe and Jensen (1996) approach using studies of the effects on other estuary species, it is predicted that under a most-likely impacts to fish or worst impacts on fish scenario mortality of eulachon adults would occur under the Proposed Project, unless individuals migrate out of the estuary to avoid poor water quality conditions (as has been observed in the Columbia River watershed, NMFS 2010b). Mortality is also predicted for spawning, incubation, and larval life stages under the Proposed Project. However, eulachon have a relatively long period of the year when they could potentially spawn in the Klamath River (January through April; Larson and Belchik 1998), and a relatively short duration of occurrence within freshwater (around one month), increasing the probability that most of the population would migrate and spawn either before or after the largest pulses of SSCs (predicted to be over 1,000 mg/L for the month of January under a worst impacts on fish scenario, Appendix E.4). Therefore, no substantial reduction in the abundance of a year class is predicted. Based on no predicted substantial short-term decrease in eulachon abundance of a year class, or substantial decrease in habitat quality or quantity, there would not be a significant impact to the eulachon population under the Proposed Project in the short term. Within a short duration (< 6 months) SSCs within the Klamath River Estuary are predicted to return to existing levels (Appendix E.4). There is no predicted substantial long-term decrease in eulachon abundance of a year class, or substantial decrease in habitat quality or quantity, and thus there would not be a significant impact to the eulachon population under the Proposed Project in the long term.

Significance

No significant impact for eulachon population in the short term and long term

Potential Impact 3.3-16 Effects on the longfin smelt population due to short-term sediment releases and long-term changes in habitat quality due to dam removal.

The Proposed Project would release dam-stored sediment downstream to the Klamath River Estuary. Longfin smelt entering the Klamath River in the winter and spring of dam removal year 2 may be exposed to high SSCs for a portion of their migration period. Although no analysis of the effects of SSCs on longfin smelt is available, based on application of the Newcombe and Jensen (1996) approach using studies of the effects on other estuary species, it is predicted that under a most-likely impacts to fish or worst impacts on fish scenario mortality would be higher under the Proposed Project than under existing conditions for a period of weeks. However, as described for eulachon above, the protracted migration season for longfin smelt (throughout the year), and relatively short duration of occurrence in the estuary (less than two months), increases the probability that most of the population would migrate and spawn either before or after the largest pulses of SSCs (predicted to be two weeks in duration or less). Based on no predicted substantial short-term decrease in longfin smelt abundance of a year class, or substantial decrease in habitat quality or quantity, there would not be a significant impact to the longfin smelt population under the Proposed Project in the short term. Within a short duration (< 6 months) SSC within the Klamath River Estuary are predicted to return to existing levels (Appendix E.4), and thus there is no predicted substantial long-term decrease in longfin smelt abundance of a year class, or substantial decrease in habitat quality or quantity, and there would not be a significant impact to the longfin smelt population under the Proposed Project in the long term.

Significance

No significant impact for longfin smelt population in the short term and long term

Potential Impact 3.3-17 Effects on species interactions between introduced resident fish species and native aquatic species due to short- and long-term changes in habitat quality and quantity due to dam removal.

Introduced fish species threaten the diversity and abundance of native fish species through competition for resources, predation, interbreeding with native populations, and causing potential physical changes to the invaded habitat (Moyle 2002). Introduced resident species occur in Lake Ewuana and Upper Klamath Lake, but the Proposed Project would not affect populations in this area.

As described in detail in Section 3.20.2.3 *Lower Klamath Project Reservoir-based Recreation*, the reservoirs currently provide a recreational fishery for non-native fishes including largemouth bass, trout, catfish, crappie, and sunfish (Hamilton et al. 2011). Fishing is popular in Copco No. 1 and Iron Gate reservoirs, especially for yellow perch (Hamilton et al. 2011). Adults yellow perch are opportunistic predators that feed on small fish, potentially including native fish species. Juvenile and adult largemouth bass tend to feed on larger invertebrates and fish as well, potentially including native species. The Proposed Project would eliminate reservoir habitat upstream of Iron Gate Dam, and thus the abundance of introduced resident species would decline substantially or be eradicated (Buchanan et al. 2011a), providing a benefit to native aquatic species.

A few introduced resident species occur in the Middle and Lower Klamath River, but water velocities within riverine habitat are too high for the introduced species that in general are adapted to the lotic conditions in the reservoirs in which they were introduced. Under the Proposed Project, conditions would be expected to become even less suitable for introduced resident species. This effect would be beneficial for native aquatic species in the short and long term.

Significance

Beneficial for the effects of introduced resident fish species on aquatic species in the short term and long term

Potential Impact 3.3-18 Effects on aquatic species from interactions among fish species due to short- and long-term changes in habitat quantity due to dam removal.

The Proposed Project would restore access for anadromous salmon and steelhead to habitat upstream of Iron Gate Dam, as described in detail above. Restoration of access would result in anadromous salmon and steelhead potentially interacting with resident redband trout and bull trout, with the potential for competition and predation. These species evolved together in the Upper Klamath Basin of the Klamath River, and co-existed prior to the construction of dams (Goodman et al. 2011).

Anadromous salmonids currently co-exist with resident rainbow trout and resident cutthroat trout downstream from Iron Gate Dam, without any obvious detriment to these native species or the aquatic ecosystem in which they reside. While there is little information on the nature of any competitive interactions between steelhead and resident trout in the Klamath Basin, research does suggest that in some circumstances, resident trout may have a competitive edge over steelhead (NMFS 2006a). Conversely, research has shown that hatchery salmon supplementation can negatively impacted resident trout abundance and salmonid biomass in a Washington watershed (Pearsons and Temple 2010). However, competition between steelhead and currently present indigenous species such as redband trout are not assumed to be a major limiting factor since these species historically co-evolved (Hooton and Smith 2008). There are many examples from nearby river systems in the Pacific Northwest that show wild anadromous steelhead and resident rainbow/redband trout can co-exist and maintain abundant populations without adverse consequences. The Deschutes River in Oregon, the Yakima River in Washington, and the river systems in Idaho are examples (NMFS 2006a). As noted by Buchanan et al. (2011a), existing trout and colonizing anadromous steelhead are expected to co-exist in the Klamath Basin, as they do in other watersheds, although there may be shifts in abundance related to competition for space and food. Overall, there is no predicted substantial short-term or long-term decrease in native aquatic species abundance of a year class, or substantial decrease in habitat quality or quantity, and there would not be a significant impact to the aquatic species populations under the Proposed Project in the short term or long term.

Significance

No significant impact for effects to aquatic species from interactions among fish species in the short term and long term

Potential Impact 3.3-19 Effects on freshwater mollusks populations due to short-term sediment releases and long-term changes in habitat quality due to dam removal.

Four species of native freshwater mussels have been observed within the Klamath Basin, including Oregon floater (*A. oregonensis*), California floater (*A. californiensis*), western ridged mussel (*G. angulata*), and western pearlshell mussel (*M. falcata*).Oregon floater and California floater (commonly referred together “floater mussels,” or “*Anodata spp*.”) occur in the mainstem Klamath River in the Hydroelectric Reach, within Lower Klamath Project reservoirs, in a reach (<15 miles) directly downstream of Iron Gate Dam, and within the Upper Shasta River. *M. falcata* are common in the mainstem Klamath River from Iron Gate Dam downstream to the confluence with the Trinity River, and within Middle Klamath tributaries such as Bogus Creek, and Shasta, Scott, and Salmon rivers. *G. angulata* is more widely distributed and more abundant than the other species and has been observed in high densities from Keno Dam downstream to the confluence with the Trinity River, and within the Shasta and Scott rivers (Davis et al. 2013). Mussel abundance also generally declines with increasing distance downstream from Iron Gate Dam, suggesting the effects of the increasing hydrologic variability of the Klamath River with distance from Iron Gate. Davis et al. (2013) concluded that habitats located further downstream had lower probabilities of supporting mussels due to more variable conditions.

Seven to eight species of fingernail clams and peaclams (Family: Sphaeriidae) also occur in the Hydroelectric Reach and from Iron Gate Dam to Shasta River. This evaluation focuses on freshwater mussels because of their similar distribution to other freshwater mollusks, similar habitat requirements, their longer life-span, and lack of information regarding the effects of sediment on clams and other mollusks.

Suspended Sediment Concentrations

Under the Proposed Project, in the Hydroelectric Reach between J.C. Boyle Dam and Copco No.1 SSCs are predicted to exceed 600 mg/L (the minimum SSC level that would be considered detrimental to freshwater mussels), for short periods of time (1–5 days) during spikes in SSCs. SSCs are expected to be higher than under existing conditions and would likely exceed 600 mg/L for two to four months after removing the dams from Copco No 1. Dam downstream to the Klamath River Estuary; however, the highest levels, well in excess of 1,000 mg/L, would occur between Seiad Valley and Iron Gate Dam. Within six months of dam removal SSCs in the mainstem Klamath River are predicted to return to levels observed under existing conditions. Under existing conditions, SSCs in the mainstem Klamath River often exceed 600 mg/L, although these spikes generally occur for a few days as opposed to several months (see also Potential Impact 3.2-3).

Predicted increases in SSC within the Hydroelectric Reach under the Proposed Project are anticipated to result in major physiological stress to *Anodata spp*., and *G. angulata*, including mortality of at least a proportion of the individuals. The most significant impacts would occur downstream from Iron Gate Reservoir, especially to those individual freshwater mussels or freshwater mussel beds upstream of Orleans and closest to Iron Gate Dam. For populations occurring downstream of the confluence with the Salmon River (*M. falcata* and *G. angulata*) dilution from tributaries would limit exposure to SSCs likely to be sublethal. Because freshwater mussels found within the Klamath River can be so long lived (from 10 to more than 100 years, depending on the species) and sexual maturity might not be reached until four years of age or more, even relatively short term (e.g., for more than five consecutive days) SSCs in excess of 600 mg/L, would be expected to be detrimental for freshwater mussel populations within the mainstem Klamath River upstream of the Salmon River confluence, in the short term. This would impact all four-mussel species, most notably *Anodata spp*., due to their limited distribution in the proximity of Iron Gate Dam. *M. falcata* and *G. angulata* are less likely to experience a substantial decline in abundance In the short term, due to their broader distribution downstream of Iron Gate Dam in the mainstem, and strong populations in tributaries.

Freshwater clams can live buried in the substrate, and are expected to suffer less impact than freshwater mussels. In addition, they are relatively short-lived (one to three years) and bear young several times throughout the spring and summer which would support rapid recovery within the short term to impacts from suspended sediment.

In the long term (i.e., greater than five years), it is anticipated that mainstem Klamath *M. falcata* and *G. angulata* populations would rebound from suspended sediment impacts, recolonizing through the transport of larvae (glochidia) by host fish from downstream populations less affected by excessive SSCs or from populations within tributaries, such as Bogus, Shasta, Scott, and Salmon rivers. *Anodata spp*. are anticipated to recover more slowly from suspended sediment impacts, due to a narrower distribution downstream of Iron Gate Dam, and limited distribution within tributaries (i.e., only found in upper Shasta River).

Changes in Bed Elevation

Silt and fine material make up the largest proportion of the volume of sediment stored behind the dams and would be transported downstream primarily as suspended sediment under the Proposed Project. Coarser material (larger than 0.063 mm) would also be transported downstream and would likely be deposited in the river channel, changing riverbed elevations from the existing conditions for approximately eight miles between Iron Gate Dam and Cottonwood Creek. The 182 miles of mainstem downstream from Cottonwood Creek are not predicted to have any substantial aggradation. Therefore, *Anodonta spp*. populations closest to Iron Gate Dam are likely to be most affected by aggradation of sediments under the Proposed Project, whereas *M. falcata* and *G. angulata* with broad distributions are unlikely to be substantially affected. It is not known how well any of these species could tolerate deposition of sediment and whether they could move upward through deposited material to the surface to breathe and feed. It is reasonable to assume that some percentage of Klamath River freshwater mussels buried under 0.5 to 3.0 feet of new sediment would not survive, especially since these same population would be exposed to the increased SSCs described above. *G. angulata* have a demonstrated ability to withstand burial in sediment and are likely to be the least affected.

Freshwater clams can live buried in the substrate and are expected to avoid impacts from bed deposition.

Changes in Bed Substrate

Removal of the Lower Klamath Project dams under the Proposed Project would result in the erosion of accumulated reservoir sediments and changes in substrate characteristics within the Klamath River, especially within the current reservoir reaches. The reformation of river channels in the reservoir reaches is expected to occur within six months (Potential Impact 3.11-5) following removal of the dams. The reformation of river channels between Iron Gate Dam and the upstream reaches of J.C. Boyle Reservoir would benefit *M. falcata* and *G. angulata* and clams in the long term by providing more suitable substrates (i.e., large gravel, cobble, and boulder) than currently exists, especially within the current reservoir reaches. However, conversion of reservoirs to riverine habitat is anticipated to have a short- and long-term impact on *Anodonta spp*., which currently occur within reservoirs, and are adapted to low-flow variability habitat.

Changes in Habitat Accessibility

In addition, the Proposed Project would also open access to river reaches upstream of Iron Gate Dam to migratory fish species, which serve as host fish for parasitic freshwater mussel larvae (glochidia). *M. falcata* in particular may benefit from the increased distribution of anadromous salmonids, which are a primary host species for their larvae. As a result, in the long term suitable habitats upstream of Iron Gate Dam might be colonized or recolonized by all four freshwater mussel species, transported as glochidia from downstream reaches by migratory fish species.

Summary

In the short term, *G. angulata* have a demonstrated ability to withstand burial in sediment and are a widespread and abundant mussel species, including within the Hydroelectric Reach, and within key tributaries upstream and downstream of Iron Gate Dam. Therefore, a relatively small proportion of their population would be directly impacted by sediment released during dam removal. Based on no predicted substantial short-term decrease in *G. angulata* abundance of a year class, or substantial decrease in habitat quality or quantity, there would not be a significant impact to the *G. angulata* population under the Proposed Project in the short term.

M. falcata have a broad distribution downstream of Iron Gate Dam in the mainstem, and strong populations in several tributaries in the Middle Klamath River. Therefore, a relatively small proportion of their population would be directly impacted by sediment released during dam removal. Based on no predicted substantial short-term decrease in *M. falcata* abundance of a year class, or substantial decrease in habitat quality or quantity, there would not be a significant impact to the *M. falcata* population under the Proposed Project in the short term.

Anodonta spp. would likely be impacted by the Proposed Project due to their close proximity to Iron Gate Dam, and preference for stable flows that currently exist in Lower Klamath Project reservoirs and downstream of Iron Gate Dam. *Anodonta spp*. likely only occurs downstream of Iron Gate Dum under existing conditions as a result of the altered hydrograph (Davis et al. 2013). Under natural conditions they would be unlikely to occur in the mainstem Klamath River downstream. Based on their limited distribution in the mainstem Klamath River, Lower Klamath Project reservoirs, and small presence in the Upper Shasta River, *Anodonta spp*. would likely decline substantially in abundance within the first six months of dam removal as a result of suspended sediment releases. In addition, their habitat would likely substantially decline in quality in the short term. Based on predicted substantial short-term decrease in *Anodonta spp* abundance of a year class, and substantial decrease in habitat quality, there would be a significant impact to the *Anodonta spp* population under the Proposed Project in the short term.

However, the Proposed Project includes aquatic resource measure AR-7 (Freshwater Mussels) to reduce the short-term effects of sediment transport during dam removal on *Anodonta spp*. Aquatic resource measures are summarized in Section 2.7.8.1 *Aquatic Resource Measures* and detailed in Appendix B: *Definite Plan – Updated AR-7, October 2018 Update*. Proposed Aquatic Resource Measure AR-7 includes salvage and relocation plan prior to Lower Klamath Project dam removal and 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 would be salvaged and relocated in dam removal year 1 prior to the reservoir drawdown. Approximately 15,000 to 20,000 mussels (primarily *Anodonta spp.)* are planned for translocation. There are currently multiple large-scale mussel relocation projects occurring nationwide (Zimmerman et al. 2017, USDA Forest Service 2016, Illinois Department of Natural Resources 2016). Initial findings from these and previous studies indicate that with planning, mussel relocation can be successful. USDA Forest Service (2016) has found that 71 percent of the translocated mussels were found a year later and that only two mussels (0.22 percent) were confirmed dead. Fernandez (2013) found that Between 55 percent and 95 percent of the transplanted *M. falcata* mussels could be accounted for in individual streams one to three years after relocation. Therefore, it appears likely that these measures could be successful. Sites considered for translocation include areas downstream from the Trinity River confluence (RM 43.4), and between J.C. Boyle Dam (RM 230.6) and Copco No. 1 Reservoir (RM 209.0). These areas would have less impact from increased SSCs but would not be completely protected from short-term effects. The areas downstream of the Trinity River confluence do not currently support *Anodonta spp*. and are unlikely to in the future (Davis et al. 2013). The reach between J.C. Boyle Dam and Copco No. 1 Reservoir does not currently support *Anodonta spp.* Therefore, translocation efforts described in proposed Aquatic Resource Measure AR-7 are anticipated to be potentially successful for *G. angulata* and *M. falcata* (based on suitable habitat in translocation sites), but is unlikely to be successful for *Anodonta spp.* With this aquatic resource measure, there would likely still be a substantial reduction in the abundance of *Anodonta spp.* species In the short term, and impacts would be significant with for *Anodonta spp.* in the short term. For development of proposed Aquatic Resource Measure AR-7, the KRRC explored several approaches to salvaging and relocating *Anodonta spp*. prior to dam removal, as described Appendix B: *Definite*

Plan − Updated AR-7, October 2018 Update. However, options such as translocating mussels to tributaries, or other reaches upstream of Iron Gate Dam were rejected after surveys suggesting that most locations would not provide suitable habitat, and the concern of risking healthy and abundant mussels populations in tributaries by translocating mussels from the mainstem reach with unknown disease risk. Therefore, the short-term significant impact on *Anodonta spp*. due to the Proposed Project cannot be avoided or substantially decreased through feasible mitigation.

Freshwater clams can live buried in the substrate and are expected to suffer less impact than freshwater mussels. In addition, they are relatively short-lived (one to three years) and bear young several times throughout the spring and summer which would support rapid recovery within the short term to impacts from suspended sediment. Based on no predicted substantial short-term decrease in freshwater clam abundance of a year class, or substantial decrease in habitat quality or quantity, there would not be a significant impact to the freshwater clam populations under the Proposed Project in the short term.

In the long term, dam removal would restore connectivity among the Lower Klamath Basin, the Hydroelectric Reach and its tributaries, and the Upper Klamath Basin, and would rehabilitate and increase availability of riverine habitat within the Hydroelectric Reach for *M. falcata* and *G. angulata*. Based on no predicted substantial long-term decrease in *M. falcata* and *G. angulata* abundance of a year class, or substantial decrease in habitat quality or quantity, there would not be a significant impact to the *M. falcata* and *G. angulata* populations under the Proposed Project in the short term.

Conditions would also improve in the long term in the Hydroelectric Reach for *Anodonta spp.* with reduced flow variability downstream of J.C. Boyle Dam, potentially creating conditions more similar to the reach downstream of Keno Dam, where *Anodonta spp*. are currently found (Byron and Tupen 2017). This additional habitat is unlikely to offset the long-term habitat lost from increased flow variability within Lower Klamath Project reservoirs and downstream of Iron Gate Dam. The current populations of *Anodonta spp*. in the Lower Klamath Project reservoirs and downstream of Iron Gate Dam are artifacts of an altered hydrology and geomorphology. The reversion of these conditions to more natural river environment (e.g., natural flow regime and increased sediment scour) would no longer support *Anodonta spp*., and the suitable habitat supporting their populations would be revert to natural spring-fed stable flow conditions, such as the Upper Shasta River. Based on predicted substantial long-term decrease in *Anodonta spp.* abundance of a year class, and substantial decrease in habitat quality and quantity, there would be a significant impact to the *Anodonta spp.* population under the Proposed Project in the long term. Because reversion of the Klamath River within and downstream of the Lower Klamath Project to more natural river conditions would be an inevitable consequence of the Proposed Project, the long-term significant impact on *Anodonta spp*. due to the Proposed Project cannot be avoided or substantially decreased through feasible mitigation.

Based on no predicted substantial long-term decrease in freshwater clam abundance of a year class, or substantial decrease in habitat quality or quantity, there would not be a significant impact to the freshwater clam populations under the Proposed Project in the long term.

Significance

No significant impact for *M. falcata* and *G. angulata* in the short or long term

Significant and unavoidable impact for *Anodonta spp.* in the short and long term

No significant impact for freshwater clams in the short or long term

Potential Impact 3.3-20 Effects on fish species from alterations to benthic macroinvertebrates due to short-term sediment releases and long-term changes in habitat quality due to dam removal.

Benthic macroinvertebrates (BMI) are small aquatic animals and the aquatic larval stages of insects. BMI are the primary food source for most freshwater fish species, and therefore, changes in abundance, distribution, or community structure can affect fish populations. A diminished food supply can limit growth of salmonids, and this is especially true at higher temperatures because as water warms, a fish's metabolic rate increases, and it needs more food to sustain growth. Growth is critical to juvenile salmonids because a larger size fish often has a survival advantage during the overwintering period, smolt outmigration, and ocean residence.

In the short term, the Proposed Project could alter SSCs and bedload sediment transport and deposition and thereby negatively affect benthic macroinvertebrates. Increases in suspended sediment and increased bedload deposition following dam removal under the Proposed Project are anticipated to result in a reduction in abundance of BMIs within the first few months of dam removal year 2 in the reach from Iron Gate Dam to confluence with the Salmon River, and SSC increases may decrease growth rates of fish rearing and feeding in the mainstem Klamath River downstream of Iron Gate Dam to around the Salmon River confluence. Short-term reductions in the abundance and diversity of BMIs has been observed following disturbance due to suspended sediment (Reid and Anderson 2000, Orr et. al 2008). During the period of greatest impact (winter of sediment release dam removal years 1 and 2), food availability related to BMI production would likely decrease in the reach downstream of Iron Gate Dam around the confluence with the Salmon River. However, within this reach a reduction in feeding by fish species is already predicted to occur in response to increased SSCs, which is a sub-lethal effect from which fish populations are anticipated to recover. In addition, salmonids typically reduce feeding during winter in response to lower water temperature and decreased metabolic demand (Bustard and Narver 1975).

While a large proportion of the BMI population in the Hydroelectric Reach and in the mainstem Klamath River downstream from Iron Gate Dam would be reduced in the short term, their populations would be expected to recover quickly because of the many sources for recolonization and their rapid dispersion through drift or aerial movement of adults. Full recovery of BMI communities is typically observed within a year following disturbance (Tsui and McCart 1981, Anderson et al. 1998). The constant "flushing" action of the Klamath River is anticipated to speed BMI recovery from negative impacts resulting from sediment deposition. Tullos et al. (2014) found that BMI communities downstream of the Brownsville (Calapooia River, Oregon) and Savage Rapids (Rogue River, Oregon) dams resembled upstream control sites within a year after dam removal. Foley et al. (2017) summarizes the effects of multiple dam removal studies and found that researcher reported that following dam removal downstream BMI abundance tends to increase and species assemblages transition to resemble sites upstream of the former dam, noting that some BMI species can double their population size in days to weeks, and quickly (within months) recover once the initial sediment pulse has passed. There, the effects of reduced BMI populations on food availability for fish species is anticipated to be of insufficient magnitude or duration to substantially effect fish species in the short term. Based on no predicted substantial short-term decrease in fish abundance of a year class, or substantial decrease in habitat quality or quantity supporting a fish species, there would not be a significant impact to fish populations under the Proposed Project in the short term from effects to BMIs.

In the long term, the Proposed Project would restore connectivity among the Lower Klamath Basin, the Hydroelectric Reach and its tributaries, and the Upper Klamath Basin, and would rehabilitate and increase availability of riverine habitat within the Hydroelectric Reach. The reformation of river channels in the reservoir reaches upstream of Iron Gate Dam, and the reversion to unimpeded sediment transport downstream of Iron Gate Dam under the Proposed Project, would benefit BMIs by providing more suitable substrates (e.g., gravel) than currently exist. Thus, suitable habitats formed upstream of Iron Gate Dam might be opened to additional colonization by BMIs through rapid dispersal by drift from upstream populations within current riverine reaches and/or dispersion of adult life stages. In addition, recolonization would occur rapidly from established BMI populations within the many tributary rivers and streams of the Klamath River. BMI populations would be expected to recover quickly and provide food availability to fish from short-term impacts because of the many sources for recolonization and their rapid dispersion through drift or aerial movement of adults.

Under the Proposed Project, peaking operations would no longer kill, through stranding, large numbers of aquatic invertebrates that are the primary prey food for resident trout in the reach between J.C. Boyle Powerhouse and Copco No. 1 Reservoir (NMFS 2006a). Based on increased habitat availability and improved habitat quality, the effect of the Proposed Project on BMI as a food source for fish species would be beneficial in the long term. Based on no predicted substantial long-term decrease in fish abundance of a year class, or substantial decrease in habitat quality or quantity supporting a fish species, there would not be a significant impact to fish populations under the Proposed Project in the long term from effects to BMIs.

Significance

No significant impact for effects of alterations to benthic macroinvertebrates on fish species in the short term

Beneficial for effects of alterations to benthic macroinvertebrates on fish species in the long term

Potential Impact 3.3-21 Effects on aquatic resources due to short-term noise disturbance and water quality alterations from construction and deconstruction activities.

This analysis relates to the potential impact to aquatic resources from various construction and deconstruction activities associated with the Proposed Project, outside of the release of reservoir sediments discussed more thoroughly above, and the relocation of the City of Yreka's water supply pipeline, discussed below as Potential Impact 3.3-23.

Disturbance to the river channel during construction related to the Proposed Project could affect aquatic species. The Proposed Project would require demolition of the dams and their associated structures, removal of power generation facilities and transmission lines, installation of cofferdams, road upgrading, hauling, reservoir restoration, and other activities (as described in Section 2.7.1 *Dam and Powerhouse Deconstruction*). These actions would include the use of heavy equipment, and blasting as necessary, and have the potential to disturb aquatic species. Activities at the Lower Klamath Project dams would affect the riverine and introduced resident species in the Hydroelectric Reach. At Iron Gate Dam and Iron Gate Hatchery, anadromous species could also be affected. These potential effects could include shockwaves associated with breaking down the dam structures using explosives or heavy equipment, potential crushing of aquatic species from operation of heavy equipment in the river, sedimentation, and release of oil, gasoline, or other toxic substances from construction sites.

Several deconstruction activities are schedule to occur prior to reservoir drawdown, including road improvements (e.g., bridge upgrades), temporary road crossings, Iron Gate modifications, Fall Creek Hatchery modifications, etc. In-water demolition of the dams and their associated structures, power generation facilities, and other activities, are scheduled to occur nearly simultaneously within the first nine months of reservoir drawdown during dam removal year 2 (see Table 2.7-1), and during the peak SSCs associated with reservoir drawdown in dam removal year 2. The aquatic resources impacts of this reservoir drawdown SSC peak are discussed earlier in this section. It is anticipated that this release of sediment during initial drawdown would result in the nearly immediate displacement of most mobile aquatic species from the mainstem into tributaries or farther downstream prior to the prolonged deconstruction or in-water work activities (e.g., cofferdam installation or removal). Native aquatic species (e.g., redband trout) that occur in the Hydroelectric Reach would have less potential refuge in the mainstem from deconstruction impacts, but would have access to key tributaries as refigure, including Jenny, Fall, and Shovel creeks. For non-mobile aquatic resources, like mussels, the impacts are anticipated to be well within the range of what is discussed for reservoir sediment release, as it is assumed that construction and deconstruction-related impacts would be of small magnitude, short duration, and low intensity when compared to those that would occur as a result of release of sediments stored behind the dams.

For aquatic species that occur within reservoirs, the effect of deconstruction is already subsumed by the impact of conversion of reservoir to riverine habitat, as described in multiple potential impacts above. For example, the reservoir habitat that supports Lost River and shortnose suckers (Potential Impact 3.3-13) would be removed, as addressed by the Aquatic Resource Measure AR-6 to salvage and relocate suckers prior to reservoir drawdown, or impacts associated with deconstruction.

To minimize potential construction impacts from crushing, sediment release, toxins, noise, etc., construction areas would be isolated from the river where possible. The Klamath River would be bypassed around the construction area while the isolated portion of the dam is removed. After a work area is isolated, fish rescue and relocation efforts, to remove any native fish trapped in the work area, would be conducted. Fish would be relocated to an area of suitable habitat within the Klamath River.

In addition, proposed soil erosion and sedimentation control and stormwater pollution prevention (Section 2.7.8.7 *Water Quality Monitoring and Construction BMPs*) measures would minimize effects of construction related toxins, soil erosion, and associated water quality effects on aquatic species downstream from the work area, during and after construction. Further, the State Water Board has issued a draft water quality certification which sets forth multiple conditions to monitor the effects of deconstruction on water quality (e.g., suspended sediment, dissolved oxygen, toxicity, etc.), and to protect aquatic resources through proper disposal of materials. Based on no predicted substantial short- or long-term decrease in aquatic species abundance of a year class, or substantial decrease in habitat quality or quantity, there would not be a significant impact to aquatic resources under the Proposed Project in the short term or long term from deconstruction effects.

Significance

No significant impact for aquatic resources from deconstruction in the short term or long term

Potential Impact 3.3-22 Effects on aquatic species due to short-term noise disturbance and water quality alterations from deconstruction activities and long-term fish screen upgrades from the relocation of the City of Yreka Water Supply Pipeline under the Proposed Project.

The existing water supply pipeline for the City of Yreka passes under the upstream end of Iron Gate Reservoir and would have to be relocated prior to decommissioning the Iron Gate Dam to prevent damage from deconstruction activities or increased water velocities and pipeline exposure once the reservoir has been drawn down. Additionally, the water supply intake screens located in Fall Creek may need to be replaced or upgraded to meet regulatory criteria. Native species currently residing in Iron Gate Reservoir that could be affected from the construction-impacts of removal of the existing pipeline and the installing of a new one in the short term would include redband trout, cutthroat trout, chub species, sucker species, and sculpin species. In the long term anadromous fish accessing habitat upstream of Iron Gate Dam could also be affected by improved screens at the water supply intakes. If the existing fish screens for the water supply intakes do not meet current regulatory agency screen criteria for anadromous fish, improved screened intakes presumably would meet criteria. As described in Section *2.7.8.7 Water Quality Monitoring and Construction BMPs,* standard construction best management practices would reduce the likelihood and extent of aquatic impacts to a less-than-significant level for water quality purposes. These levels are set for protection of aquatic resources. Therefore, based on no predicted substantial short- or long-term decrease in aquatic species abundance of a year class, or substantial decrease in habitat quality or quantity, there would not be a significant impact to aquatic resources under the Proposed Project in the short term or long term from the relocation of the City of Yreka water supply pipeline and intake screens.

Significance

No significant impact to aquatic resources from the relocation of the City of Yreka water supply pipeline and intake screens in the short or long-term

Potential Impact 3.3-23 Effects on anadromous salmonid populations due to short-term and long-term Bogus Creek flow diversions for the Iron Gate Hatchery.

Under the Proposed Project, up to 8.75 cfs of water would be diverted from Bogus Creek to operate Iron Gate Hatchery for eight years (dam removal year 2 through post-dam removal year 7), as described in Section 2.7.6 *Hatchery Operations*. This diversion would replace the current water supply from Iron Gate Reservoir. Specific diversion rates from Bogus Creek would be as follows:

- 6.50 cfs October through November
- 8.75 cfs in December
- 3.50 cfs January through March
- 8.25 cfs April through May
- 0.00 cfs June through September

To reduce the potential adverse effects of diverting water from Bogus Creek on naturally spawning and rearing salmon, the KRRC proposes to construct the pump station for the hatchery water supply would be constructed as far downstream toward the Klamath River confluence as practicable (within 1,000 feet, Figure 2.7-10). This would result in up to a 1,000-foot reach in lower Bogus Creek that would experience lower fall, winter, and spring flows than under existing conditions (Figure 2.7-11). As further discussed below, CDFW and NMFS have proposed monitoring and adaptation of operations to minimize habitat impacts.

Based on adult migrant monitoring (Knechtle and Chesney 2011, 2016, 2017), fall-run Chinook salmon are observed to return to Bogus Creek to spawn from mid-September to early November, coho salmon adults return from late October to early January, and steelhead from November through March. Therefore, flow diversions of 6.5 cfs during October and November, and 8.75 cfs in December could affect upstream migration of adult salmonids into Bogus Creek through the lower reach. The volume of flow required for adult salmonids to migrate upstream through lower Bogus Creek has not been directly assessed. Depending on stream gradient, channel width, and other geomorphic conditions, flows below the diversion may continue to be sufficient for upstream passage, or they could result in conditions that restrict passage at times, particularly in early October prior to increased precipitation. The geomorphic conditions that determine passage are subject to change as precipitation events alter the streambed.

Based on two years of recent migration observations in Bogus Creek (Knechtle and Chesney 2016, 2017) during the low flow years of 2015 and 2016, fall-run Chinook salmon were observed migrating at flows as low as 4.5 cfs in September 2016, and 8 fish were observed migrating at flows between 4.5 and 5 cfs. During the fall-run Chinook salmon migration peak in 2015 and 2016, flows were between 10 and 20 cfs. Based on this data, flows greater than around 4.5 cfs enabled at least some upstream migration in the past. If this flow was sufficient for Chinook salmon, it would also be sufficient for coho salmon and steelhead, which have less restrictive passage requirements. Long-term flow monitoring data are not available for Bogus Creek. However, the available data from 2013–2016 includes severe and extreme drought conditions and are therefore likely appropriate to observe minimum flows to support passage. Based on four years of available data (Figure 2.6-8), proposed water diversions could result in flow reductions during the adult migratory period of around 10 to 40 percent in the affected reach during fall-run Chinook salmon migration, potentially resulting in flows less than 4.5 cfs in at least some years, for at least a few days. By the time coho salmon and steelhead are migrating flows are high enough to provide greater than 4.5 cfs, based on the data available. Based on available data it appears that under the Proposed Project insufficient flows for Chinook salmon passage could result in delays for up five days in some years. Delay of migration for even one day has been observed to increase disease risk by increasing the density of holding adults and increasing mortality of adults prior to spawning (McLaughlin et al. 2012, Connor et al. 2018). Temporary increasing in crowding may be similar to similar to what is observed under existing conditions during periods of low rainfall, but could be exacerbated by decreasing flows in lower Bogus Creek. These impacts are anticipated to effect a small proportion of migrants during the 14-week fall-run Chinook salmon migration period (Table 3.3-3). In addition, any redds that are deposited along channel margins (shallow water areas) downstream of the diversion may be susceptible to stranding when diversion rates increase (e.g., primarily December, as well as March), although the affected reach is relatively short (< 1,000 feet). Rearing fish (mobile) are unlikely to be affected by the relatively low magnitude of flow fluctuations.

As described in detail in Section 2.7.6 *Hatchery Operations*, the proposal for Iron Gate Hatchery operation includes protection for fish passage in Bogus Creek (Appendix B: *Definite Plan – Section 7.8.3*, NMFS and CDFW 2018). To minimize effects of Bogus Creek diversions on fish habitat, NMFS and CDFW would coordinate to ensure that at least 50 percent of the flow would remain in Bogus Creek at the point of diversion, conduct an assessment to determine that the habitat below the diversion provides connectivity for fish spawning and rearing habitat, identify appropriate flow levels or percentages of diversion permitted each month, and establish reporting specifications (Section 2.7.6 *Hatchery Operations*).

Based on the potential for low flows (i.e., less than 4.5 cfs) in the Bypass Reach during the salmonid migration periods in some years resulting in delayed migration and increased crowding, the uncertainty in the migration flow levels in Bogus Creek, and the uncertainty in the commitment to ensure flows to protect anadromous salmon volitional migration, the flow diversions from Bogus Creek could decrease the abundance of multiple (up to eight) year classes of anadromous salmonids produced from spawning activity in Bogus Creek. However, only a portion of the fall-run migration could be affected, and the total potential production from redds in Bogus Creek is a low proportion of all the production from the Klamath River Basin for Chinook salmon, coho salmon, and steelhead. Based on the less than substantial decrease in abundance of a year class and habitat quality that could occur under the Proposed Project in the short- and long-term, the effect of reduced instream flows in Bogus Creek under the Proposed Project would not be significant in the short- and long-term.

Although CEQA Guidelines Section 15126.4(a)(3) states that mitigation measures are not required for effects which are not found to be significant, Mitigation Measure AQR-3 would even further reduce the potential for short- and long-term effects of reduced instream flows in lower Bogus Creek under the Proposed Project on anadromous salmon by increasing certainty that fish passage conditions are projected. Mitigation Measure AQR-3 below includes additional components beyond those listed as part of the Proposed Project which would further reduce the potential short-term impacts on migrating anadromous salmonids resulting from hatchery operations. With Mitigation Measure AQR-3, the potential effect of instream flow diversions is further reduced.

Mitigation Measure AQR-3 – Bogus Creek Flow Diversions.
Implementation of Iron Gate Hatchery operations plan (Described in Appendix B: *Definite Plan – Section 7.8.3*) shall include a minimum flow in Bogus Creek of 4.5 cfs, unless a study is conducted that determines an alternative minimum flow is required to provide volitional fish migration for Chinook salmon, coho salmon, and steelhead. If the hatchery diversions cause a flow within Bogus Creek downstream of the bypass that is less than 4.5 cfs (or the minimum flow identified for each species during their migration

period), then hatchery operations shall be adjusted, in coordination with NMFS and CDFW, to reduce the percentage of flow diverted from Bogus Creek to be protective of anadromous fish passage.

Significance

No significant impact with mitigation on Chinook salmon, coho salmon, or steelhead in the short term or long term

Potential Impact 3.3-24 Effects on anadromous salmonid populations due to short-term and long-term Fall Creek flow diversions for the Fall Creek Hatchery .

Under the Proposed Project, up to 9.24 cfs of water would be diverted from Fall Creek to operate Fall Creek Hatchery for eight years (through post-dam removal year 7), as described in Section 2.7.6 *Hatchery Operations*. Specific diversion rates from Fall Creek would be as follows:

- 8.48 cfs in October
- 9.24 cfs in November
- 6.32 cfs in December
- 5.77 cfs in January
- 1.47 cfs in February
- 1.76 cfs in March
- 1.84 cfs in April
- 1.08 cfs in May
- 0.58 cfs in June
- 1.01 cfs in July
- 1.48 cfs in August
- 2.29 cfs in September

In addition, the City of Yreka maintains a water right to divert up to 15 cfs from Fall Creek for municipal purposes (City of Yreka 2012). The primary water intake for this water pipeline is located along the PacifiCorp Fall Creek powerhouse return canal at Dam A (Figure 2.7-17), which is upstream of the proposed Fall Creek Hatchery water diversion. Under the Proposed Project no fish passage would be possible past the existing Dam A or Dam B on Fall Creek (Figure 2.7-8; Appendix B: *Definite Plan – Section 7.8.3*), approximately one mile upstream from the projected confluence of Fall Creek with the Klamath River. Depending on final site selection, discharge from the hatchery would re-enter Fall Creek from between 0.08 and 0.36 miles upstream from the confluence with the Klamath River. Therefore, most of the one mile of spawning and rearing habitat for salmonids in Fall Creek, from Dam A and Dam B to the confluence with the Klamath River, would be subject to reduced flows as a result of Fall Creek Hatchery water diversions.

Based on historical records and current assessments of habitat suitability, Fall Creek likely has the potential to provide around one mile of spawning and rearing habitat for fall-run and spring-run Chinook salmon, coho salmon, steelhead, and Pacific lamprey following the removal of the fish passage barrier of Iron Gate Dam (NMFS 2006a, Hamilton et al. 2005, 2011).

The City of Yreka is required to bypass a minimum flow of 15 cfs or the natural flow of Fall Creek, whenever the natural flow is less than 15 cfs. Under existing conditions Yreka uses less than the 15 cfs allocation, but the City has used the full allocation in the past, and for this analysis it is assumed that the City of Yreka would use their full water right of up to 15 cfs. The Fall Creek Hatchery diversion and return flow points would occur between the City of Yreka water supply intake and the City's compliance point for the Fall Creek minimum flow, which is at the Fall Creek USGS gage (USGS No. 11512000). Between the Fall Creek Hatchery diversion and return flow points, the flow remaining in Fall Creek after the diversions for the City of Yreka and the Fall Creek Hatchery would usually be greater than 15.0 cfs, but it could occasionally be slightly less than 15.0 cfs in late summer to early fall (i.e., mid-July to mid-September) when natural Fall Creek flows reach a minimum. Fall Creek Hatchery diversion flows during the late summer would be 1.01 to 2.29 cfs, potentially reducing flows within the hatchery diversion affected reach to less than 15 cfs in dry water years with particularly low flows. However, this slight reduction during late summer is not anticipated to have a substantial effect on habitat availability or fish passage, due to the volume of instream flows remaining in the reach. During periods of the year when hatchery diversions would be higher (e.g., October through January), typically flows greater than 20 cfs would occur in this section of Fall Creek (Figure 2.7-13), which based on the habitat and channel morphology in Fall Creek is anticipated to provide suitable migratory, rearing, and spawning conditions. Any redds that are deposited downstream of the diversion along channel margins (shallower water) during fall may be susceptible to stranding (i.e., reduced egg-to-emergence survival) when diversion rates increase (e.g., primarily October and November). Rearing fish (mobile) are unlikely to be affected by the relatively low magnitude of flow fluctuations.

Under the Proposed Project anadromous salmonids would have increased habitat access upstream of Iron Dam, including within around one mile of habitat within Fall Creek that is currently inaccessible. Overall, a relatively small diversion of water from Fall Creek relative to existing creek flows would occur under the Proposed Project. In addition, the proportion of anadromous salmonids anticipated to use the habitat in Fall Creek is relatively minor in comparison with the totality of newly accessible habitat upstream of Iron Gate Dam under the Proposed Project. Therefore, based on no predicted substantial short- or long-term decrease in anadromous salmonid population abundance of a year class, or substantial decrease in habitat quality or quantity, there would not be a significant impact to anadromous salmonids under the Proposed Project in the short term or long term from Fall Creek Hatchery flow diversions.

Significance

No significant impact on Chinook salmon, coho salmon, or steelhead in the short term or long term

3.3.6 References

Ackerman, N. K., B. Pyper, I. Courter, and S. Cramer. 2006. Estimation of returns on naturally produced coho to the Klamath River. Klamath Coho Integrated Modeling Framework Technical Memorandum 1 of 8. Review draft. Prepared by Cramer Fish Sciences, Gresham, Oregon for Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls, Oregon.

Adams, P. B., C. B. Grimes, J. E. Hightower, S. T. Lindley, and M. L. Moser. 2002. Status review for North American green sturgeon, *Acipenser medirostris*. National Marine Fisheries Service, Santa Cruz, California.

Adams P. B., C. Grimes, J. E. Hightower, S. T. Lindley, M. L. Moser, and M. J. Parsley. 2007. Population status of North American green sturgeon, Acipenser medirostris. Environ Biol Fish 79: 339–356.

Aldridge, D. W., B. S. Payne, and B. C. Miller. 1987. The effects of intermittent exposure to suspended solids and turbulence on three species of freshwater mussels. Environmental Pollution 45: 17–28

Alexander, J. D., J. L. Bartholomew, K. A. Wright, N. A. Som, and N. J. Hetrick. 2016. Integrating models to predict distribution of the invertebrate host of myxosporean parasites. Freshwater Science 35: 1,263–1,275.

Allen, M. B., R. O. Engle, J. S. Zendt, F. C. Shrier, J. T. Wilson, and P. J. Connolly. 2016. Salmon and steelhead in the White Salmon River after the removal of Condit Dam–planning efforts and recolonization results. Fisheries 41: 190–203.

Anderson, P. G., C. G. J. Fraikin and T. J. Chandler. 1998. Impacts and recovery in a coldwater stream following a natural gas pipeline crossing. Proceedings of the Internationa Pipeline Conference. Volume 2: 1013-1020. Calgary, AB, Canada. American Society of Mechanical Engineers.

Andreasen, J.K. 1975. Systematics and status of the family Catostomidae in southern Oregon. Doctoral dissertation, Oregon State University, Corvallis, Oregon.

Aquatic Scientific Resources. 2005. Preliminary research on Aphanizomenon flosaquae at Upper Klamath Lake, Oregon. Investigations to set direction for research of factors with potential for influencing Aphanizomenon growth at Upper Klamath Lake. Prepared by Aquatic Scientific Resources, Portland, Oregon for Klamath Basin Ecosystem Restoration Office, Klamath Falls Fish and Wildlife Office, Klamath Falls, Oregon.

Araki, H., B. Cooper M. S. Blouin. 2007. Genetic effects of captive breeding cause a rapid, cumulative fitness decline in the wild. Science 318: 100–103.

Asarian, E., and J. Kann. 2011. Phytoplankton and Nutrient Dynamics in Iron Gate and Copco No. 1 Reservoirs 2005–2010. Prepared by Kier Associates, Eureka, California and Aquatic Ecosystem Sciences, LLC, Ashland, Oregon for the Yurok Tribe Environmental Program, Klamath, California.

Atkinson, S., and J. Bartholomew. 2010. Disparate infection patterns of *Ceratomyxa shasta* (Myxozoa) in rainbow trout (*Oncorhynchus mykiss*) and Chinook salmon (*Oncorhynchus tshawytscha*) correlate with internal transcribed spacer-1 sequence variation in the parasite. International Journal for Parasitology 40: 599–604.

Balance Hydrologics, Inc. 1996. Initial assessment of pre-and post-Klamath Project Hydrology on the Klamath River and impacts of the Project on instream flows and fishery habitat. Berkeley, California.

Banish, N. P., B. J. Adams, R. S. Shively, M. M. Mazur, D. A. Beauchamp, and T. M. Wood. 2009. Distribution and habitat associations of radio-tagged adult Lost River and shortnose suckers in Upper Klamath Lake, Oregon. Transactions of the American Fisheries Society 138: 153–168.

Barnhart, R. A. 1994. Salmon and steelhead populations of the Klamath-Trinity Basin, California. Pages 73-97 in TJ Hassler, editor. Klamath Basin fisheries symposium. California Cooperative Fishery Research Unit, Humboldt State University, Arcata.

Bartholow, J. M. 2005. Recent water temperature trends in the lower Klamath River, California. North American Journal of Fisheries Management 25: 152–162.

Bartholow, J. M., S. G. Campbell, and M. Flug. 2005. Predicting the thermal effects of dam removal on the Klamath River. Environmental Management 34: 856–874.

Bartholomew, J., S. Hallett, R. Holt, J. Alexander, S. Atkinson, R. Craig, A. Javaheri, and M. Babar-Sebens. 2017. Klamath River fish health studies: salmon disease monitoring and research. FY2016 April 01, 2016-March 31, 2017. Oregon State University, BOR/USGS Interagency Agreement #R15PG00065.

Bartholomew, J. L., M. J. Whipple, D. G. Stevens, and J. L. Fryer. 1997. The life cycle of *Ceratomyxa shasta*, a myxosporean parasite of salmonids, requires a freshwater polychaete as an alternate host. Journal of Parasitology 83: 859–868.

Bartholomew, J. L., S. D. Atkinson, S. L. Hallett, C. M., Zielinski, and J. S. Foott. 2007. Distribution and abundance of the salmonid parasite *Parvicapsula minibicornis* (Myxozoa) in the Klamath Basin (Oregon-California, USA). Diseases of Aquatic Organisms 78: 137.

Bartholomew, J. L., and J. S. Foott. 2010. Compilation of information relating to myxozoan disease effects to inform the Klamath Basin Restoration Agreement. Department of Microbiology, Oregon State University, Corvallis, and U.S. Fish and Wildlife Service, California-Nevada Fish Health Center.

Bash, J., C. Berman, and S. Bolton. 2001. Effects of turbidity and suspended solids on salmonids. Center for Streamside Studies, University of Washington, Seattle.

Beamish, R. J., C. Mahnken, and C. M. Neville. 1997. Hatchery and wild production of Pacific salmon in relation to large-scale, natural shifts in the productivity of the marine environment. ICES Journal of Marine Science 54: ,1200–1,215

Beeman, J. W., G. M. Stutzer, S. D. Juhnke, and N. J. Hetrick. 2007. Survival and migration behavior of juvenile coho salmon in the Klamath River relative to discharge at Iron Gate Dam, 2006. Final Report. Prepared by U.S. Geological Survey, Cook, Washington and U. S. Fish and Wildlife Service, Arcata California for Bureau of Reclamation, Mid-Pacific Region, Klamath Basin Area Office, Klamath Falls, Oregon.

Beeman, J. W., G. M. Stutzer, S. D. Juhnke, and N. J. Hetrick. 2008. Survival and migration behavior of juvenile coho salmon in the Klamath River relative to discharge at Iron Gate Dam, 2006. Open-File Report 2008-1332. U.S. Geological Survey.

Behnke, R. J. 1992. Native trout of western North America. American Fisheries Society, Bethesda, Maryland.

Behnke, R. J. 2002. Trout and salmon of North America. The Free Press, New York.

Belchik, M. 2003. Use of thermal refugial areas on the Klamath River by juvenile salmonids; summer 1998. Final report, Grant #8-FG-20-17510. Prepared for Bureau of Reclamation, Klamath Area Office by Yurok Tribal Fisheries Program, Klamath, California.

Belchik, M., D. Hillemeir, and R. M. Pierce. 2004. The Klamath River Fish Kill of 2002; Analysis of Contributing Factors. Yurok Tribal Fisheries Program, Klamath, California.

Bell, M. C. 1991. Fisheries handbook of engineering requirements and biological criteria. Prepared by U.S. Army Corps of Engineers, Fish Passage Development and Evaluation Program, Portland, Oregon.

Benson, R. L., S. Turo, and B. W. McCovey. 2007. Migration and movement patterns of green sturgeon (*Acipenser medirostris*) in the Klamath and Trinity rivers, California, USA. Environmental Biology of Fishes 79: 269–279.

Bentivoglio, A. A. 1998. Investigations into the Endemic Sculpins (*Cottus princeps, Cottus tenuis*), in Oregon's Upper Klamath Lake Watershed, with Information on Other Sculpins of Interest (*C. evermanni*, *C. spp*., and *C. "pretendor*"). U.S. Geological Survey, Reston, Virginia.

Berg, L., and T. G. Northcote. 1985. Changes in territorial, gill-flaring, and feeding behavior in juvenile colo salmon (*Oncorhynchus kisutch*) following short-term pulses of suspended sediment. Canadian Journal of Fisheries and Aquatic Sciences 42: 1,410–1,417.

Bisson, P. A., and R. E. Bilby. 1982. Avoidance of suspended sediment of juvenile coho salmon. North American Journal of Fisheries Management 2: 371–374.

Bjork, S. J., and J. L. Bartholomew. 2010. Invasion of Ceratomyxa shasta (Myxozoa) and comparison of migration to the intestine between susceptible and resistant fish hosts. International Journal for Parasitology 40: 1,087–1,095.

Bjornn, T. C., M. A. Brusven, M. P. Molnau, J. H. Milligan, R. A. Klamt, E. Chacho, and C. Schaye. 1977. Transport of granitic sediment in streams and its effects on insects and fish. Research Technical Completion Report, Project B-036-IDA. Prepared by University of Idaho, Moscow for Office of Water Research and Technology, U.S. Department of the Interior, Washington, D.C.

BLM (Bureau of Land Management). 2002. Instream flow analysis for the Bureau of Land Management Federal Reserved Water Right, Claim Number 376, for the Klamath Wild and Scenic River in Oregon.

Boyle, J. C. 1976. 50 years on the Klamath. Klocker Printery, Medford, Oregon.

Brett, J. R. 1971. Energetic responses of salmon to temperature. A study of some thermal relations in the physiology and freshwater ecology of sockeye salmon (*Oncorhynchus nerka*). American Zoologist 11: 99–113.

Bryant, M. D., B. J. Frenette, and S. J. McCurdy. 1999. Colonization of a watershed by anadromous salmonids following installation of a fish ladder in Margaret Creek, Alaska. North American Journal of Fisheries Management 19: 1,129–1,136.

Buchanan, D., M. Buettner, T. Dunne, and G. Ruggerone. 2011a. Scientific assessment of two dam removal alternatives on resident fish. Draft report. Klamath River Expert Panel.

Buchanan, R., R. Townsend, J. Skalski, and K. Ham. 2011b. The effect of bypass passage on adult returns of salmon and steelhead: an analysis of PIT-tag data using the program ROSTER. Draft report. Prepared by Battelle, Pacific Northwest Division, Richland, Washington for U.S. Army Corps of Engineers, Walla Walla District, Washington.

Buer, K. 1981. Klamath and Shasta rivers spawning gravel enhancement study. Department of Water Resources, Northern District, Red Bluff, California.

Buettner, M., and G. Scoppettone. 1990. Life history and status of Catostomids in Upper Klamath Lake, Oregon. Completion Report. U.S. Fish and Wildlife Service, National Fisheries Research Center, Reno Field Station, Nevada.

Buettner, M., R. Larson, J. Hamilton, and G. Curtis. 2006. Contribution of Klamath reservoirs to federally listed sucker populations and habitat. U.S. Fish and Wildlife Service, Yreka, California.

Burger, C. V., K T. Scribner, W. J. Speannan, C. O. Swanton, and D. E. Campton. 2000. Genetic contribution of three introduced life history forms of sockeye salmon to colonization of Fraser Lake, Alaska. Canadian Journal of Fisheries Aquatic Sciences 57: 2,096–2,111.

Burks, N., and K. Cowan. 2007. *Yurok Tribe Macroinvertebrate Report: March 7, 2005–July 6, 2005*. Prepared by the AmeriCorps Watershed Stewards Program for the Yurok Tribe Environmental Program, Klamath, California.

Busby, P. J., T. C. Wainwright, and R. S. Waples. 1994. Status review for Klamath Mountains Province steelhead. NOAA Technical Memorandum NWFSC-19. National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, Washington.

Bustard, D. R., and D. W. Narver. 1975. Preferences of juvenile coho salmon (*Oncorhynchus kisutch*) and cutthroat trout (*Salmo clarki*) relative to simulated alteration of winter habitat. Journal of the Fisheries Research Board of Canada 32: 681-687.

Butler, V. L., A. E. Stevenson, J. A. Miller, D. Y. Yang, C. F. Speller, and N. Misarti. 2010. The use of archaeological fish remains to establish predevelopment salmonid biogeography in the Upper Klamath Basin. Final Report. Department of Anthropology, Portland State University, Portland, Oregon.

Byron, E & Tupen, J. (2017). Mussels of the upper Kamath River, Oregon and California. California Fish and Game. 103. 21-26.

California Bay-Delta Authority (CALFED). 2007. Green sturgeon (*Acipenser medirostris*). *In* Delta regional ecosystem restoration implementation plan. Draft report. CALFED Ecosystem Restoration Program, Sacramento, California.

California HSRG (California Hatchery Scientific Review Group). 2012. California Hatchery Review Report. Prepared for the US Fish and Wildlife Service and Pacific States Marine Fisheries Commission. June 2012.

Carlson, T. J., G. Ploskey, R. L. Johnson, R. P. Mueller, M. A. Weiland, and P. N. Johnson. 2001. Observations of behavior and distribution of fish in relation to the Columbia River navigation channel and channel maintenance activities. Prepared by Pacific Northwest National Laboratory, Richland, Washington for U.S. Army Corps of Engineers, Portland, Oregon.

Carter, K., and S. Kirk. 2008. Fish and fishery resources of the Klamath River basin. Prepared by North Coast Regional Water Quality Control Board and Oregon Department of Environmental Quality.

CBD (Center for Biological Diversity), Oregon Wild, EPIC (Environmental Protection Information Center), and The Larch Company. 2011. Petition to list Upper Klamath Chinook salmon (*Oncorhynchus tshawytscha*) as a threatened or endangered species.

CDFG (California Department of Fish and Game). 1990a. Juvenile salmonid sampling within the Klamath-Trinity Basin, 1984. Draft report. CDFG, Inland Fisheries Division, Arcata, California.

CDFG. 1990b. Distribution, abundance, fork length and coded-wire tag recovery data for juvenile anadromous salmonids within the Klamath-Trinity Basin, 1985. Draft report. CDFG, Inland Fisheries Division, Arcata, California.

CDFG. 1990c. Status and management of spring-run chinook salmon. CDFG, Inland Fisheries Division, Arcata, California.

CDFG. 2000. Documentation of the Klamath River fish kill, June 2000. Memorandum. Redding, California.

CDFG. 2002a. Status review of California coho salmon north of San Francisco. Candidate Species Status Review Report 2002-3. Report to the California Fish and Game Commission.

CDFG. 2002b. California Department of Fish and Game comments to NOAA Fisheries Service regarding green sturgeon listing.

CDFG. 2004. September 2002 Klamath River fish-kill: final analysis of contributing factors and impacts. Northern California-North Coast Region. Redding, California.

CDFG. 2005. Upper Klamath River Wild Trout Area Fisheries Management Plan. Prepared by CDFG, Northern California and North Coast Region, Redding, California.

CDFG. 2009. Status review of the longfin smelt (*Spirinchus thaleichthys*) in California. Report to the Fish and Game Commission. Prepared by CDFG, Sacramento, California.

CDFG. 2010. Klamath River Mainstem Spawner Escapement Estimates, 1978–2009. Unpublished data received from M. Knechtle, Biologist, California Department of Fish and Game, Yreka, California.

CDFG and USDA Forest Service. 2002. Unpublished data. Summer-run steelhead escapement for the Klamath River Basin, 1998–2002. Available at: http://www.krisweb.com/krisklamathtrinity/krisdb/webbuilder/md_c30.htm

CDFW (California Department of Fish and Wildlife). 2013. 2012 Scott River Salmon Studies. Final Report. Northern Region. Klamath River Project. Yreka, California.

CDFW. 2014. Hatchery and Genetic Management Plan for Iron Gate Hatchery Coho Salmon. Prepared by CDFW, Redding, California and PacifiCorp, Portland, Oregon for National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Arcata, California.

CDFW. 2015a Recovery Strategy for California Coho Salmon. Progress Report 2004–2012. Prepared for the California Fish and Game Commission.

CDFW. 2015b. Klamath River Basin spring Chinook salmon spawner escapement, river harvest and run-size estimates, 1980-2014 https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=100231&inline

CDFW. 2016a. Trinity River Basin Salmon and Steelhead Monitoring Project: Chinook and Coho Salmon and Fall-Run Steelhead Run-Size Estimates Using Mark-Recapture Methods 2015-16 Season. Annual Report. Northern Region. Klamath-Trinity Program. Redding, California.

CDFW. 2016b. Annual Report, Iron Gate Hatchery, 2015-2016. CDFW, Northern Region, Inland Fisheries.

CDFW. 2017. Klamath River Basin fall Chinook salmon spawner escapement, in-river harvest and run-size estimates, 1978-2016 http://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=123560.

CDFW. 2018a. California Natural Resources Agency Department of Fish and Wildlife Biogeographic Data Branch California Natural Diversity Database state and federally listed endangered and threatened animals of California. Available at: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=109405&inline.

CDFW. 2018b. Klamath River Renewal Corporation, Definite Plan for the Lower Klamath Project, Appendix I – Aquatic Resources Measures, June 2018 (and addendum dated October 10, 2018). Prepared by CDFW, Region 1, Redding, California.

CDFW. 2018c. Fisheries Branch—Fisheries Production and Distribution Documents. Annual anadromous fish trap counts. https://nrm.dfg.ca.gov/documents/ContextDocs.aspx?cat=Fisheries--

FishProductionDistribution&sub=Anadromous_Fish_Trap_Counts [Accessed October 2018].

CH2M Hill. 1985. Klamath Basin fisheries resource plan. Prepared for U.S. Department of the Interior, Bureau of Indian Affairs by CH2M Hill, Redding, California.

CH2M Hill. 2003. Literature based characterization of resident fish entrainment and turbine-induced mortality Klamath Hydroelectric Project (FERC No. 2082). Draft Technical Memorandum. Prepared by CH2M Hill for PacifiCorp.

CH2M Hill. 2009a. Analysis of microcystin in resident fish and mussel tissues in the vicinity of the Klamath Hydroelectric Project in 2008. Prepared for PacifiCorp Energy, Portland, Oregon by CH2M Hill, Redding, California.

CH2M Hill. 2009b. Occurrence of microcystin in Chinook salmon and steelhead in the Klamath River in 2007. Prepared for PacifiCorp Energy, Portland, Oregon by CH2M Hill, Redding, California.

Chapman, D. W. 1988. Critical Review of Variables Used to Define Effects of Fines in Redds of Large Salmonids. Transactions of the American Fisheries Society 117: 1–21.

Chase, Z., P.G. Strutton, and B. Hales. 2007. Iron links river runoff and shelf width to phytoplankton biomass along the U.S. West Coast. Geophysical Research Letters 34, L04607, doi:10.1029/2006GL028069

Chesney, W. R., and E. M. Yokel. 2003. Shasta and Scott River juvenile salmonid outmigrant study, 2001-2002. Project 2a1. Steelhead Research and Monitoring Program annual report. California Department of Fish and Game, North Coast Region, Redding.

Chesney, W. R., W. B. Crombie, and H. D. Langendorf. 2009. Shasta and Scott River juvenile salmonid outmigration monitoring project. Final report. California Department of Fish and Game, Anadromous Fish Research and Monitoring Project, Yreka.

Chilcote, M. W. 2003. Relationship between natural productivity and the frequency of wild fish in mixed spawning populations of wild and hatchery steelhead (*Oncorhynchus mykiss*). Canadian Journal of Fisheries and Aquatic Sciences 60: 1,057–1,067.

City of Klamath Falls. 1986. Application for license – Salt Caves Hydroelectric Project. Initial Stage consultation, Volume II. Klamath Falls, Oregon.

City of Yreka. 2012. Amended permit for diversion and use of water, Permit 15379. Prepared by City of Yreka, California for California Environmental Protection Agency and State Water Resources Control Board, Sacramento, California.

Close, D. A., M. S. Fitzpatrick, and H. W. Li. 2002. The ecological and cultural importance of a species at risk of extinction, Pacific lamprey. Fisheries 27: 19–25.

Close, D. A., M. Docker, T. Dunne, and G. Ruggerone. 2010. Scientific assessment of two dam removal alternatives on lamprey. Final report. Klamath River Expert Panel.

Connor, W. P., K. F. Tiffan, J. A. Chandler, D. W. Rondorf, B. D. Arnsberg, and K. C. Anderson. 2018. Upstream Migration and Spawning Success of Chinook Salmon in a Highly Developed, Seasonally Warm River System. Reviews in Fisheries and Aquaculture, DOI: 10.1080/23308249.2018.1477736.

Cooperman, M. S., and D. F. Markle. 2004. Abundance, size, and feeding success of larval shortnose suckers and Lost River suckers from different habitats of the littoral zone of Upper Klamath Lake. Environmental Biology of Fishes 71: 365–377.

Coots, M. 1962. Shasta River, Siskiyou County, 1958 king salmon count, with yearly totals from 1930-1961. California Department of Fish and Game, Inland Fisheries Branch, Sacramento, California.

Coots, M. and J. H. Wales. 1952. King salmon activity in Jenny Creek and the old Klamath River channel between the Forebay Dam and Copco #2 Plant. California Department of Fish and Game.

Cunanan, M. 2009. Historic anadromous fish habitat estimates for Klamath River mainstem and tributaries under Klamath Hydropower reservoirs. U.S. Fish and Wildlife Service, Arcata, California.

Daniels, R. A., and P. B. Moyle. 1984. Geographic variation and a taxonomic reappraisal of the marbled sculpin, *Cottus klamathensis*. Copeia 4: 949–959.

Davis, E.A., David, A.T., Norgaard, K.M., Parker, T.H., McKay, K., Tennant, C., Soto, T., Rowe, K. & Reed, R. 2013. Distribution and abundance of freshwater mussels in the mid Klamath subbasin, California. Northwest Science 87, 189-206.

Dean, M. 1994. Life history, distribution, run size, and harvest of spring Chinook salmon in the south fork Trinity River Basin. Chapter VII - Job VII in Trinity River Basin monitoring project 1991–1992.

Dean, M. 1995. Life history, distribution, run size, and harvest of spring Chinook salmon in the south fork Trinity River Basin. Chapter VII - Job VII in Trinity River Basin monitoring project 1992–1993.

Dennis, T., M. M. Hentz, and C. Wickman. 2017. Mid Klamath 2016 winter coho spawner survey. Prepared by Mid Klamath Watershed Council, Orleans, California.

De Robertis, A., C. A. Morgan, R. A. Schabetsberger, R. W. Zabel, R. D. Brodeur, R. L. Emmett, C. M. Knight, G. K. Krutzikowsky, and E. Casillas. 2005. Columbia River plume fronts. II. Distribution, abundance, and feeding ecology of juvenile salmon. Marine Ecology Progress Series 299: 33–44.

Desjardins, M., and D. F. Markle. 1999. *Distribution and Biology of Suckers in Lower Klamath Reservoirs. 1999 Final Report.* Submitted to PacifiCorp by Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon.

DOI (Department of the Interior). 2006. U.S. Department of the Interior preliminary Section 18 prescriptions, Klamath Hydroelectric Project – FERC No. 2082. Prepared by National Marine Fisheries Service and U.S. Fish and Wildlife Service.

DOI. 2007. Modified terms and conditions, and prescriptions for fishways filed pursuant to sections 4(e) and 18 of the Federal Power Act with the Federal Energy Regulatory Commission for the Klamath River Hydroelectric Project No. 2082. Bureau of Land Management, Bureau of Reclamation, U.S. Fish and Wildlife Service, and National Marine Fisheries Service. Sacramento, California.

Dunne, T., G. Ruggerone, D. Goodman, K. Rose, W. Kimmerer, and J. Ebersole. 2011. Scientific assessment of two dam removal alternatives on coho salmon and steelhead. Klamath River Expert Panel final report. Prepared with assistance of Atkins.

Dunsmoor, L. K. 2006. Observations and significance of fish and invertebrate stranding during the first few major peaking cycles in 2006 downstream from the J.C. Boyle Hydroelectric Project. Technical Memorandum. Klamath Tribes, Chiloquin, Oregon.

Dunsmoor L. K., and C. W. Huntington. 2006. Suitability of environmental conditions within Upper Klamath Lake and the migratory corridor downstream for use by anadromous salmonids. Technical Memorandum. Klamath Tribes, Chiloquin, Oregon.

Elder, D., B. Olson, A. Olson, J. Villeponteaux, and P. Brucker. 2002. Salmon River subbasin restoration strategy: steps to recovery and conservation of aquatic resources. Prepared by Klamath National Forest, Yreka California and Salmon River Restoration Council, Sawyers Bar, California for the Klamath Basin Restoration Task Force.

Emmett, R. L., S. L. Stone, S. A. Hinton, and M. E. Monaco. 1991. Distribution and abundance of fishes and invertebrates in West Coast estuaries. Volume 2: Species life history summaries. Estuarine Living Marine Resources Program Report No. 8. NOAA/NOS Strategic Environmental Assessments Division, Rockville, Maryland.

Farnsworth, K. L., and J. A. Warrick. 2007. Sources, dispersal, and fate of fine sediment supplied to coastal California. U.S. Geological Survey Scientific Investigations Report 2007-5254.

Feldhaus, J. W., T. L. Hoffnagle, and R. W. Carmichael. 2016. The influence of size at release on performance of Imnaha River Chinook salmon hatchery smolts. North American Journal of Fisheries Management 36: 363-374.

Felleman, F. L., J. R. Heimlich-Boran, and R. W. Osborne. 1991. Feeding ecology of the killer whale (*Orcinus orca*). Pages 113–147 *in* K. Pryor, and K. S. Norris, editors. Dolphin societies. University of California Press, Berkeley.

FERC (Federal Energy Regulatory Commission). 2007. Final Environmental Impact Statement for Hydropower License, Klamath Hydroelectric Project, FERC Project No. 2082-027. FERC/EIS-0201F. FERC, Office of Energy Projects, Division of Hydropower Licensing, Washington, DC.

Fernandez, M. K. 2013. Transplants of western pearlshell mussels to unoccupied streams on Willapa National Wildlife Refuge, Southwestern Washington. Journal of Fish and Wildlife Management 4: 316–325.

Fetcho, K. 2006. Klamath River blue-green algae bloom report: Water Year 2005. Prepared for Yurok Tribe Environmental Program.

Fetcho, K. 2011. Final 2009 Klamath River blue-green algae summary report. Yurok Tribe Environmental Program, Klamath, California.

Flagg, T. A., B. A. Berejikian, J. E. Colt, W. W. Dickhoff, L. W. Harrell, D. J. Maynard, C. E. Nash, M. S. Strom, R. N. Iwamoto, and C. V. W. Mahnken. 2000. Ecological and Behavioral Impacts of Artifical Production Strategies on the Abundance of Wild Salmon Populations. NOAA Technical Memorandum. National Marine Fisheries Service, Seattle, Washington.

Foley, M. M., J. R. Bellmore, J. E. O'Connor, J. J. Duda, A. E. East, G. E. Grant, C. W. Anderson, J. A. Bountry, M. J. Collins, P. J. Connolly, L. S. Craig, J. E. Evans, S. L. Greene, F. J. Magilligan, C. S. Magirl, J. J. Major, G. R. Pess, T. J. Randle, P. B. Shafroth, C. E. Togersen, D. Tullos, and A. C. Wilcox. 2017. Dam removal: listening in, Water Resources Research 53: 5,229–5,246.

Foott, J. S., R. Stone, E. Wiseman, K. True, and K. Nichols. 2007. Longevity of *Ceratomyxa shasta* and *Parvicapsula minibicornis* actinospore infectivity in the Klamath River. Journal of Aquatic Animal Health 19: 77–83.

Foott, J. S., J. Strange, and R. Slezak. 2009. FY2007 Technical Report: *Ceratomyxa shasta myxospore* survey of adult Rainbow trout/Steelhead, Chinook and Coho salmon in the Klamath River basin in 2007–2008: Cooperative Humboldt State University - Yurok Fisheries-CA-NV FHC project. U.S. Fish and Wildlife Service California – Nevada Fish Health Center, Anderson, California.

Foott, J. S., R. Fogerty, R. Stone, S. Bjork, and J. Bigelow. 2012. Effects of a simulated Klamath River summer temperature profile on juvenile Chinook salmon (*Oncorhynchus tshawytscha*) immune function. FY 2010 Technical Report. U.S. Fish and Wildlife Service, California Nevada Fish Health Center, Anderson, California.

Ford, J. K. B., G. M. Ellis, P. F. Olesiuk, and K. C. Balcomb, III. 2009. Linking killer whale survival and prey abundance: food limitations in the oceans' apex predator? Biology Letters. doi:10.1098/rsbl.2009.0468.

Fortune, J. D., A. R. Gerlach, and C. J. Hanel. 1966. A study to determine the feasibility of establishing salmon and steelhead in the Upper Klamath Basin. Pacific Power and Light.

Fry, D. H., Jr. 1979. Anadromous fishes of California. California Department of Fish and Game, Sacramento.

Fujiwara, M., M. S. Mohr, A. Greenberg, J. S. Foott, and J. L. Bartholomew. 2011. Effects of ceratomyxosis on population dynamics of Klamath fall Chinook salmon. Transactions of the American Fisheries Society 140: 1,380–1,391

Gannett, M., K. E. Lite, Jr, J. L. La Marche, B. J. Fisher, and D. J. Polette. 2007. Ground-water hydrology of the Upper Klamath Basin, Oregon and California. Scientific Investigations Report 2007-5050. U.S. Geological Survey in cooperation with Oregon Water Resources Department.

Geyer, W. R., P. Hill, T. Milligan, and P. Traykovski. 2000. The structure of the Eel River plume during floods. Continental Shelf Research 20: 2,067–2,093.

Glen, D. 2002. Recovery of salmon and trout following habitat enhancement works: review of case studies 1995–2002. Pages 93–112 *in* M. O'Grady editor. Proceedings of the 13th international salmonid habitat enhancement workshop, Westport, County Mayo, Ireland. Central Fisheries Board. Dublin.

Green Diamond Resource Company. 2018. Green Diamond Forest Habitat Conservation Plan.

Goodman, D. and N. J. Hetrick. 2017. Response to request for technical assistance – distribution of Pacific lamprey in the reach immediately downstream of Iron Gate Dam, Klamath River. Prepared by U.S. Fish and Wildlife Service, Arcata, California for California Department of Fish and Wildlife, Sacramento, California.

Goodman, D., and S. Reid. 2012. Pacific Lamprey (*Entosphenus tridentatus*) assessment and template for conservation measures in California. U.S. Fish and Wildlife Service, Arcata, California.

Goodman, D. H., and S. B. Reid. 2015. Regional implementation plan for measures to conserve Pacific lamprey (*Entosphenus tridentatus*), California - North Coast Regional Management Unit. Arcata Fisheries Technical Report Number TR 2015-12. Prepared by U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, California.

Goodman, D., M. Harvey, R. Hughes, W. Kimmerer, K. Rose, and G. Ruggerone. 2011. Klamath River Expert Panel, Addendum to Final Report, Scientific Assessment of Two Dam Removal Alternatives on Chinook Salmon. Addendum to Final Report. Prepared with the assistance of Atkins, Portland, Oregon.

Grimes, C. B., and J. H. Finucane. 1991. Spatial distribution and abundance of larval and juvenile fish, chlorophyll and macrozooplankton around the Mississippi River discharge plume, and the role of the plume in fish recruitment. Marine Ecology Progress Series 75: 109–119.

Gustafson, R. G., M. J. Ford, D. Teel, and J. S. Drake. 2010. Status review of eulachon (*Thaleichthys pacificus*) in Washington, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-105. National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle and Port Orchard, Washington.

Gustafson, R. G., L. Weitkamp, Y. Lee, E. Ward, K. Somers, V. Tuttle, and J. Jannot. 2016. status review update of eulachon *(Thaleichthys pacificus)* listed under the Endangered Species Act: Southern Distinct Population Segment. National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, Washington.

Haley, L., Ellis, and J. Cook. 2007. Reproductive timing of freshwater mussels and potential impact of pulsed flows on reproductive success. PEIR Final Project Report. Contract 500-01-044. California Energy Commission, Sacramento.

Hallett, L.S., J. L. Bartholomew. 2006. Application of a real-time PCR assay to detect and quantify the myxozoan parasite Ceratomyxa Shasta in river water samples. Diseases of Aquatic Organisms. 71:109-118.

Hamilton, J. B., G. L. Curtis, S. M. Snedaker, and D. K. White. 2005. Distribution of anadromous fishes in the upper Klamath River Watershed prior to hydropower dams -- a synthesis of the historical evidence. Fisheries 30: 10–20.

Hamilton, J. B., D. Rondorf, M. Hampton, R. Quinones, J. Simondet, and T. Smith. 2011. Synthesis of the Effects to Fish Species of Two Management Scenarios for the Secretarial Determination on Removal of the Lower Four Dams on the Klamath. Prepared by the Biological Subgroup for the Secretarial Determination Regarding Potential Removal of the Lower Four Dams on the Klamath River. Accessed on December 21, 2011.

Hamilton, J. B., D. W. Rondorf, W. T. Tinniswood, R. J. Leary, T. Mayer, C. Gavette, and L. A. Casal. 2016. The persistence and characteristics of Chinook salmon migrations to the upper Klamath River prior to exclusion by dams. OHQ 117: 326–377.

Hanson, B. 2015. Distribution and Diet of Southern Resident Killer Whales. Marine Mammal and Seabird Ecology Team, Conservation Biology Division Northwest Fisheries Science Center, July 28, 2015 Program Review Presentation. https://swfsc.noaa.gov/uploadedFiles/Events/Meetings/MMT_2015/Presentations/3.1percent20PPT%20ProgramReviewSRKWDistributionDiet071515MBHv2.pdf.

Hanson, M. B., R. W. Baird, J. K. B. Ford, J. Hempelmann-Halos, D. M. Van Doornik, J. R. Candy, C. K. Emmons, G. S. Schorr, B. Gisborne, K. L. Ayres, S. K. Wasser, K. C. Balcomb, K. Balcomb-Bartok, J. G. Sneva, and M. J. Ford. 2010. Species and stock identification of prey consumed by endangered Southern Resident Killer Whales in their summer range. Endangered Species Research 11: 69–82.

Hardy, T., and C. Addley. 2001. Evaluation of interim instream flow needs in the Klamath River. Phase II. Final Report. Prepared for U.S. Department of the Interior, Washington, DC by Institute for Natural Systems Engineering, Utah Water Research Laboratory, Utah State University, Logan.

Hardy, T., C. Addley, and E. Saraeva. 2006. Evaluation of instream flow needs in the lower Klamath River. Phase II. Final Report. Prepared for U.S. Department of the Interior, Washington, D.C. by Institute for Natural Systems Engineering, Utah Water Research Laboratory, Utah State University, Logan.

Heimlich-Boran, J. R. 1988. Behavioral ecology of killer whales (*Orcinus orca*) in the Pacific Northwest. Canadian Journal of Zoology 66: 565–578.

Hendrix, N. 2011. Forecasting the response of Klamath Basin Chinook populations to dam removal and restoration of anadromy versus no action. Review Draft Report. R2 Resource Consultants, Redmond, Washington.

Hendry, A. P., H. V. Castric, M. T. Kinnison, and T. P. Quinn. 2004. The evolution of philopatry and dispersal: homing versus straying in salmonids. Pages 52–91 *in* A. P. Hendry and S. C. Stearns, editors. Evolution illuminated: salmon and their relatives. Oxford University Press, New York.

Henley, W. F., M. A. Patterson, R. J. Neves, and A. D. Lemly. 2000. Effects of sedimentation and turbidity on lotic food webs: a concise review for natural resource managers. Reviews in Fisheries Science 8: 125–139.

Hentz, M. M., and C. Wickman. 2016. Mid Klamath River coho spawning surveys, winter 2015/2016. Prepared by Mid Klamath Watershed Council, Orleans, California for PacifiCorp, Portland, Oregon.

Herbert, D. M. W., and J. C. Merkens. 1961. The effects of suspended mineral solids on the survival of trout. International Journal of Air and Water Pollution 5: 46–55.

Hetrick, N. J., T. A. Shaw, P. Zedonis, J. C. Polos, and C. D. Chamberlain. 2009. Compilation of information to inform USFWS principals on the potential effects of the proposed Klamath Basin Restoration Agreement (Draft 11) on fish and fish habitat conditions in the Klamath Basin, with emphasis on fall Chinook salmon. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata, California.

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

Hiner, M. 2006. Seasonal water quality in the Klamath River Estuary and surrounding sloughs, 2001–2003. Yurok Tribal Fisheries Program, Klamath, California.

Hoar, W. S. 1988. The physiology of smolting salmonids. Pages 275–343 *in* WS Hoar and DJ Randall, editors. Fish physiology: Vol. XI, The physiology of developing fish, Part B, Viviparity and posthatching juveniles. Academic Press, San Diego.

Hodge, B. W., M. A. Wilzbach, W. G. Duffy, R. M. Quiñones, and J. A. Hobbs. 2016. Life history diversity in Klamath River steelhead. Transactions of the American Fisheries Society 145: 227-238.

Holtby, L. B., B. C. Andersen, and R. K. Kadowaki. 1990. Importance of smolt size and early ocean growth to interannual variability in marine survival of coho salmon (Oncorhynchus kisutch). Canadian Journal of Fisheries and Aquatic Sciences 47: 2,181–2,194.

Hooton, B., and R. Smith. 2008. A plan for the reintroduction of anadromous fish in the Upper Klamath Basin. Public Review Draft. Oregon Department of Fish and Wildlife, Klamath Watershed District.

Hopelain, J. S. 1998. Age, growth, and life history of Klamath Basin steelhead trout (*Oncorhynchus mykiss irideus*) as determined from scale analysis. Inland Fisheries Administration Report 98-3. California Department of Fish and Game, Sacramento.

Howard, J. K., and K. M. Cuffey. 2003. Freshwater mussels in a California North Coast Range river: occurrence, distribution, and controls. Journal of The North American Benthological Society 22: 63–77.

Huang, J., and B. Greimann. 2010. User's manual for SRH-1D 2.5, Sedimentation and River Hydraulics – One Dimension Version 2.5. Bureau of Reclamation, Technical Service Center, Denver, Colorado.

Humboldt County. 2017. Humboldt County General Plan for the Areas Outside the Coastal Zone.

Huntington, C. W. 2004. Klamath River flows within the J.C. Boyle Bypass and below the J.C. Boyle Powerhouse. Clearwater BioStudies, Canby, Oregon.

Huntington, C. W. 2006. Estimates of anadromous fish runs above the site of Iron Gate Dam. Clearwater BioStudies, Canby, Oregon.

Hurst, C. N., R. A. Holt, and J. L. Bartholomew. 2012. Dam Removal and Implications for Fish Health: Ceratomyxa Shasta in the Williamson River, Oregon, USA. North American Journal of Fisheries Management 32:1, 014-023

Ibelings, B. W. and I. Chorus. 2007. Accumulation of cyanobacterial toxins in freshwater "seafood" and its consequences for public health: A review. Environmental pollution 150(1):177-92.

Illinois Department of Natural Resources. 2016. CONSERVATION PLAN. (Application for an Incidental Take Authorization). Per 520 ILCS 10/5.5 and 17 Ill. Adm. Code 1080 https://www.dnr.illinois.gov/conservation/NaturalHeritage/Documents/ITA_Conservation_Plans/Conservation_Plans/56_CP.pdf

Israel, A. J., J. F. Cordes, M. A. Blumberg, and B. May. 2004. Geographic patterns of genetic differentiation among collections of green sturgeon. North American Journal of Fisheries Management 24: 922–931.

Jepsen, S., C. LaBar, and J. Zarnoch. 2010. *Gonidea angulata* (Lea, 1838) Western ridged mussel. The Xerces Society for Invertebrate Conservation, Portland, Oregon.

Johnson, O. W., M. H. Ruckelshaus, W. S. Grant, F. W. Waknitz, A. M. Garrett, G. J. Bryant, K. Neely, and J. J. Hard. 1999. Status review of coastal cutthroat trout from Washington, Oregon, and California. NOAA Technical Memorandum NOAA Fisheries Service-NWFSC-37. National Marine Fisheries Service, Seattle, Washington.

Kann, J. 2008. Microcystin bioaccumulation in Klamath River fish and freshwater mussel tissue: preliminary 2007 results. Technical Memorandum. Prepared by Aquatic Ecosystem Sciences, Ashland, Oregon for Karuk Tribe of California, Orleans, California.

Kann, J. 2010. Compilation of Klamath Tribes Upper Klamath Lake water quality data, 1990–2009. Prepared by Aquatic Ecosystem Sciences, Ashland, Oregon for the Klamath Tribes Natural Resources Department, Chiloquin, Oregon.

Kann, J., L. Bowater, and S. Corum. 2010a. Middle Klamath River toxic cyanobacteria trends, 2009. Technical Memorandum. Prepared by Aquatic Ecosystem Sciences, Ashland, Oregon, and Karuk Tribe Department of Natural Resources, Orleans, California.

Kann, J., S. Corum, and K. Fetcho. 2010b. Mycrocystin bioaccumulation in the Klamath River, freshwater mussel tissue: 2009 results. Technical Memorandum. Aquatic Ecosystem Sciences, Ashland, Oregon; Karuk Tribe Natural Resources Department, Orleans, California; and Yurok Tribe Environmental Program, Klamath, California.

Kann, J., C. Bowman, L. Bowater, G. Johnson, and S. Raverty. 2013. Microcystin bioaccumulation in Klamath River salmonids; 2010 Study Results (Updated 6-12-2013). Technical memorandum. Prepared by Aquatic Ecosystem Sciences for the Karuk Tribe Department of Natural Resources, Orleans California.

Kemp, P., D. Sear, A. Collins, P. Naden, and I. Jones. 2011. The impacts of fine sediment on riverine fish. Hydrological Processes 25: 1,800-1,821.

Kiffney, P. M., G. R. Pess, J. H. Anderson, P. Faulds, K. Burton, S. C. Riley. 2009. Changes in fish communities following recolonization of the Cedar River, Washington, USA by Pacific salmon after 103 years of local extirpation. River Research and Applications 25: 438–452.

Kinziger, A. P., M. Hellmair, and D. G. Hankin. 2008. Genetic structure of Chinook salmon (*Oncorhynchus tshawytscha*) in the Klamath-Trinity Basin: implications for within-basin genetic stock identification. Hoopa Valley Tribal Fisheries Department and Humboldt State University, Department of Fisheries Biology, Arcata, California.

Kinziger, A. P., M. Hellmair, and D. G. Hankin. 2013. Contemporary population structure in Klamath River basin Chinook salmon revealed by analysis of microsatellite genetic data. Transactions of the American Fisheries Society 142: 1,347-1,357.

Kirk, S., D. Turner, and J. Crown. 2010. Upper Klamath and Lost River sub-basins total maximum daily load (TMDL) and water quality management plan (WQMP). Oregon Department of Environmental Quality, Bend, Oregon.

Kjelland, M. E., C. M. Woodley, T. M. Swannack, and D. L. Smith. 2015. A review of the potential effects of suspended sediment on fishes: potential dredging-related physiological, behavioral, and transgenerational implications. Environmental System and Decisions 35: 334–350.

Klamath County. 2010. Comprehensive plan for Klamath County, Oregon. Available at: https://www.klamathcounty.org/721/Comprehensive-Plan

KHSA (Klamath Hydroelectric Settlement Agreement). 2016. Klamath Hydroelectric Settlement Agreement. As amended April 6, 2016.

Klimley, A. P., P. J. Allen, J. A. Israel, J. T. Kelly. 2007. The green sturgeon and its environment: introduction. Environmental Biology of Fishes 79: 187–190.

Knechtle, M., and D. Chesney. 2011. Bogus Creek salmon studies 2010 final report. Prepared by California Department of Fish and Game, Northern Region, Yreka, California.

Knechtle, M., and D. Chesney. 2016. Bogus Creek salmon studies 2015 final report. Prepared by California Department of Fish and Wildlife, Northern Region, Yreka, California.

Knechtle, M., and D. Chesney. 2017. Bogus Creek salmon studies 2016 final report. Prepared by California Department of Fish and Wildlife, Northern Region, Yreka, California.

Knight, R. L., F. J. Margraf, and R. F. Carline. 1984. Piscivory by walleyes and yellow perch in western Lake Erie. Transactions of the American Fisheries Society 113: 677–693.

Kondolf, G. M., M. G. Wolman. 1993. The sizes of salmonid spawning gravels. Water Resources Research 29: 2,275–2,285.

Kostow, K. E., A. R. Marshall, and S. R. Phelps. 2003. Naturally spawning hatchery steelhead contribute to smolt production but experience low reproductive success. Transactions of the American Fisheries Society 132: 780–790.

Kostow, K. E., and S. Zhou. 2006. The effect of an introduced summer steelhead hatchery stock on the productivity of a wild winter steelhead population. Transactions of the American Fisheries Society 135: 825–841.

KRBFTF (Klamath River Basin Fisheries Task Force). 1991. Long range plan for the Klamath Basin Conservation Area Fishery Restoration Program. Prepared with assistance from William, M. Kier Associates, Sausalito. Yreka, California.

KRRC (Klamath River Renewal Corporation) Recreation Technical Team. 2018. Draft water temperature data collection at Shovel Creek. Prepared by KRRC Recreation Technical Team, San Francisco, California for State Water Resources Control Board, Sacramento, California.

KRTT (Klamath River Technical Team). 2011. Ocean abundance projections and prospective harvest levels for Klamath River fall Chinook, 2011 season.

KRTT. 2013. Ocean abundance projections and prospective harvest levels for Klamath River fall Chinook, 2013 season.

KRTT. 2015. Ocean abundance projections and prospective harvest levels for Klamath River fall Chinook, 2015 season.

Lasko, G. R., R. G. Titus, J. R. Ferreira, and R. M. Coleman. 2014. Straying of latefall run Chinook salmon from the Coleman National Fish Hatchery into the lower American River, California. California Department of Fish Game 100: 665–682.

Larson, Z. S., and M. R. Belchik. 1998. A preliminary status review of eulachon and Pacific lamprey in the Klamath Basin. Yurok Tribal Fisheries Program, Klamath, California.

Leider, S. A. 1989. Increased straying by adult steelhead trout, *Salmo gairdneri*, following the 1980 eruption of Mount St. Helens. Environmental Biology of Fishes 24: 219–229.

Leidy, R. A., and G. R. Leidy. 1984. Life stage periodicities of anadromous salmonids in the Klamath River basin, northwestern California. Sacramento, California. U.S. Fish and Wildlife Service.

Lemly, A. D. 1982. Modification of benthic insect communities in polluted streams: combined effects of sedimentation and nutrient enrichment. Hydrobiologia 87: 229–245.

Lindley, S. T., and H. Davis. 2011. Using model selection and model averaging to predict the response of Chinook salmon to dam removal. Review Draft Report. National Marine Fisheries Service, Fisheries Ecology Division, NOAA Fisheries Service Southwest Fisheries Science Center, Santa Cruz, California.

Lorion, C. M., D. F. Markle, S. B. Reid, and M. F. Docker. 2000. Redescription of the presumed-extinct Miller Lake lamprey, *Lampetra minima*. Copeia 2000: 1,019–1,028.

Love, M. S. 2011. Certainly More than you want to know about the fishes of the Pacific Coast. Really Big Press, Santa Barbara, California.

Mageroy, J. 2016. Rocky Mountain ridged mussel (Gonidea angulata) in the Okanagan Valley, BC: Final report on potential threats from limited fish host availability, introduced fish species, and river restoration, and mitigation of direct damage from the public. Unpublished report, the University of British Columbia Okanagan, Kelowna, BC. On file at the British Columbia Ministry of Environment, Victoria, BC.

Magneson, M. D., and S. Gough. 2006. Mainstem Klamath River coho salmon redd surveys 2001 to 2005. Arcata Fisheries Data Series Report DS 2006-7. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata, California.

Magneson, M. D., and K. Wright. 2010. Mainstem Klamath River fall Chinook salmon redd survey 2009. Arcata Fisheries Data Series Report DS 2010-19. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata, California

Markle, D. F., M. R. Cavalluzzi, and D. C. Simon. 2005. Morphology and taxonomy of Klamath Basin suckers (Catostomidae). Western North American Naturalist 65: 473-489.

Maule, A. G., S. P. VanderKooi, J. B. Hamilton, R. Stocking, and J. Bartholomew. 2009. Physiological development and vulnerability to *Ceratomyxa shasta* of fall-run Chinook salmon in the Upper Klamath River watershed. North American Journal of Fisheries Management 29: 1,743–1,756.

McAllister, D. E. 1963. A revision of the smelt family, Osmeridae. Bulletin of the National Museum of Canada 191: 1–53.

McClelland, W. T., and M. A. Brusven. 1980. Effects of sedimentation on the behavior and distribution of riffle insects in a laboratory stream. Aquatic Insects 2: 161–169.

McCovey, B. W. 2011a. Klamath River green sturgeon acoustic tagging and biotelemetry monitoring, 2010. Final Technical Report. Yurok Tribal Fisheries Program, Hoopa, California.

McCovey, Jr., B. 2011b. Yurok Tribe Studies of Eulachon Smelt in the Klamath River Basin, California. Progress report, November 1, 2010 to April 30, 2011. NOAA Grant NA10NMF4720374.

McCovey, Jr., B. 2012. Yurok Tribe Studies of Eulachon Smelt in the Klamath River Basin, California. Progress report, November 1, 2011 to April 30, 2012. NOAA Grant NA10NMF4720374.

McCovey, Jr. B., and L. Walker. 2013. Yurok Tribe Studies of Eulachon Smelt in the Klamath River Basin, California. Progress report, November 1, 2012 to April 30, 2013. NOAA Grant NA10NMF4720374.

McCullough, D. A. 1999. A review and synthesis of effects of alterations to the water temperature regime on freshwater life stages of salmonids, with special reference to chinook salmon. Prepared for U.S. Environmental Protection Agency, Region 10, Seattle, Washington. Available at: www.critfc.org/tech/EPAreport.htm.

McGinnis, S. M. 1984. Freshwater fishes of California. California Natural History Guides: 49. University of California Press, Berkeley.

McLaughlin, R. L., E. R. B. Smyth, T. Castro-Santos, M. L. Jones, M. A. Koops, T. C. Pratt, and L. A. Vélez-Espino. 2013. Unintended consequences and trade-offs of fish passage. Fish and Fisheries 14: 580-604. http://dx.doi.org/10.1111/faf.12003.

McLean, J. E., P. Bentzen, and T. P. Quinn. 2003. Differential reproductive success of sympatric, naturally spawning hatchery and wild steelhead trout (*Oncorhynchus mykiss*) through the adult stage. Canadian Journal of Fisheries and Aquatic Sciences 60: 433–440.

McMichael, G. A., C. S. Sharpe, and T.N. Pearsons. 1997. Effects of residual hatchery-reared steelhead on growth of wild rainbow trout and spring Chinook salmon. Transactions of the American Fisheries Society 126: 230–239.

Mertes, L. A. K., and J. A. Warrick. 2001. Measuring flood output from 110 coastal watersheds in California with field measurements and SeaWiFS. Geology 29: 659–662.

Messmer, R., and R. Smith. 2007. Adaptive management for Klamath Lake redband trout. *In* R. K. Schroeder, and J.D. Hall, editors. Redband trout: resilience and challenge in a changing landscape. Oregon Chapter of the American Fisheries Society, Corvallis.

Miller, R. R., and G. R. Smith. 1981. Distribution and evolution of Chasmistes (Pisces: Catostomidae) in western North America. Occasional Papers of the Museum of Zoology, University of Michigan, Ann Arbor 696: 1–46.

Milner, A. M., A. L. Robertson, K. Monaghan, A. J. Veal, and E. A. Flory. 2008. Colonization and development of a stream community over 28 years; Wolf Point Creek in Glacier Bay, Alaska. Frontiers in Ecology and the Environment 6: 413–419.

Mintier & Associates, Jones & Stokes and Associates, S. Lowens, and Del Norte County Community Development Department. 2003. Del Norte County General Plan.

Morgan, C. A., A. De Robertis, and R. Q. Zabel. 2005. Columbia River plume fronts. I. Hydrology, zooplankton distribution, and community composition. Marine Ecology Progress Series 299: 19–31.

Moser, M. L., and S. T. Lindley. 2007. Use of Washington estuaries by subadult and adult green sturgeon. Environmental Biology of Fishes 79: 243–253.

Moyle, P. B. 1976. Inland fishes of California. University of California Press, Berkeley and Los Angeles.

Moyle, P. B. 2002. Inland fishes of California. Second edition. University of California Press, Berkeley.

Moyle, P. B., R. M. Yoshiyama, J. E. Williams, and E. D. Wikramanayake. 1995. Fish species of special concern in California. Prepared by Department of Wildlife and Fisheries Biology, University of California, Davis for California Department of Fish and Game, Inland Fisheries Division, Rancho Cordova.

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

Moyle, P. B., R. A. Lusardi, P. J. Samuel, and J. V. E. Katz. 2017. State of the salmonids: status of California's emblematic fishes 2017. Prepared by Center for Watershed Sciences, University of California, Davis and California Trout, San Francisco, California.

Moyle, P. B., R. M. Quiñones, J. V. Katz and J. Weaver. 2015. Fish species of special concern in California. Prepared by California Department of Fish and Wildlife, Sacramento, California.

Myers, J. M., R. G. Kope, T. D. Bryant, L. J. Lierheimer, T. C. Wainwright, W. S Grant, F. W. Waknitz, K. Neely, S. T. Lindley, and R. S. Waples. 1998. Status review of chinook salmon from Washington, Idaho, Oregon, and California. NMFS-NWFSC-35. National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, Washington.

Nawa, R. 2003. A petition for rules to list: Pacific lamprey (*Lampetra tridentata*); river lamprey (*Lampetra ayresi*); western brook lamprey (*Lampetra richardsoni*); and Kern brook lamprey (*Lampetra hubbsi*) as threatened or endangered under the Endangered Species Act. Letter to U.S. Fish and Wildlife Service, Washington, D.C.

Nedeau, E., A. K. Smith, and J. Stone. 2005. Freshwater mussels of the Pacific Northwest. U.S. Fish and Wildlife Service, Vancouver, Washington.

Nedeau, E. J., A. K. Smith, J. Stone, and S. Jepsen. 2009. Freshwater mussels of the Pacific Northwest. Second edition. The Xerces Society for Invertebrate Conservation.

Newcombe, C. P., and D. D. MacDonald. 1991. Effects of suspended sediments on aquatic ecosystems. North American Journal of Fisheries Management 11: 72–82.

Newcombe, C. P., and J. O. T. Jensen. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management 16: 693–727.

NMFS and USFWS (National Marine Fisheries Service and U. S. Fish and Wildlife Service). 2013. Biological opinions on the effects of proposed Klamath Project operations from May 31, 2013, through March 31, 2023, on five federally listed threatened and endangered species. Prepared by NMFS, Southwest Region, Northern California Office; and USFWS, Pacific Southwest Region, Klamath Falls Fish and Wildlife Office.

NMFS. 1997a. Endangered and threatened species: threatened status for southern Oregon/northern California coast evolutionarily significant unit of coho salmon. Federal Register 62: 24,588–24,609.

NMFS. 1997b. Designated critical habitat; Central California Coast and Southern Oregon/Northern California Coast Coho Salmon. Federal Register 62: 62,741–62,751.

NMFS. 1999a. Status review update for deferred ESUs of west coast Chinook salmon (*Oncorhynchus tshawytscha*) from Washington, Oregon, California, and Idaho. Report of West Coast Biological Review Team to NOAA Fisheries Service, Seattle, Washington. Available at: http://www.nwr.noaa.gov/Publications/Biological-Status-Reviews/loader.cfm?csModule=security/getfile&pageid=21676.

NMFS. 1999b. Designated critical habitat; Central California Coast and Southern Oregon/Northern California Coast coho salmon. Federal Register 64: 24,049–24,062.

NMFS. 2001. Endangered and threatened species: final listing determination for Klamath Mountains Province steelhead. Federal Register 66: 17,845–17,856.

NMFS. 2005. Endangered and threatened wildlife and plants: endangered status for Southern Resident Killer Whales. Federal Register 70: 69,903–69,912.

NMFS. 2006a. Decision in the matter of Klamath Hydroelectric Project, FERC Project Number 2082. Docket Number 2006-NOAA Fisheries Service-0001, September 27, 2006. Alameda, California. Available at: http://www.fws.gov/yreka/P2082/20060927/2Klamath_DNO_Final.pdf.

NMFS. 2006b. Endangered and threatened wildlife and plants: threatened status for Southern Distinct Population Segment of North American green sturgeon: final rule. Federal Register 71: 17,757–17,766.

NMFS. 2006c. Endangered and threatened species; designation of critical habitat for Southern Resident Killer Whale. Federal Register 71: 69,054–69,070.

NMFS. 2007a. Magnuson-Stevens Reauthorization Act Klamath River coho salmon recovery. Prepared by F.R. Rogers, Lagomarsino, I.V., and Simondet, J.A. for NOAA Fisheries Service, Southwest Region, Long Beach, California.

NMFS. 2007b. National Marine Fisheries Service Modified Prescriptions for Fishways and Alternatives Analysis Pursuant to Section 18 and Section 33 of the Federal Power Act for the Klamath Hydroelectric Project (FERC Project No. 2082). Sacramento, California.

NMFS. 2009a. Endangered and threatened wildlife and plants; proposed threatened status for Southern Distinct Population Segment of eulachon. Federal Register 75 13,012–13,024.

NMFS. 2009b. Endangered and threatened wildlife and plants; final rulemaking to designate critical habitat for the threatened Southern Distinct Population Segment of North American green sturgeon. Federal Register 74: 52,300–52,351.

NMFS. 2010a. Biological opinion on the operation of the Klamath Project between 2010 and 2018. Prepared for Bureau of Reclamation by NOAA Fisheries Service, Southwest Region. Available at: http://swr.nmfs.noaa.gov/klamath/FINAL-Klamath_Ops_031510.pdf

NMFS. 2010b. Endangered and threatened wildlife and plants; threatened status for Southern Distinct Population Segment of eulachon. Federal Register 75 13,012–13,024.

NMFS. 2011. Endangered and threatened species, designation of critical habitat for Southern Distinct Population Segment of eulachon. Final rule. Federal Register 76: 65,324–65,352.

NMFS. 2012. Biological Opinion on the Proposed Issuance of an Incidental Take Permit to PacifiCorp Energy for Implementation of the PacifiCorp Klamath Hydroelectric Project Interim Operations Habitat Conservation Plan for Coho Salmon. Prepared by NMFS, Southwest Region, Long Beach, California.

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

NMFS. 2016a. 2016 5-Year Review: Summary & Evaluation of the Southern Oregon/Northern California Coast Coho Salmon. National Marine Fisheries Service. Arcata, California.

NMFS. 2016b. Endangered Species Act Recovery Plan for the Southern Distinct Population Segment of Eulachon (*Thaleichthys pacificus*). Draft Recovery Plan October

2016. Prepared by NMFS, West Coast Region, Protected Resources Division, Portland, Oregon.

NMFS. 2017. Environmental assessment to analyze impacts of NOAA's National Marine Fisheries Service determination that six hatchery programs for Snohomish River basin salmon as described in joint state-tribal hatchery and genetic management plans satisfy the Endangered Species Act Section 4(d) rule. Final Environmental Assessment. Prepared by NMFS, West Coast Region, Seattle, Washington in cooperation with the Bureau of Indian Affairs, Northwest Region, Portland, Oregon.

NMFS. 2018a. Endangered and threatened wildlife; 90-day finding on a petition to list Chinook salmon in the Upper Klamath-Trinity Rivers Basin as threatened or endangered under the Endangered Species Act. Federal Register 83: 8,410–8,414.

NMFS. 2018b. Southern resident killer whales and West Coast Chinook salmon fact sheet. Available at: https://www.westcoast.fisheries.noaa.gov/publications/protected_species/marine_mammals/killer_whales/srkw-salmon-sources-factsheet.pdf.

NMFS and CDFW. 2018. Technical staff recommendation for Klamath River Hatchery operations in California post-dam removal. Arcata, California.

NMFS and WDFW (Washington Department of Fish and Wildlife). 2018, Southern resident killer whale priority Chinook stocks report. NOAA Fisheries West Coast Region and Washington Department of Fish and Wildlife. Available at: https://www.westcoast.fisheries.noaa.gov/publications/protected_species/marine_mammals/killer_whales/recovery/srkw_priority_chinook_stocks_conceptual_model_report___list_22june2018.pdf

NRC (National Research Council). 2004. Endangered and threatened fishes in the Klamath Basin: causes of decline and strategies for recovery. The National Academies Press, Washington, D.C. Available at: http://www.nap.edu/openbook.php?isbn=0309090970.

NRC. 2008. Hydrology, ecology, and fishes of the Klamath Basin. The National Academies Press, Washington, D.C. Available at: http://www.nap.edu/catalog.php?record_id=12072#orgs.

Nichols, K., and J. S. Foott. 2005. Health monitoring of juvenile Klamath River chinook salmon. FY 2004 Investigational Report. U.S. Fish and Wildlife Service, California-Nevada Fish Health Center, Anderson, California.

North Coast Regional Board (North Coast Regional Water Quality Control Board). 2010. Action plan for the Klamath River Total Maximum Daily Loads addressing temperature, dissolved oxygen, nutrient, and microcystin impairments in the Klamath River, California, and Site-specific objectives for dissolved oxygen in the Klamath River in California, and implementation plans for the Klamath and Lost River basins. NCRWQCB, Santa Rosa, California. Available at: http://www.swrcb.ca.gov/northcoast/water_issues/programs/tmdls/klamath_river/.

North Coast Regional Board. 2011. Water Quality Control Plan for the North Coast region (Basin Plan). Santa Rosa, California.

Odemar, M. W. 1964. Southern range extension of the eulachon, *Thaleichthys pacificus*. California Fish and Game 50: 305–307. Available at: http://archive.org/details/californiafishga50_4cali.

ODEQ (Oregon Department of Environmental Quality). 2002. Upper Klamath Lake drainage Total Maximum Daily Load and Water Quality Management Plan. ODEQ, Portland.

ODEQ. 2010. Upper Klamath and Lost River Subbasins Total Maximum Daily Load (TMDL) and Water Quality Management Plan (WPMP). DEQ 10-WQ-030. ODEQ, Portland, Oregon. Available at: http://www.deq.state.or.us/wq/TMDLs/docs/klamathbasin/uklost/KlamathLostTMDLWQMP.pdf.

ODFW. 2011. Observations of spawning Chinook in the former impoundment at Gold Ray Dam. Unpublished data received from D. Van Dyke, Rogue District Fish Biologist, Oregon Department of Fish and Wildlife, Central Point, Oregon.

Olson, A. 1996. Freshwater rearing strategies of spring Chinook salmon (*Oncorhynchus tshawytscha*) in Salmon River tributaries, Klamath Basin, California. Master's thesis. Humboldt State University, Arcata, California.

Olson, J. M. 1998. Temporal and spatial distribution patterns of sightings of southern community and transient orcas in the inland waters of Washington and British Columbia. Master's thesis, Western Washington University, Bellingham, Washington.

Oosterhout, G. R. 2005a. KlamRAS Results of Fish Passage Simulations on the Klamath River. Prepared by Decision Matrix, Inc., for PacifiCorp and The Habitat Modeling Group, Portland, Oregon.

Orr C. H., S. J. Kroiss, K. L. Rogers, and E. H.Stanley. 2008. Downstream benthic responses to small dam removal in a coldwater stream. River Research and Applications 24: 804–822.

Osborne, R. W. 1999. A historical ecology of Salish Sea "resident" killer whales (*Orcinus orca*): with implications for management. Doctoral dissertation. University of Victoria, Victoria, British Columbia.

PacifiCorp. 2004a. Environmental Report. Final License Application, Volume 2, Exhibit E. Klamath Hydroelectric Project, FERC No. 2082. Portland, Oregon.

PacifiCorp. 2004b. Klamath Hydroelectric Project (FERC project no. 2082): fish resources. Final technical report Prepared by PacifiCorp, Portland, Oregon.

PacifiCorp. 2004c. Water Resources. Final Technical Report. Final License Application. Klamath Hydroelectric Project, FERC No. 2082. Portland, Oregon.

PacifiCorp. 2005. Response to FERC AIR AR-2, anadromous fish restoration for the Klamath Hydroelectric Project (FERC Project No. 2082). Final Technical Report, with figures. Portland, Oregon.

PacifiCorp. 2006. PacifiCorp positions on important topics. Klamath Hydroelectric Project, FERC No. 2082. Portland, Oregon.

PacifiCorp. 2010. Analysis of Microcystin in Fish in Copco and Iron Gate Reservoirs in 2009. Technical Memorandum. Portland, Oregon.

PacifiCorp. 2012. PacifiCorp Klamath Hydroelectric Project Interim Operations Habitat Conservation Plan for Coho Salmon. Prepared by PacifiCorp Energy, Inc, Portland, Oregon for National Marine Fisheries Service, Arcata Area Office, Arcata, California.

PacifiCorp. 2013. PacifiCorp Klamath Hydroelectric Project Interim Operations Habitat Conservation Plan for Lost River and Shortnose Suckers. Prepared by PacifiCorp Energy, Inc., Portland, Oregon for U.S. Fish and Wildlife Service, Klamath Falls Fish and Wildlife Office, Klamath Falls, Oregon.

PacifiCorp. 2014. Klamath Hydroelectric Settlement Agreement Implementation Report. FERC Project No. 2082. Prepared by PacifiCorp, Portland, Oregon.

PacifiCorp. 2018. Klamath Hydroelectric Settlement Agreement Implementation Report FERC Project No. 2082. PacifiCorp, Portland, Oregon. August 2018.

Papa, R., J. A. Israel, M. F. Nonnis, and B. May. 2007. Assessment of genetic variation between reproductive ecotypes of Klamath River steelhead reveals differentiation associated with different run-timings. Journal of Applied Ichthyology 23: 142–146.

Pearcy, W. G., and J. P. Fisher. 2011. Ocean distribution of the American shad (*Alosa sapidissima*) along the Pacific coast of North America. Fishery Bulletin 109: 440-453.

Pearsons, T. N., and G. M. Temple. 2010. Changes to rainbow trout abundance and salmonid biomass in a Washington watershed as related to hatchery salmon supplementation. Transactions of the American Fisheries Society 139: 502–520.

Perkins, D. J., J. Kann, and G. Scoppettone. 2000. The role of poor water quality and fish kills in the decline of endangered Lost River and shortnose suckers in the Upper Klamath Lake. Final Report. Prepared by U.S. Geological Survey, Biological Resources Division for Bureau of Reclamation, Klamath Falls Project Office, Klamath Falls, Oregon.

Perry, R. W., J. C. Risley, S. J. Brewer, E. C. Jones, and D. W. Rondorf. 2011. Simulating water temperature of the Klamath River under dam removal and climate change scenarios. Open File Report. U.S. Geological Survey, Reston, Virginia.

Pess, G. R. 2009. Patterns and processes of salmon colonization. Dissertation. University of Washington, Seattle, Washington.

Pess, G. R., T. J. Beechie, J. E. Williams, D. R. Whitall, J. I. Lange, and J. R. Klochak. 2003. Chapter 8: Watershed assessment techniques and the success of aquatic restoration activities. Pages 185–201. *in* R. C. Wissmar and P. A. Bisson, editors.

Strategies for restoring river ecosystems: sources of variability and uncertainty in natural and managed systems. American Fisheries Society. Bethesda, Maryland.

Pess, G. R., P. M. Kiffney, M. C. Liermann, T. R. Bennett, J. H. Anderson, and T. P. Quinn. 2011. The influences of body size, habitat quality, and competition on the movement and survival of juvenile coho salmon during the early stages of stream recolonization. Transactions of the American Fisheries Society 140: 883–897.

PFMC (Pacific Fishery Management Council). 2005. Klamath River Chinook salmon stock-recruitment analysis. PFMC, Portland, Oregon.

PFMC. 2012. Pacific Coast Salmon Fishery Management Plan for commercial and recreational salmon fisheries off the coasts of Washington, Oregon, and California as revised through Amendment 17. PFMC, Portland, Oregon.

Poff, N. L., J. D. Allan, M. B. Bain, J. R. Karr, K. L. Prestegaard, B. Richter, R. Sparks, and J. Stromberg. 1997. The natural flow regime: a new paradigm for riverine conservation and restoration. BioScience 47: 769–784.

Prendergast, L., and K. Foster. 2010. Analysis of microcystin in fish in Copco and Iron Gate reservoirs in 2009. Technical memorandum. PacifiCorp, Portland, Oregon.

Prince, D. J., S. M. O'Rourke, T. Q. Thompson, O. A. Ali, H. S. Lyman, I. K. Saglam, T. J. Hotaling, A. P. Spidle, and M. R. Miller. 2017. The evolutionary basis of premature migration in Pacific salmon highlights the utility of genomics for informing conservation. Science Advances 3: e1603198.

Pullen, J. D., and J. S. Allen. 2000. Modeling studies of the coastal circulation off northern California: shelf response to a major Eel River flood event. Continental Shelf Research 20: 2,213–2,238.

Quinn, T. P. 1984. Homing and straying in Pacific salmon. Pages 357–362 *in* J. D. McCleave, G. P. Arnold, J. J. Dodson, and W. H. Neill, editors. Mechanisms of migration in fishes. Plenum Press, New York.

Quinn, T. P., R. S. Nemeth, and D. O. McIsaac. 1991. Homing and straying patterns of fall chinook salmon in the lower Columbia River. Transaction of the American Fisheries Society 120: 150–156.

Quiñones, R. M., M. L. Johnson, and P. B. Moyle. 2013. Hatchery practices may result in replacement of wild salmonids: adult trends in the Klamath basin, California. Environmental Biology of Fishes DOI 10.1007/s10641-013-0146-2.

Ray, R. A., R. W. Perry, N. A. Som, and J. L. Bartholomew. 2014. Using cure models for analyzing the influence of pathogens on salmon survival. Transactions of the American Fisheries Society 143: 387-398.

Redding, J. M., C. B. Schreck, and F. H. Everest. 1987. Physiological effects on coho salmon and steelhead of exposure to suspended solids. Transactions of the American Fisheries Society 116: 737–744.

Reid, S. M., and P. G. Anderson. 2000. Effects of sediment released during open-cut pipeline water crossings. Hydrobiologia 79:271–276.

Reisenbichler, R., S. and Rubin. 1999. Genetic changes from artificial propagation of Pacific salmon affect the productivity and viability of supplemented populations. ICES Journal of Marine Science 56: 459–466

Roninger, T. 2012. Memo to the file prepared by Trisha Roninger, July 2, 2012. U.S. Fish and Wildlife Service, Klamath Falls, Oregon.

Ryan, J. P., F. P. Chavez, and J. G. Bellingham. 2005. Physical-biological coupling in Monterey Bay, California: topographic influences on phytoplankton ecology. Marine Ecology Progress Series 287: 23-32.

Ryan, P. A. 1991. Environmental effects of sediment on New Zealand streams: a review. New Zealand Journal of Marine and Freshwater Research 25: 207–221.

Sartori, J. C. 2006. Comparative otolith microstructural analysis of adult, juvenile, and fry life stages of Salmon River spring Chinook salmon of northwestern CA. Technical report. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata, California.

Schabetsberger, R., C. A. Morgan, R. D. Brodeur, C. L. Potts, W. T. Peterson, and R. L. Emmett. 2003. Prey selectivity and diel feeding chronology of juvenile chinook (*Oncorhynchus tshawytscha*) and coho (*O. kisutch*) salmon in the Columbia River plume. Fisheries Oceanography 12: 523–540.

Scheiff, A. J., J. S. Lang, and W. D. Pinnix. 2001. Juvenile salmonid monitoring on the mainstem Klamath River at Big Bar and mainstem Trinity River at Willow Creek 1997-2000. Annual report of the Klamath River Fisheries Assessment Program. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, Arcata, California.

Scheuerell, M. D., R. W. Zabel, and B. P. Sandford. 2009. Relating juvenile migration timing and survival to adulthood in two species of threatened Pacific salmon (*Oncorhynchus* spp.). Journal of Applied Ecology 46: 983–990.

Schrank, A. J., F. J. Rahel, and H. C. Johnstone. 2003. Evaluating laboratory derived thermal criteria in the field: An example involving Bonneville cutthroat trout. Transactions of the American Fisheries Society 132: 100–109.

Scoppetone, G. G. 1988. Growth and longevity of the cui-ui and other catostomids and cyprinids in western North America. Transactions of the American Fisheries Society 117: 301–307.

Scott, W. B., and E. J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin No. 184.

Servizi, J. A., and D. W. Martens. 1992. Sublethal responses of coho salmon (*Oncorhynchus kisutch*) to suspended sediments. Canadian Journal of Fisheries and Aquatic Sciences 49: 1,389–1,395.

Shaw, T. A., C. Jackson, D. Nehler, and M. Marshall. 1997. Klamath River (Iron Gate Dam to Seiad Creek) life stage periodicities for Chinook, coho, and steelhead. Prepared by U.S. Fish and Wildlife Service, Coastal California Fish and Wildlife Office, Arcata, California.

Shea, C., N. J. Hetrick, and N. A. Som. 2016. Sediment Mobilization and Flow History in Klamath River below Iron Gate Dam. Technical report. Prepared by U. S. Fish and Wildlife Service for Dept. of Natural Resources. Arcata, CA.

Simondet, J. A. 2006. Expert testimony provided for trial-type hearing. Matter of the Klamath Hydroelectric Project (License Applicant PacifiCorp), Docket Number 2006-NMFS-0001, FERC Project Number 2082. Final Ruling dated 27 September 2006.

Sinnott, S., and M. Hanington. 2008. *Yurok Tribe Macroinvertebrate Report: April–June 2008*. Prepared by the AmeriCorps Watershed Stewards Program for the Yurok Tribe Environmental Program, Klamath, California.

Siskiyou County. 1973. The conservation element of the general plan: Siskiyou County, California. Prepared by Siskiyou County Planning Department, California.

Siskiyou County. 1980. Siskiyou County general plan land use and circulation element.

Siskiyou County. 1997. Siskiyou County General Plan Land Use Polices.

Snyder, J. O. 1931. Salmon of the Klamath River, California. Division of Fish and Game of California, Sacramento. Fish Bulletin No. 34: 5–22.

Snyder, M. A., L. C. Sloan, and J. L. Bell. 2004. Modeled regional climate change in the hydrologic regions of California: a CO_2 sensitivity study. Journal of the American Waters Resources Association 40: 591–601.

Som, N. A., N. J. Hetrick. 2016a. *Ceratonova shasta* waterborne spore stages. Prepared by U.S. Fish and Wildlife Service for Dept. of Natural Resources. Arcata, California.

Som, N. A., N. J. Hetrick. 2016b. Polychaete distribution and infections. Prepared by U.S. Fish and Wildlife Service for Dept. of Natural Resources. Arcata, California.

Soto, T., A. Corum, H. Voight, D. Hillemeier, and L. Lestelle. 2008. The role of the Klamath River mainstem corridor in the life history and performance of juvenile coho salmon (*Oncorhynchus kisutch*). Draft report to Bureau of Reclamation.

Stanford, J. A., J. V. Ward, W. J. Liss, C. A. Frissell, R. N. Williams, J. A. Lichatowich, and C. C. Coutant. 1996. A general protocol for restoration of regulated rivers. Regulated Rivers: Research & Management 12: 391–413.

Starcevich, S. J., S. E. Jacobs, and W. Tinniswood. 2006. Effects of dams on redband trout life history in the Upper Klamath River: a summary and synthesis of past and recent studies. Oregon Department of Fish and Wildlife, Corvallis.

Stillwater Sciences. 2008. Klamath River dam removal study: sediment transport DREAM-1 simulation. Technical Report. Prepared by Stillwater Sciences, Arcata, California for California Coastal Conservancy, Oakland, California.

Stillwater Sciences. 2009a. Effects of sediment release following dam removal on the aquatic biota of the Klamath River. Technical Report. Prepared by Stillwater Sciences, Arcata, California for State Coastal Conservancy, Oakland, California. Available at: http://www.Reclamation.gov/mp/kbao/kbra/docs/other/Klamath%20Dam%20Removal%20Biological%20Analysis_FINAL.pdf.

Stillwater Sciences. 2009b. Dam removal and Klamath River water quality: A synthesis of the current conceptual understanding and an assessment of data gaps. Technical Report. Prepared by Stillwater Sciences, Arcata, California for State Coastal Conservancy, Oakland, California.

Stillwater Sciences. 2010. Potential responses of coho salmon and steelhead downstream from Iron Gate Dam to No-Action and Dam-Removal alternatives for the Klamath Basin. Prepared by Stillwater Sciences, Arcata, California for Bureau of Reclamation in support of the Biological Subgroup for the Klamath Basin Secretarial Determination. Arcata, California.

Stocking, R. W., R. A. Holt, J. S. Foott, and J. L. Bartholomew. 2006. Spatial and temporal occurrence of the salmonid parasite *Ceratomyxa shasta* (Myxozoa) in the Oregon-California Klamath Basin. Journal of Aquatic Animal Health 18: 194–202.

Stocking, R. W., and J. L. Bartholomew. 2007. Distribution and habitat characteristics of *Manayunkia speciosa* and infection prevalence with the parasite *Ceratomyxa shasta* in the Klamath River, Oregon-California. Journal of Parasitology 93: 78–88.

Strange, J. 2007a. Adult Chinook salmon migration in the Klamath River basin: 2005 Sonic Telemetry Study Final Report. Prepared by Yurok Tribal Fisheries Program, Hoopa, California and University of Washington, School of Aquatic and Fishery Sciences, Seattle, Washington, in collaboration with Hoopa Valley Tribal Fisheries, California.

Strange, J. 2007b. Adult Chinook salmon migration in the Klamath River basin: 2006 Telemetry Study Final Report. Prepared by Yurok Tribal Fisheries Program, Hoopa, California and University of Washington, School of Aquatic and Fishery Sciences, Seattle, Washington.

Strange, J. 2008. Adult Chinook salmon migration in the Klamath Basin, 2007 Biotelemetry monitoring study final report. Yurok Tribal Fisheries Program, Klamath, California and University of Washington, School of Aquatic and Fishery Science, Seattle, Washington, in collaboration with Hoopa Valley Tribal Fisheries, Hoopa, California.

Strange, J. 2010. Summary of Scientific Evidence to Guide Special Flow Releases to Reduce the Risk of Adult Fall Chinook Salmon Mass Disease Mortality in the Lower Klamath River. Yurok Tribal Fisheries Program Technical Report.

Stutzer, G. M., J. Ogawa, N. J. Hetrick, and T. Shaw. 2006. An initial assessment of radio telemetry for estimating juvenile coho salmon survival, migration behavior, and habitat use in response to Iron Gate Dam discharge on the Klamath River, California. Arcata Fisheries Technical Report Number TR2006-05. U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office, California.

Sullivan, A. B., M. L. Deas, J. Asbill, J. D. Kirshtein, K. Butler, and J. Vaughn. 2009. Klamath River water quality data from Link River Dam to Keno Dam, Oregon, 2008. Open-File Report 2009-1105. U.S. Geological Survey.

Sullivan, C. M. 1989. Juvenile life history and age composition of mature fall Chinook salmon returning to the Klamath River, 1984-1986. Master's thesis. Humboldt State University, Arcata, California.

Sweeting, R. M., R. J. Beamish, D. J. Noakes, and C. M. Neville. 2003. Replacement of wild coho salmon by hatchery-reared coho salmon in the Strait of Georgia over the past three decades. Transactions of the American Fisheries Society 23: 492–502.

Sykes, G. E., C. J. Johnson, and J. M. Shrimpton. 2009. Temperature and flow effects on migration timing of Chinook salmon smolts. Transactions of the American Fisheries Society 138: 1,252–1,265.

Thompson, T. Q., R. M. Bellinger, S. M. O'Rourke, D. J. Prince, A. E. Stevenson, A. T. Rodrigues, M. R. Sloat, C. F. Speller, D. Y. Yang, V. L. Butler, M. A. Banks, and M. R. Miller. 2018. Anthropogenic habitat alteration leads to rapid loss of adaptive variation and restoration potential in wild salmon populations. bioRxiv 310714: doi https://doi.org/10.1101/310714.

Thorp, J. H., and A. P. Covich, editors. 2001. Ecology and classification of North American freshwater invertebrates. Second edition. Academic Press.

Trihey and Associates. 1996. Instream flow requirements for tribal trust species in the Klamath River. Concord, California.

True K., J. S. Foott, A. Bolick, S. Benson, and R. Fogerty. 2010. Myxosporean parasite (*Ceratomyxa shasta* and *Parvicapsula minibicornis*) incidence and severity in Klamath Basin juvenile Chinook salmon, April-August 2009. FY 2009 Investigational Report. U.S. Fish and Wildlife Service, California–Nevada Fish Health Center, Anderson, California.

True K., A. Bolick, and J. S. Foott. 2013. Myxosporean Parasite (Ceeratomyxa Shasta and Parvicapsula minibicornis) Prevalence of Infection in Klamath River Basin Juvenile Chinook Salmon, April-August 2012. FY 2012 Investigational Report. U.S. Fish and Wildlife Service, California–Nevada Fish Health Center, Anderson, California.

Tsui, P. T. P., and P. J. McCart. 1981. Effects of stream crossing by a pipeline on the benthic macroinvertebrate communities of a small mountain stream. Hydrobiologia, 79: 271–276.

Tullos, D. D., D. S. Finn, and C. Walter. 2014. Geomorphic and ecological disturbance and recovery from two small dams and their removal. PLoS One 9: e108091, doi:10.1371/journal.pone.0108091.

USBR (Unites States Bureau of Reclamation). 2002. Final biological assessment: the effects of Proposed Projects related to Klamath Project Operation (April 1, 2002–March 31, 2012) on federally listed and endangered species. Bureau of Reclamation, Mid-Pacific Region, Klamath Basin Area Office, Oregon.

USBR. 2005. Natural Flow of the Upper Klamath River – Phase I. November 2005.

USBR. 2010. Biological opinion: operation of the Klamath Project between 2010 and 2018. Prepared by National Marine Fisheries Service, Southwest Region for Bureau of Reclamation, Mid-Pacific Region, Klamath Basin Area Office, Oregon.

USBR. 2011. Klamath Project. Website. https://www.usbr.gov/projects/index.php?id=470 [Accessed 11 September 2017].

USBR. 2012. Hydrology, Hydraulics and Sediment Transport Studies for the Secretary's Determination on Klamath River Dam Removal and Basin Restoration, Technical Report No. SRH-2011-02. Prepared for Mid-Pacific Region, Bureau of Reclamation, Technical Service Center, Denver, CO. Report dated April 2011, updated January 2012. Available at: http://klamathrestoration.gov/keep-me-informed/secretarial-determination/role-of-science/secretarial-determination-studies

USBR. 2016. Klamath Facilities Removal Environmental Impact Statement/Environmental Impact Report Supplemental Information Report. State Clearinghouse #2010062060.

USDA Forest Service. 2016. Western Pearlshell Mussel (Margaritifera falcata) Upper Truckee River Forest Service Relocation Efforts To Date July 2016. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd515735.pdf

U.S. District Court. 2017a. Hoopa Valley Tribe v. National Marine Fisheries Service et al. Order RE motions for summary judgement, motions to strike, and motion to dismiss. Case No. 16-cv-04294-WHO. U.S. District Court, Northern District of California.

U.S. District Court. 2017b. Hoopa Valley Tribe v. U.S. Bureau of Reclamation et al. and Klamath Water Users Association et al. Stipulated request to extend federal defendants' responsive pleading deadline and the case management conference deadline. Case No. 3:16-cv-04294-WHO. U.S. District Court, Northern District of California, San Francisco Division.

U.S. District Court. 2017c. Hoopa Valley Tribe v. U.S. Bureau of Reclamation et al. and Klamath Water Users Association et al. Order modifying February 8, 2017 injunction. Case No. 3:16-cv-04294-WHO. U.S. District Court, Northern District of California, San Francisco Division.

USEPA (U.S. Environmental Protection Agency). 1986. Ambient water quality criteria for dissolved oxygen. EPA 440/5-86-003. Office of Water Regulations and Standards, Washington, D.C.

USEPA. 2002. Guidelines for Reviewing TMDLs under Existing Regulations issued in 1992. Prepared by USEPA.

USEPA. 2003. EPA Region 10 guidance for Pacific Northwest State and tribal temperature and water quality standards. EPA 910-B-03-002. Region 10 Office of Water, Seattle, Washington.

USEPA. 2008. Lost River, California total maximum daily loads; nitrogen and biochemical oxygen demand to address dissolved oxygen and pH impairments. Final Report. U.S. Environmental Protection Agency, Region IX.

USFWS (U.S. Fish and Wildlife Service). 1988. Endangered and threatened wildlife and plants: Determination of endangered status for the shortnose sucker and Lost River sucker. Federal Register 53: 27,130–27,134.

USFWS. 1993. Shortnose sucker *(Chasinistes brevirostris*) and Lost River (*Deltistes luxatus*) Sucker Recovery Plan. Portland, Oregon.

USFWS. 1998. Klamath River (Iron Gate Dam to Seiad Creek) life state periodicities for Chinook, coho, and steelhead. Prepared by USFWS, Coastal California Fish and Wildlife Office, Arcata.

USFWS. 2000. Endangered and threatened wildlife and plants; 12-month finding for a petition to list the Great Basin redband trout as threatened or endangered. Federal Register 65: 14,932–14,936.

USFWS. 2001. Juvenile salmonid monitoring on the mainstem Klamath River at Big Bar and mainstem Trinity River at Willow Creek, 1997–2000. Annual report of the Klamath River Fisheries Assessment Program. Arcata Fish and Wildlife Office, Arcata, California.

USFWS. 2003. Klamath River fish die-off, September 2002: Report on estimate of mortality. Report No. AFWO-01-03. Arcata Fish and Wildlife Office, Arcata, California.

USFWS. 2004. Endangered and threatened wildlife and plants: 90-day finding on a petition to list three species of lampreys as threatened or endangered. Federal Register 69: 77,158–77,167.

USFWS. 2007. Shortnose sucker (*Chasmistes brevirostris*) 5-year review summary and evaluation. Klamath Falls Fish and Wildlife Office, Klamath Falls, Oregon.

USFWS. 2008. Biological/conference opinion regarding the effects of the Bureau of Reclamation's proposed 10-year Operation Plan (April 1, 2008–March 31, 2018) for the Klamath Project and its effects on the endangered Lost River and shortnose suckers. USFWS, Klamath Falls Fish and Wildlife Office, Klamath Falls, Oregon, and Yreka Fish and Wildlife Office, Yreka, California.

USFWS. 2009. Endangered and threatened wildlife and plants; 12-month finding on a petition to list the San Francisco Bay-Delta population of the longfin smelt (*Spirinchus thaleichthys*) as Endangered. Federal Register 74: 16,169–16,175.

USFWS. 2011. Mark-recapture trapping efficiency summary for coho captured in the McGarvey Creek frame net/pipe trap from 1999–2008. Unpublished data acquired from D. Gale, Fish and Wildlife Biologist, U.S. Fish and Wildlife Service. January 3, 2011.

USFWS. 2012. Endangered and threatened wildlife and plants; designation of critical habitat for Lost River sucker and shortnose sucker; final rule. Federal Register 77: 73,740–73,768.

USFWS. 2013a. Revised Recovery Plan for the Lost River sucker and Shortnose sucker. Pacific Southwest Region. Sacramento, California

USFWS. 2013b. Lost River Sucker (*Deltistes luxatus*) 5-Year Review: Summary and Evaluation USFWS U.S. Fish and Wildlife Service Klamath Falls Fish and Wildlife Office Klamath Falls, Oregon August 2013.

USFWS. 2013c. Shortnose Sucker (*Chasmistes brevirostris*) 5-Year Review: Summary and Evaluation USFWS U.S. Fish and Wildlife Service Klamath Falls Fish and Wildlife Office Klamath Falls, Oregon August 2013

USGS (U.S. Geological Survey). 2010. Water-quality monitoring in the Keno Reach of the Klamath River. Available at: http://or.water.usgs.gov/proj/keno_reach/monitors.html.

VanderKooi, S. P., S. M. Burdick, K. R. Echols, C. A. Ottinger, B. H. Rosen, and T. M. Wood. 2010. Algal toxins in upper Klamath Lake, Oregon: Linking water quality to juvenile sucker health. Fact Sheet 2009-3111. U.S. Geological Survey, Western Fisheries Research Center, Seattle, Washington. Available at: http://pubs.usgs.gov/fs/2009/3111/pdf/fs20093111.pdf.

Van Eenennaam, J. P., J. Linares-Casenave, S. I. Doroshov, D. C. Hillemeier, T. E. Willson, and A. A. Nova. 2006. Reproductive conditions of the Klamath River green sturgeon. Transactions of the American Fisheries Society 135: 151–163.

Vannote, R. L., and G. W. Minshall. 1982. Fluvial processes and local lithology controlling abundance, structure, and composition of mussel beds. Proceedings of the National Academy of Sciences of the United States of America 79: 4,103–4,107.

Vuori, K. M., and I. Joensuu. 1996. Impact of forest drainage on the macroinvertebrates of a small boreal headwater stream: do buffer strips protect lotic biodiversity? Biological Conservation 77: 87–95.

Wales, J. and M. Coots. 1950. Second report on the effect of the Klamath River Water Fluctuations upon salmonid fishes. Memo from the California Department of Fish and Game District Fisheries Biologist to the Bureau of Fish Conservation: 6p.

Wallace, M. 1998. Seasonal water quality monitoring in the Klamath River Estuary, 1991–1994. Administrative Report No. 98−9. California Department of Fish and Game, Inland Fisheries Division, Arcata.

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

Ward, E. J., E. E. Holmes, and K. C. Balcomb. 2009. Quantifying the effects of prey abundance on killer whale reproduction. Journal of Applied Ecology, 46: 632–640.

Weinheimer, J., J. Anderson, R. Cooper, S. Williams, M. McHenry, P. Crain, S. Brenkman, and H. Hugunin. 2018. Age structure and hatchery fraction of Elwha River Chinook salmon: 2017 carcass survey report. Prepared by Washington Department of Fish and Wildlife, Olympia, Washington.

West, J. R., O. J. Dix, A. D. Olson, M. V. Anderson, S. A. Fox, and J. H. Power. 1990. Evaluation of fish habitat conditions and utilization in Salmon, Scott, Shasta, and Mid-Klamath sub-basin tributaries. Annual report for interagency agreement 14-16-0001-89508. Prepared by USDA Forest Service, Klamath National Forest, Yreka, California and Shasta Trinity National Forest, Weaverville, California.

Westover, M. 2010. Freshwater mussel distribution, abundance and habitat use in the middle Klamath River. Bachelor of Science thesis submitted to Biology Department, Whitman College.

White, J. L., and B. C. Harvey. 1999. Habitat separation of prickly sculpin, *Cottus asper*, and the coastrange sculpin, *Cottus aleuticus*, in the mainstream Smith River, northwestern California. Copeia 2: 371–375.

Williams, J. E., D. B. Bowman, J. E. Brooks, A. A. Echelle, R. J. Edwards, D. A. Hendrickson, and J. J. Landye. 1985. Endangered aquatic ecosystems in North American deserts with a list of vanishing fishes of the region. Journal of the Arizona-Nevada Academy of Science 20: 1–62.

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

Williams, T. H., J. C. Garza, N. Hetrick, S. T. Lindley, M. S. Mohr, J. M. Myers, M. R. O'Farrell, R. M. Quinones, and D. J. Teel. 2011. Upper Klamath and Trinity River Chinook salmon Biological Review Team report. National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, California.

Williamson, K., and D. Hillemeier. 2001. An assessment of pinniped predation upon fall-run Chinook salmon in the Klamath River Estuary, CA, 1998. Prepared by Yurok Tribal Fisheries Program, Klamath, California.

Willson, M. F., R. H. Armstrong, M. C. Hermans, and K. Koski. 2006. Eulachon: a review of biology and an annotated bibliography. AFSC Processed Report 2006-12. National Marine Fisheries Service, Alaska Fisheries Science Center, Juneau, Alaska.

Withler, F. C. 1982. Transplanting Pacific salmon. Canadian Technical Report of Fisheries and Aquatic Sciences 1079.

Wood. A. Assembly Bill No. 2640: An act to amend Section 5515 of, and to add Sections 2081.11 and 3858 to, the Fish and Game Code, relating to fish and wildlife. Approved by Governor September 20, 2018. Filed with Secretary of State September 20, 2018.

Wood, T. M., G. R. Hoilman, and M. K. Lindenberg. 2006. Water-quality conditions in Upper Klamath Lake, Oregon, 2002–04. Scientific Investigations Report 2006-5209. U.S. Geological Survey.

WQST (Water Quality Sub Team). 2011. Assessment of long-term water quality changes for the Klamath River basin resulting from KHSA, KBRA, and TMDL and NPS reduction programs. Final report. Prepared by the Water Quality Sub Team for the Secretarial Determination regarding potential removal of the lower four dams on the Klamath River.

Zaroban, D., M. Mulvey, T. Maret, R. Hughes, and G. Merritt. 1999. Classification of species attributes for Pacific Northwest freshwater fishes. Northwest Science 73: 81–93.

Zimmerman, G. F., A. Kelly, P. T. Mathias, R. Anderson, J. Allison, E. Chapman, J. Kagel, R. Schwegman, and the Hunter Station Bridge Replacement Mussel Salvage Team. 2017. PENNDOT Hunter Station Bridge Replacement: the story of the largest endangered species relocation project in the world; a tale of teamwork, a tale of conservation and recovery. Freshwater Mollusk Conservation Society Symposium presentations. http://molluskconservation.org/EVENTS/2017Symposium/2017_FMCS-Symposium.html.