Appendix 12
Aquatic Biological Resources

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APPENDIX 12A
Aquatic Species Life Histories

12A.1 Description of Aquatic Species of Primary Management Concern within the Extended, Secondary, and Primary Study Areas

This appendix provides additional information on the life history characteristics of the target aquatic species assessed in the Sites Reservoir Project (Project) Environmental Impact Report/Statement (EIR/EIS). This information is intended to provide a more holistic understanding of how these species use the water bodies influenced by changes in operation of the Central Valley Project (CVP) and State Water Project (SWP)UC attributable to the Project and to help clarify relationships that provide the logical foundation for conclusions regarding the potential environmental consequences associated with Project implementation. This appendix addresses the following species:

- Chinook Salmon
  - Central Valley Winter-run Chinook Salmon
  - Central Valley Spring-run Chinook Salmon
  - Central Valley Fall-run and Late Fall-run Chinook Salmon
  - Upper Klamath and Trinity Rivers Spring-run Chinook Salmon
- Steelhead
  - Central Valley Steelhead
  - Klamath Mountains Province Steelhead
- Coho Salmon
- Green Sturgeon
- Delta Smelt
- Longfin Smelt
- Pacific Lamprey
- River Lamprey
- Sacramento Splittail
- Hardhead
- Eulachon
- Southern Resident Killer Whale
- White Sturgeon
- Striped Bass
- American Shad
- Black Bass

12A.1.1 Chinook Salmon (*Oncorhynchus tshawytscha*)

Chinook salmon are anadromous (they spend much of their lives in the ocean and return to fresh water as adults to spawn). There are four runs of Chinook salmon found in the Primary, Secondary, and Extended study areas: winter-run, spring-run, fall-run, and late-fall-run.

All four runs are found in the Sacramento River watershed. Only fall-run and spring-run are found in the Trinity River watershed. The Feather River downstream of the Fish Barrier Dam supports spring- and fall-run. The American River downstream of Nimbus Dam and the San Joaquin River system support fall-run. Winter-run and spring-run are the two runs protected pursuant to the federal Endangered Species Act (FESA) and the California Endangered Species Act (CESA). Life history characteristics that differentiate the salmon runs include the time of year that adults return to fresh water to spawn, and state of sexual maturity upon arrival to the streams where they were born (natal streams). Table 12A-1 shows the timing of spawning and the early life stages of Sacramento River Chinook salmon upstream of Hamilton City.

The major factors that limit the range and abundance of Chinook salmon are flow, water temperature, barriers to upstream migration, habitat quality, entrainment in water diversions, and ocean conditions. Climate change and its impact on water temperature, hydrology, and ocean conditions will have potentially substantial effects on Chinook salmon populations in the future.

Chinook salmon exhibit two generalized freshwater life history types (Healey, 1991). “Stream-type” Chinook salmon enter fresh water months before spawning and reside in fresh water for one year or more following emergence, whereas “ocean-type” Chinook salmon spawn soon after entering fresh water and migrate to the ocean within their first year. Table 12A-2 summarizes monitoring data for juvenile Chinook salmon and shows the migration timing for the runs of Chinook salmon at points along the river. The majority of juvenile Chinook salmon migrate downstream in the Sacramento River when flow and turbidity are high.

12A.1.1.1 Central Valley Winter-run Chinook Salmon

Status

The California-Nevada chapter of the American Fisheries Society petitioned the National Marine Fisheries Service (NMFS) to list the run as a threatened species in 1985 (AFS, 1985) and, following a dangerously low year-class in 1989, NMFS issued an emergency listing for Sacramento River winter-run Chinook Salmon as a threatened species (Federal Register, 1989); the California Fish and Game Commission listed the winter run as endangered in the same year. After several years of low escapements in the early 1990s, the status of winter-run was changed from threatened to endangered by NMFS in 1994, which was reaffirmed in 2005 and 2011 (Federal Register, 1994a, 2005b; NMFS, 2011).

Critical habitat was designated for winter-run Chinook salmon on June 16, 1993 (Federal Register, 1993a) and includes the Sacramento River from Keswick Dam downstream to Chipps Island at the westward margin of the Delta; all waters from Chipps Island westward to the Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and the Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge; and all waters of San Francisco Bay (north of the San Francisco-Oakland Bay Bridge) to the Golden Gate Bridge (Figure 12A-1). Critical habitat includes the river water, river bottom, and the adjacent riparian zone.

Table 12A-1
Life Stage Occurrence of Chinook Salmon and Steelhead in the Sacramento River

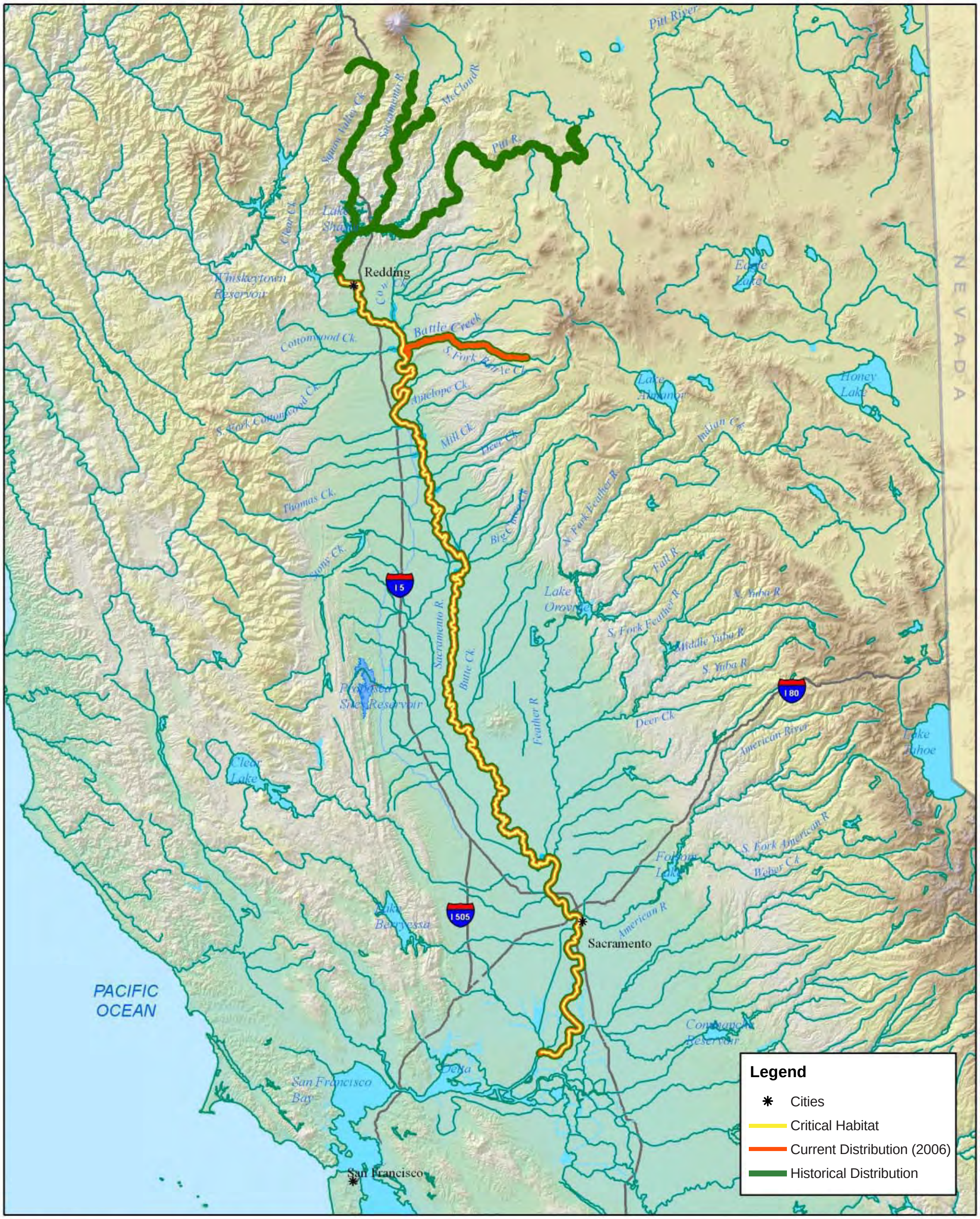
Life Stage	Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Adult Migration	Winter-run Chinook				X								
	Spring-run Chinook												
	Fall-run Chinook										X		
	Late-Fall-run Chinook											X	
	Steelhead										X		
Spawning	Winter-run Chinook						X						
	Spring-run Chinook									X			
	Fall-run Chinook											X	
	Late-Fall-run Chinook		X										
	Steelhead			X									
Egg Incubation	Winter-run Chinook												
	Spring-run Chinook												
	Fall-run Chinook												
	Late-Fall-run Chinook												
	Steelhead												
Juvenile Rearing & Migration	Winter-run Chinook												
	Spring-run Chinook												
	Fall-run Chinook												
	Late-Fall-run Chinook												
	Steelhead												

Note:
Shading indicates the duration/timing of migration, spawning, and egg incubation, while 'x' indicates the peak timing.
Source: Hallock, 1989, Vogel and Marine, 1991

Table 12A-2
Juvenile Chinook Salmon Migration Timing at Monitoring Stations on the Sacramento River

Species	Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Winter-run	RBDD								X	XX	XX	X	
	GCID									X	XX	X	
Spring-run	RBDD			XX	XX								XX
	GCID				XX								
	Knights Landing	X		XX	X								X
Fall-run	RBDD	X	XX	X	X								X
	GCID		X	X	XX	XX	XX						
	Knights Landing	XX	XX	X									
Late-Fall-run	RBDD				XX	X			X	X		X	
	Average lengths (mm)												
	GCID										XX	XX	
	Knights Landing				XX		XX						XX
	Average lengths (mm)												

Notes:
XX = High Abundance
X = Moderate Abundance
= Low Abundance
GCID = Glenn-Colusa Irrigation District
mm = millimeter
RBDD = Red Bluff Diversion Dam
Source: CDFG, 2005; USFWS, 2002; CDFG, 2000a



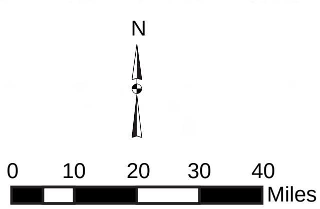


FIGURE 12A-1
Current and Historical Distribution of Winter-run Chinook Salmon in the Central Valley Drainages including Critical Habitat Designation
Sites Reservoir Project EIR/EIS

Dam construction has greatly diminished the range of winter-run Chinook salmon. Historically, winter-run used winter high flows during their migration to access the headwaters of the Sacramento River, such as the upper Sacramento, McCloud, Pit, and Fall rivers (Figure 12A-1). The upper reaches of Battle Creek also may have supported winter-run before the development of hydroelectric dams. Winter-run Chinook salmon may have also ascended into the upper reaches of the Feather and American rivers (Yoshiyama et al., 2001). Since the construction of Shasta Dam, winter-run Chinook salmon have been confined to the mainstem Sacramento River and Battle Creek (Figure 12A-1).

In contemporary records, there have been fewer winter-run Chinook salmon than either spring-run or fall-run. The number of returning adult winter-run Chinook salmon in the Sacramento River has decreased since 1969 (NMFS, 2009a). Winter-run Chinook salmon adult returns have declined from approximately 120,000 in the mid- to late-1960s to a few hundred in the early 1990s. Beginning in the mid-1990s and continuing through 2006, adult escapement showed a trend of increasing abundance, approaching 20,000 fish in 2005 and 2006. However, recent population estimates of winter-run Chinook Salmon spawning upstream of the RBDD have declined since the 2006 peak. The escapement estimate for 2007 through 2014 has ranged from a low of 738 adults in 2011 to a high of 5,959 adults in 2013. The escapement estimate of 738 adults in 2011 was the lowest total escapement estimate since the all-time low escapement estimate of 144 adults in 1994 (California Department of Fish and Wildlife [CDFW], 2014).

Factors that likely led to past increases in abundance include improved freshwater and marine habitat, changes in hatchery production, restricted commercial harvest, improvements to Shasta Dam operations, decreases in the length of time that the RBDD gates were in, and changes to operations at the CVP and SWP Delta pumping plants (NMFS, 2009a). Poor ocean productivity (Lindley et al., 2009), drought conditions from 2007 to 2009, and low in-river survival (NMFS, 2011) are suspected to have contributed to the recent decline in escapement of adult winter-run Chinook Salmon.

General Biology and Life History

Adult Migration and Holding

Historically, adequate stream flows were necessary to allow adult passage to holding habitat in the upper reaches of spawning streams and rivers, and high flows likely continue to be an important queue for adults holding in the San Francisco bay to begin migration. The preferred temperature range for upstream migration is 38 degrees Fahrenheit (ºF) to 56ºF (CDFG, 1998), but water temperatures between 57ºF and 67ºF are suitable (NMFS, 1997).

Adult winter-run Chinook salmon enter San Francisco Bay from November through June (Hallock and Fisher, 1985) and migrate past RBDD from mid-December through early August (NMFS, 1997). The majority of the run passes RBDD from January through May, and peaks in mid-March (Hallock and Fisher, 1985). The timing of migration may vary somewhat because of changes in river flows from dam operation and runoff. In recent years, upstream passage of winter-run adults at RBDD was addressed by raising the gates between September 15 and May 15, which encompasses the vast majority of the upstream migration period for winter-run Chinook Salmon. As of 2012, the gates at RBDD are open year-round to allow for upstream passage.

Adults hold in deep cold pools until they are sexually mature and ready to spawn in spring or summer. This trait distinguishes winter-run salmon from the other Central Valley runs. Winter-run hold in the Sacramento River mostly between Bend Bridge and Keswick Dam (NMFS, 1997) where the river is confined between natural bluffs and volcanic formations, and the pools are between 20 and 60 feet deep.

Adult winter-run Chinook Salmon require large, deep pools with flowing water for summer holding, tending to hold in pools with depths greater than 4.9 feet (greater than 1.5 m) that contain cover from undercut banks, overhanging vegetation, boulders, or woody debris (Lindsay et al., 1986), and have water velocities ranging from 0.5 to 1.2 feet/s (15 to 37 centimeters per second [cm/s]) (Marcotte, 1984).

In general, adult Chinook Salmon appear capable of migrating upstream under a wide range of temperatures. In holding areas, water temperatures between 55ºF and 56ºF are ideal for gamete (male and female sexual reproductive cells) development and egg viability. Suitability for holding adults begins to decline when water temperatures are higher than 60ºF (NMFS, 1997; California Department of Water Resources [DWR], 1988). Temperatures higher than 69.8ºF begin to cause mortality (McCullough, 1999) and are lethal when greater than 80.6°F (Moyle et al., 1995). During the period that adults are holding, late spring and summer water temperatures are dependent on the volume of coldwater storage and releases to the Sacramento River.

Spawning and Egg Incubation

The onset of spawning begins in late April, peaks in May and June, and usually subsides by mid-August (NMFS, 1997). When compared to the other runs of Chinook salmon, winter-run Chinook salmon may select deeper spawning sites over seemingly equally suitable shallow sites. Winter-run Chinook salmon have been observed spawning at depths in excess of 21 feet in Lake Redding (NMFS, 1997). Most winter-run Chinook salmon spawn in the Redding area of the Sacramento River (CDFG, 2007). With the changes in RBDD gate operations, volitional spawning below RBDD is negligible in most years. Since fish passage improvements were completed at the ACID Dam in 2001, winter-run Chinook Salmon spawning has shifted upstream. The majority of winter-run Chinook Salmon in recent years (i.e., more than 50 percent since 2007) spawn in the area from Keswick Dam to the ACID Dam (approximately 5 miles) (NMFS, 2009a).

Chinook salmon spawn in gravel bedded areas in rivers and creeks with moderate flow and depths typically greater than 9.5 inches (Allen and Hassler, 1986). Upon finding a suitable site, the female excavates the nest (known as a redd), deposits her eggs, and pushes gravel over them once they have been fertilized by the male. Gravels free of excessive fine sediment (less than 5 percent sand, silt, and clay) that allow movement of water through the egg pockets are important for egg development and survival., Water circulation through the egg pocket delivers oxygen and removes metabolic waste (Platts et al., 1979; Reiser and Bjornn, 1979). It is also important that excess sediment does not block the emergence of fry from the gravel (Allen and Hassler, 1986). After spawning, Chinook salmon die, often within a few days.

Dams reduce the suitability of spawning habitat by capturing sediment and reducing high flow events. The capture of sediment behind dams causes the streambed in spawning areas to coarsen and Chinook salmon are unable to excavate redds in the large cobble that remains. The loss of regular high flows, which scour the streambed, causes fine sediment to clog the spaces between cobbles. The cobbles and fine sediment that comprise the bed eventually become locked together and difficult or impossible to excavate by spawning Chinook salmon.

Eggs develop in the gravel in approximately 40 to 60 days, where they remain for another four to six weeks until the yolk sac is completely absorbed. The rate of development increases with increasing water temperature (NMFS, 1997). Appropriate temperatures for incubation are between 42ºF and 56ºF; 52ºF is ideal (DWR, 1988). At 57.5ºF, significant mortality begins to occur, and total mortality results at 62ºF

(DWR, 1988; NMFS, 1997). Following absorption of the yolk sac, fry begin to emerge from the gravel (Allen and Hassler, 1986). Emergence occurs from mid-June through mid-October. Post-emergent fry inhabit calm shallow waters with fine substrates and depend on fallen trees, undercut banks, and overhanging riparian vegetation for refuge (Healey, 1991). During the post-emergent fry (≤ 45mm fork length) and juvenile stages, water temperatures generally between 53ºF and 57ºF are beneficial (NMFS, 1997; DWR, 1988). A water temperature of 60ºF is considered the upper temperature limit for juvenile Chinook growth and rearing (NMFS, 1997).

Juvenile Rearing and Migration

Winter-run fry emerge from the spawning gravels from mid-June through mid-October (NMFS, 1997). Because spawning is concentrated upstream in the reaches below Keswick Dam, the entire Sacramento River can serve as a nursery area for juveniles as they migrate downstream. Emigrating juvenile Sacramento River winter-run Chinook Salmon pass the RBDD beginning as early as mid-July, typically peaking in September, and can continue through March in dry years (Reclamation, 1991; NMFS, 1997). Many juveniles apparently rear in the Sacramento River below RBDD for several months before they reach the Delta (Williams, 2006). From 1995 to 1999, all Sacramento River winter-run Chinook Salmon outmigrating as fry passed the RBDD by October, and all outmigrating presmolts and smolts passed the RBDD by March (Martin et al., 2001).

Riparian zones on the Sacramento River are considered essential for the conservation of winter-run Chinook salmon because they provide important areas for fry and juvenile rearing. For example, studies of Chinook salmon smolts in the middle reaches of the Sacramento River found higher densities in natural eroding bank habitats with woody debris than other habitat types (U.S. Fish and Wildlife Service [USFWS], 2000). Dams have impacted juvenile Chinook salmon habitat. Dams block the recruitment of woody debris, and management of releases for irrigation and flood management can disrupt the hydraulic and geomorphic processes necessary to establish riparian forest (SRCAF, 2003).

Optimal rearing habitat includes abundant instream cover, such as undercut banks, submerged and emergent vegetation, logs, roots, and dense riparian vegetation. These features provide cover from predators and an abundant supply of invertebrate and larval fish prey. Before becoming independent swimmers, fry also depend on calm shallow areas among these features to avoid getting swept downstream (CDFG, 1998). Ephemeral habitats, such as floodplains and the lower reaches of small streams, are also very important to rearing Chinook salmon (Maslin et al., 1997; Sommer et al., 2001a). These areas can be much more productive than the main channel and provide a safe haven from predatory fish (examples are the Cosumnes River Floodplain [Swenson et al., 2001] and the Yolo Bypass [Sommer et al., 2001a]). It remains unclear whether these differences in feeding and growth translate into improved survival., The use of side channels and low gradient floodplains also subjects juveniles to stranding when high flows subside quickly (NMFS, 1997). In the intertidal zone, mudflats and tule marshes become important habitat for juveniles during high tides. In the Suisun Marsh, Chinook salmon fry tend to remain close to the banks and vegetation, near protective cover, and in dead-end tidal channels (Moyle et al., 1986).

Delta and Estuarine Rearing

Juvenile winter-run Chinook salmon occur in the Sacramento-San Joaquin Delta from primarily November through early May based on data collected from trawls in the Sacramento River at West Sacramento, although the overall timing may extend from September to early May (NMFS, 2011). The timing of migration varies somewhat because of changes in river flows, dam operations, seasonal water temperatures, and hydrologic conditions (water year type). Winter-run Chinook Salmon juveniles remain in the Delta until they are between 5 and 10 months of age, after reaching a fork length of approximately 118 mm. Distinct emigration pulses from the Delta appear to coincide with periods of high precipitation and increased turbidity (Del Rosario et al., 2013).

The entire population of the Sacramento River winter-run Chinook Salmon passes through the Delta as migrating adults and emigrating juveniles. Because winter-run Chinook Salmon use only the Sacramento River system for spawning, adults are likely to migrate upstream primarily along the western edge of the Delta through the Sacramento River corridor. Juveniles likely use a wider area within the Delta for migration and rearing than adults; juvenile winter-run salmon have been collected at various locations in the Delta, including the SWP and CVP south Delta export facilities. Studies using acoustically tagged juvenile and adult Chinook Salmon are ongoing to further investigate the migration routes, migration rates, reach-specific mortality rates, and the effects of hydrologic conditions (including the effects of SWP/CVP export operations) on salmon migration through the Delta. Tagging studies have indicated that juvenile salmon entering the interior Delta via the Delta Cross Channel and Georgiana Slough survive at a lower rate than fish migrating within the Sacramento River (Newman and Brandes, 2010; Perry et al., 2010, 2012). Juvenile winter-run Chinook Salmon likely inhabit Suisun Marsh for rearing and may inhabit the Yolo Bypass when flooded, although use of these two areas is not well understood.

There is little information regarding the residence of the juvenile winter-run Chinook salmon in the estuary downstream of the Delta. Juveniles usually spend approximately 40 days migrating through the estuary to marine waters, and demonstrate little or no real estuarine dependence in their growth and development (MacFarlane and Norton, 2002).

Nearshore and Marine Residence

Winter-run Chinook salmon begin entering the ocean from January through June. Before entering the ocean and estuary, juveniles undergo a physiological change known as smoltification that allows them to thrive in the ocean’s saltwater environment. Winter-run Chinook salmon mature primarily at age three (67 percent) and two (25 percent). The remaining eight percent are four+ year olds (NMFS, 1997; Fisher, 1994).

Information on winter-run Chinook ocean distribution is scarce. The data are derived from commercial fisheries, and are biased in favor of locations where fisheries activities occur. Returns from marked winter-run Chinook salmon indicate that most winter-run salmon caught in the ocean are landed between Monterey and Fort Bragg. Mixed results make it difficult to tell if any winter-run Chinook salmon were landed north of Fort Bragg (Hallock and Fisher, 1985). Regardless, it is believed that winter-run Chinook salmon, similar to all Central Valley Chinook salmon, remain localized primarily in California coastal waters. The timing of the onset of ocean upwelling is critical for juvenile salmon that migrate to the ocean in the spring. Juveniles can grow rapidly, and survival is good if upwelling is well-developed when they reach the ocean. If upwelling is not well-developed or is delayed, growth and survival can be poor (NMFS, 2009b).

12A.1.1.2 Central Valley Spring-run Chinook Salmon

Status

The Central Valley spring-run Chinook salmon Evolutionarily Significant Unit (ESU) is listed as a threatened species pursuant to both CESA and FESA. The State and federal listing decisions were finalized in February 1999 and September 1999, respectively. The federal listing was reaffirmed in 2005 when critical habitat for Central Valley spring-run Chinook salmon was designated on September 2, 2005 in the Sacramento River Watershed (Federal Register, 2005b). Spring-run Chinook salmon also occur in the Trinity River downstream of Lewiston Dam. Spring-run in the Trinity River are included in the upper Klamath and Trinity Evolutionarily Significant Unit (ESU) and are not listed pursuant to FESA or CESA, but were proposed for listing in 1998.

Designated critical habitat for Central Valley spring-run Chinook Salmon includes stream reaches of the American, Feather, Yuba, and Bear rivers; tributaries of the Sacramento River, including Big Chico, Butte, Deer, Mill, Battle, Antelope, and Clear creeks; and the main stem of the Sacramento River from Keswick Dam through the Delta. Designated critical habitat in the Delta includes portions of the Delta Cross Channel, Yolo Bypass, and portions of the network of channels in the northern Delta. Critical habitat for spring-run Chinook Salmon was not designated for the Stanislaus or San Joaquin rivers. A map of spring-run critical habitat is shown in Figure 12A-2. Critical habitat includes the river, river bottom, and the adjacent riparian zone.

Spring-run Chinook salmon populations once occupied the headwaters of all major river systems in the Sacramento-San Joaquin Basin up to any natural barrier (Yoshiyama et al., 2001). Historically, they were widely distributed in streams of the Sacramento-San Joaquin basin, spawning and rearing over extensive areas in the upper and middle reaches (elevations ranging from 1,400 to 5,200 feet [450 to 1,600 m]) of the San Joaquin, American, Yuba, Feather, Sacramento, McCloud, and Pit rivers (NMFS, 1998). Spring Chinook Salmon runs in the San Joaquin River were extirpated in the mid- to late 1940s following the closure of Friant Dam and diversion of water for agricultural purposes to the San Joaquin Valley. Approximately 72 percent (1,066 miles) of available salmon spawning, holding, and rearing habitat have been lost due to the construction of dams, barriers, and the dewatering of streams in the Sacramento-San Joaquin Basin. In general, spring-run Chinook Salmon that are most genetically similar to the runs that occurred historically in the Sacramento basin are currently confined to spawning primarily in Deer, Mill, and Butte creeks, with perhaps a few spawning in the mainstem Sacramento River (Figure 12A-2) (Yoshiyama et al., 2001).

Spring-run were at least the second most abundant run in the Central Valley prior to the 20th century (CDFG, 1998) and may have been the most abundant (NMFS, 1997). The Central Valley river drainages are estimated to have supported spring Chinook salmon runs as large as 600,000 fish in the early 1880s. Spring-run Chinook Salmon have since declined to remnant populations totaling a few thousand fish, sometimes approaching 30,000 to 40,000 in good years (Mills and Fisher, 1994; NMFS, 1999). Populations of spring-run Chinook Salmon in Butte Creek have increased since the 1990s, and Butte Creek currently has the largest naturally spawning spring-run population (CDFW, 2014). A few naturally spawning fish are also present in Battle, Clear, Cottonwood, Antelope, Mill, Deer, and Big Chico creeks (CDFW, 2014).

There have been many restoration efforts focused on spring-run recovery, including gravel augmentation and channel restoration on Clear Creek and improvement of fish passage with the construction or reconstruction of fish ladders and the removal of dams on Mill, Deer, Butte, Battle, and Clear creeks. Regulatory agencies have also negotiated agreements with hydroelectric plant operators and water agencies to increase flows during holding and spawning periods. Restrictions on ocean harvest to protect winter-run Chinook Salmon, as well as improved ocean conditions, have likely had a positive impact on spring-run Chinook Salmon adult returns to the Central Valley.

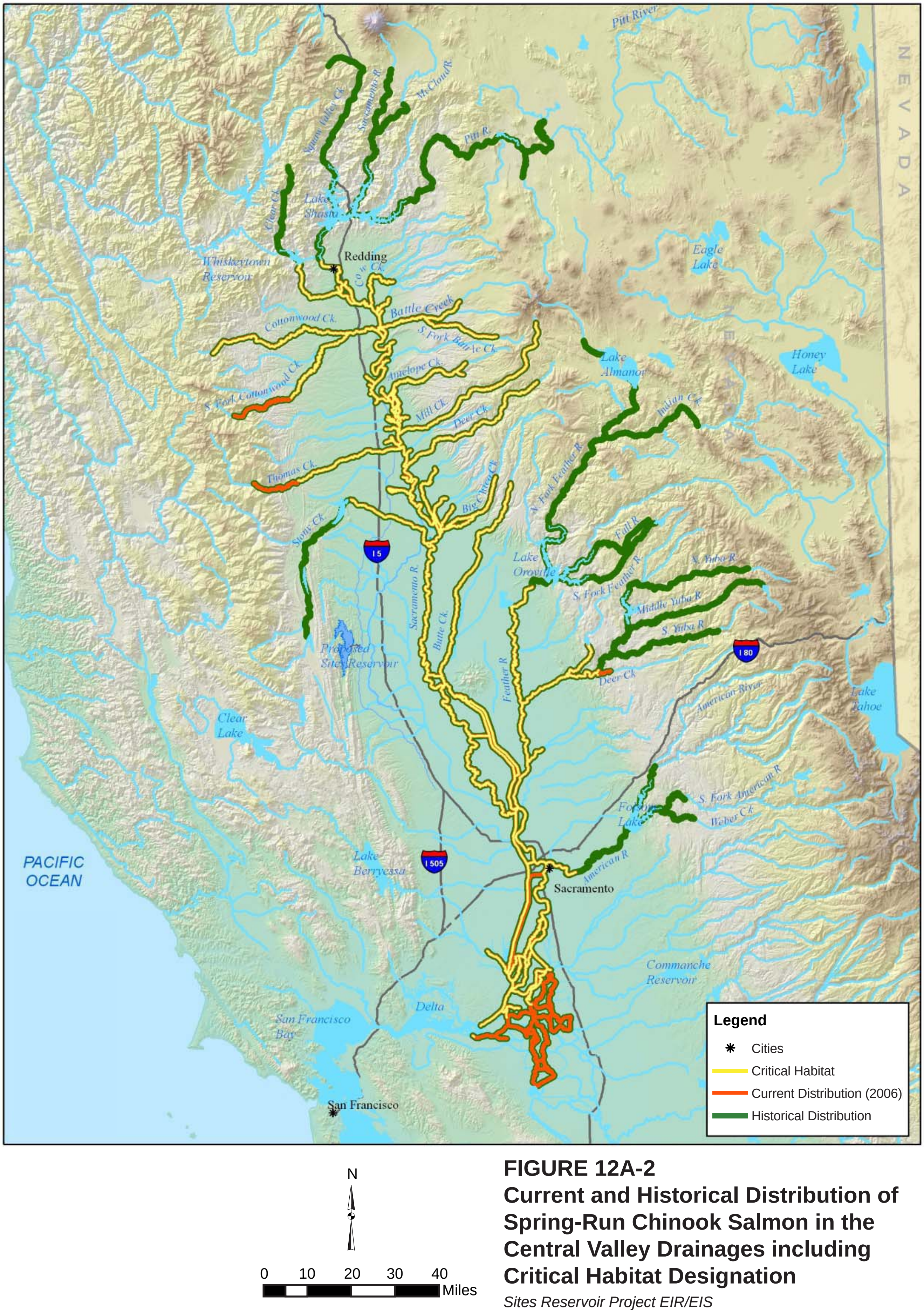


FIGURE 12A-2
Current and Historical Distribution of Spring-Run Chinook Salmon in the Central Valley Drainages including Critical Habitat Designation
Sites Reservoir Project EIR/EIS

General Biology and Life History

Adult spring-run Chinook Salmon may return between the ages of 2 to 5 years. Historically, adults of this run are believed to have returned predominantly at ages 4 and 5 years at a large size. Most spring-run Chinook Salmon now return at age 3, although some portion returns at age 4 (Fisher, 1994, McReynolds et al., 2005) probably because of intense ocean harvest (which removes the largest fish from the population and selects for fish that spend fewer years at sea). In 2003, an estimated 69 percent of the spring run in Butte Creek returned at age 4 (Ward et al., 2004); however, in most years, the proportion of age 4 adults is much smaller.

Adult Migration and Holding

Adult Central Valley spring-run Chinook Salmon begin their upstream migration in late January and early February (CDFG, 1998) and enter the Sacramento River between February and September, primarily in May and June (CDFG, 1998; NMFS, 1998). Lindley et al. (2006) reported that adult Central Valley spring-run Chinook Salmon enter native tributaries from the Sacramento River primarily between mid-April and mid-June. In the Sacramento River, upstream migration of spring-run Chinook Salmon overlaps to a certain extent with that of winter-run Chinook Salmon; and adults from particular runs are not generally distinguishable from one another by physical appearance alone. In the Klamath (Trinity) River drainage, adults migrate up the Klamath River from April through August (Snyder, 1931; Strange, 2008).

Adults require large, deep pools with moderate flows for holding over the summer prior to spawning in the fall. Marcotte (1984) reported that suitability of pools declines at depths less than 7.9 feet (2.4 m) and that optimal water velocities range from 0.5 to 1.2 feet/s (15 to 37 cm/s). In the John Day River in Oregon, spring-run adults usually hold in pools deeper than 4.9 feet (1.5 m) that contain cover from undercut banks, overhanging vegetation, boulders, or woody debris (Lindsay et al., 1986). As a result of cold water releases from Shasta Reservoir and natural channel characteristics, numerous deep pools with suitable holding habitat are located between Keswick Dam and Red Bluff (Northern California Water Association and Sacramento Valley Water Users, 2011). Although there are several deep pools in the upper Sacramento River that may provide holding habitat for adult spring-run Chinook Salmon, it is not clear which pools are heavily used.

Water temperatures for adult spring-run Chinook Salmon holding and spawning are reportedly best when less than 60.8°F (16°C), and are lethal when greater than 80.6°F (27°C) (Boles et al., 1988; CDFG, 1998). Spring Chinook Salmon in the Sacramento River typically hold in pools below 69.8 to 77°F (21 to 25°C). Adults may be particularly sensitive to temperatures during July and August, when energy reserves are low and adults are preparing to spawn.

Spawning and Egg Incubation

The majority of spring-run Chinook Salmon used to spawn upstream in tributaries rather than in the mainstem Sacramento River. Under historical conditions, it is doubtful that spring-run Chinook Salmon spawned in the mainstem Sacramento in significant numbers (Lindley et al., 2004). However, the completion and operation of Shasta Dam reduced water temperatures in the main stem downstream of Keswick Dam, which permitted spring-run Chinook Salmon to spawn there, resulting in hybridization with fall-run stocks. Although spring-run Chinook Salmon spawn earlier than fall-run, the timing of spawning of the two runs overlaps enough that hybridization can occur where they share the same spawning areas. Where the spring run is now forced to share spawning grounds in the mainstem Sacramento River with the fall run, fall-run Chinook Salmon may dominate because of their longer growth period in the ocean, slightly larger size, and less time spent holding in the stream prior to spawning.

Hybridization between the two runs has tended to be to the detriment of the spring run life history. Because of this hybridization with fall-run Chinook Salmon in the mainstem channel, there are considered to be only three “pure” self-sustaining populations of wild spring-run Chinook Salmon remaining in Deer, Mill, and Butte creeks. Similar patterns have been observed in the Feather River, where the spring run historically spawned upstream of the location of Oroville Dam, and where they are now forced to spawn in the same area as the fall run, as well as in the Yuba and American rivers, where forced sympatry on the spawning grounds and subsequent hybridization following dam construction led to CDFW concluding that the spring run was “extinct” in those rivers.

The timing of spring run spawning in the mainstem Sacramento River has shifted later in the year, which is believed to be a result of genetic introgression with the fall run (Association of California Water Agencies and California Urban Water Agencies, 1996). Populations in Deer and Mill creeks, which do not appear to have significantly hybridized with the fall run, generally spawn earlier than those in the main stem (Lindley et al., 2004). Redd counts have indicated that spring-run Chinook Salmon spawning typically begins in late August, peaks in September, and concludes in October in both Deer and Mill creeks (Harvey, 1995; Moyle et al., 1995; Federal Register, 2004a).

In the Feather River, the time of river entry for spring-run Chinook Salmon has apparently shifted to later in the season, and is now intermediate between timing of entry of spring run into other tributaries and timing of entry of the fall run. Coded-wire tag data and anecdotal information from anglers indicate that Feather River fish do not enter fresh water until June or July (Association of California Water Agencies and California Urban Water Agencies, 1997). Overlap of spring- and fall-run spawning habitat is a problem in the Feather River and has likely lead to hybridization between the two runs (CDFG, 1998).

In the Sacramento River and its tributaries, egg incubation for spring-run Chinook Salmon extends from August to March (Fisher, 1994; Ward and McReynolds, 2001). Egg incubation generally lasts between 40 and 90 days at water temperatures of 42.8 to 53.6°F (6 to 12°C) (Vernier, 1969; Bams, 1970; Heming, 1982). At temperatures of 37°F (2.7°C), time to 50 percent hatching can take up to 159 days (Alderdice and Velsen, 1978). Alevins remain in the gravel for 2 to 3 weeks after hatching while absorbing their yolk sacs. Emergence from the gravels occurs from November to March in the Sacramento River basin (Fisher, 1994; Ward and McReynolds, 2001). In the Trinity River basin, emergence takes place from March until early June (West et al., 1990).

Juvenile Rearing and Migration

Fry and juvenile rearing takes place in the natal streams, the mainstem of the Sacramento River, inundated floodplains (including the Sutter and Yolo bypasses), and the Delta. During the winter, some spring-run juveniles have been found rearing in the lower portions of non-natal tributaries and intermittent streams (Maslin et al., 1997; Snider et al., 2001).

Once fry emerge from the gravel, they initially seek areas of shallow water and low velocities while they finish absorbing the yolk sac (Moyle, 2002). As juvenile Chinook Salmon grow, they move into deeper water with higher current velocities, but still seek shelter and velocity refugia to minimize energy expenditures (Healey, 1991). USFWS catches of juvenile salmon in the Sacramento River near West Sacramento showed that larger juvenile salmon were captured in the main channel and smaller fry were typically captured along the channel margins (USFWS, 1997).

The rearing and outmigration patterns exhibited by spring-run Chinook Salmon are highly variable, with fish rearing anywhere from 3 to 15 months before outmigrating to the ocean (Fisher, 1994). Variation in length of juvenile residence may be observed both within and among streams (e.g., Butte versus Mill creeks, [USFWS, 1996]). Some may disperse downstream soon after emergence as fry in March and April, with others smolting after several months of rearing, and still others remaining to oversummer and emigrate as yearlings (USFWS, 1996). Scale analysis indicates that most returning adults have emigrated as subyearlings (NMFS, 1998).

Extensive outmigrant trapping in Butte Creek has shown that spring-run Chinook Salmon outmigrate primarily as juvenile (age 0+) fish from November through June, with a small proportion remaining to emigrate as yearlings beginning in mid-September and extending through March, with a peak in November (Association of California Water Agencies and California Urban Water Agencies, 1997; Hill and Webber, 1999; Ward et al., 2004). Peak movement of juvenile spring-run Chinook Salmon in the Sacramento River at Knights Landing generally occurs in December, and again in March. However, juveniles also have been observed migrating between November and the end of May (Snider and Titus, 2000).

Coded-wire-tag studies conducted on Butte Creek spring-run Chinook Salmon have shown that juveniles use the Sutter Bypass as a rearing area until it begins to drain in the late winter or spring (Hill and Webber, 1999). Few juvenile Chinook Salmon are observed in the bypass after mid-May. Five recaptures indicate that juveniles leaving the Sutter Bypass migrate downstream rapidly and do not use the mainstem Sacramento River as rearing habitat (Hill and Webber, 1999).

Delta and Estuarine Rearing

Within the Delta, juvenile Chinook Salmon forage in shallow areas with protective cover, such as tidally influenced sandy beaches and shallow water areas with emergent aquatic vegetation (Meyer, 1979; Healey, 1980). Very little information is available on the estuarine rearing of spring-run Chinook Salmon (Federal Register, 2004a). NMFS postulates that, because spring-run Chinook Salmon yearling outmigrants are larger than fall-run Chinook Salmon smolts, and are ready to smolt upon entering the Delta, they may spend little time rearing in the estuary (Federal Register, 2004a). Juvenile spring-run Chinook salmon occur in the Sacramento-San Joaquin Delta from October through early May (CDFG, 1998).

There is little information regarding the residence of the juvenile Chinook salmon in the estuary downstream of the Delta. Juveniles usually spend approximately 40 days migrating through the estuary to marine waters, and demonstrate little or no real estuarine dependence in their growth and development (MacFarlane and Norton, 2002).

Nearshore and Marine Residence

Information on Chinook ocean distribution is scarce. The data are derived from commercial fisheries, and are biased in favor of locations where fisheries activities occur. Once in the ocean, spring-run Chinook Salmon perform extensive offshore migrations before returning to their natal streams to spawn. It is believed that spring-run Chinook salmon, similar to all Central Valley Chinook salmon, remain localized primarily in California coastal waters. The timing of the onset of ocean upwelling is critical for juvenile salmon that migrate to the ocean in the spring. As described for winter-run, upwelling influences juvenile growth and survival.

12A.1.1.3 Central Valley Fall-run and Late-Fall-run Chinook Salmon

Status

The Central Valley fall-run Chinook salmon ESU is comprised of two runs: fall and late-fall. NMFS classifies late fall-run Chinook Salmon as part of the Central Valley fall-run and late fall-run Chinook Salmon ESU, reasoning that the late fall-run population represents a life-history variation of the fall-run salmon population rather than a distinct run (Federal Register, 2004b). However, agencies generally treat late fall-run salmon in the Sacramento River basin as a distinct run, conducting separate carcass and redd surveys for them, and publishing separate reports to address the fall-run and late fall-run populations.

Following a status review of the Central Valley fall- and late-fall-run Chinook salmon ESU, National Oceanic and Atmospheric Administration (NOAA) Fisheries determined that listing this ESU as threatened or endangered was not warranted. Long-term population trends appear generally stable or increasing; however, it is unclear if natural populations are self-sustaining. Fall- and late-fall run populations are heavily augmented with hatchery production, and natural fall-run Chinook are not readily distinguishable from hatchery fall-run Chinook (Federal Register, 1999a). NOAA Fisheries designated the Central Valley fall-run ESU as a Species of Concern on April 15, 2004 (Federal Register, 2004b). Fall and late-fall-run Chinook are both California Species of Special Concern (CDFW, 2016).

Fall-run Chinook salmon are the most abundant and widely distributed of the four runs of salmon in the Sacramento-San Joaquin Basin (CDFW, 2014). In the Sacramento-San Joaquin Basin, abundance of adult fall-run Chinook salmon has varied from approximately 50,000 to more than 800,000 adults. From 2002 to 2009, the number of adult fall-run returning to the Central Valley and San Joaquin Valley dropped substantially, but has recovered to near-average levels in recent years (CDFW, 2014). The declines were largely the result of ocean conditions (Lindley et al., 2009). In the Central Valley, the fall-run range has not been substantially diminished like that of spring- and winter-run (Figure 12A-3) (Fisher, 1994).

Late-fall-run are less abundant than fall-run and primarily return to the Sacramento River and Battle Creek. Between 1967 and 1976, late fall-run salmon escapements averaged 22,000 adults (USFWS, 1996); however, between 1977 and 1985, escapements averaged only about 9,900 adults (CDFW, 2014). Population estimates of late fall-run salmon after 1985 are complicated by changes in RBDD gate operations, when Reclamation began raising the dam gates during winter months to facilitate the upstream migration of winter-run Chinook Salmon. Run size estimates for late-fall-run Chinook salmon have ranged from more than 40,000 to less the 1,000 adults (CDFW, 2014).

General Biology and Life History

Fall- and late-fall-run Chinook salmon are ocean-type Chinook salmon, emigrating predominantly as fry and sub-yearlings and remaining off the California coast during their ocean migration. The primary differences between the two runs are related to timing of migration into fresh water, timing of spawning, timing of juvenile emergence, and length of time juveniles remain in fresh water (Moyle, 2002).

Adult Migration and Spawning

In the Central and San Joaquin valleys, fall-run migrate between June and December, with a peak in September and October. Spawning begins in late September and October, peaks in November, and subsides by late December (Vogel and Marine, 1991). Late-fall-run return from the ocean from mid-October through mid-April. Spawning begins in January, peaks in February and March, and subsides by late April (Vogel and Marine, 1991). Run timing for Trinity River fall-run Chinook salmon is similar to that of Central Valley fall-run Chinook salmon.

Source:
Yoshiyama et al. 2001; Shick et al. 2005)

FIGURE 12A-3
Current and Historical Distribution of Fall-Run Chinook Salmon in the Central Valley Drainages
Sites Reservoir Project EIR/EIS

Fall-run Chinook salmon typically spawn soon after arriving at their spawning grounds between late September and December, with peak spawning activity in late October and early November. This is in contrast to both the winter-run and spring-run Chinook salmon that mature in the river over a period of months. Late-fall-run typically mature in fresh water and begin spawning from 1 to 3 months after entering the river. Fisher (1994) reports that peak spawning in the Sacramento River occurs in early February, but carcass surveys conducted in the late 1990s suggest that peak spawning may occur in January (Snider et al., 1998, 1999, 2000).

Historically, late-fall-run Chinook salmon likely spawned farther upstream than fall-run, where water temperatures remained tolerable for the juveniles through the summer. However, rivers are generally higher and more turbid in winter, so late-fall-run adults are hard to observe, and less is known about them and their historical range than about other runs (Williams, 2006). Spawning in the Sacramento River occurs primarily from Keswick Dam to the RBDD, but spawning has been observed as far downriver as Hamilton City (CDFG, 2007). In the San Joaquin Valley, fall-run spawn in the tributaries to the San Joaquin River (Fisher, 1994).

Fall-run and late fall-run Chinook Salmon are generally able to spawn in deeper water with higher velocities than Chinook Salmon in other runs because of their larger size (Healey, 1991). Late fall-run salmon tend to be the largest individuals of the Chinook Salmon species that occur in the Sacramento River basin (USFWS, 1996).

Juvenile Rearing and Migration

Fall-run Chinook Salmon in the Sacramento River generally exhibit two rearing strategies: migrating to the lower reaches of the river or Delta as fry, or remaining to rear in the gravel-bedded reach for about 3 months and then smolting and outmigrating. The highest abundances of fry in the Delta are observed in wet years (Brandes and McLain 2001). Fall-run Chinook Salmon fry rear during a time and in a location where floodplain inundation is most likely to occur, thereby expanding the amount of rearing habitat available. Relative survival of fry appears to be higher in the upper Sacramento River than in the Delta or bay, especially in wet years (Brandes and McClain, 2001). Stream habitat requirements are similar to those described for spring- and winter-run Chinook salmon.

Fall-run Chinook Salmon juvenile smolt during early spring, prior to increases in water temperatures. Juvenile Chinook Salmon feed and grow as they move downstream in spring and summer; larger individuals are more likely to move downstream earlier than smaller juveniles (Nicholas and Hankin 1989, Beckman et al., 1998), and it appears that in some systems juveniles that do not reach a critical size threshold will not outmigrate, but will remain to oversummer (Bradford et al., 2001).

As fall-run Chinook Salmon fry and parr migrate downstream, they also use the lower reaches of non-natal tributaries as rearing habitat (Maslin et al., 1997). During periods of high winter and spring runoff, fall-run Chinook Salmon juveniles are also diverted into the bypasses that border the Sacramento River, where growing conditions are generally better than mainstem rearing habitats, which can facilitate higher rates of juvenile survival (Sommer et al., 2001b). Natural floodplain or riparian areas that become inundated during high flows may also provide good habitat for juvenile Chinook Salmon and prevent them from being displaced downstream (The Nature Conservancy, 2003).

Research conducted in the Central Valley suggests that seasonally inundated, shallow water habitats may provide superior rearing habitat for juvenile salmonids than mainstem channels (Sommer et al., 2001b). Juvenile fall-run salmon migrate downstream between January and June when floodplains and bypasses are periodically flooded during wet water years. By promoting faster growth, prolonged floodplain inundation likely helps the fall-run population by increasing juvenile salmon survival.

Late fall-run fry emerge from redds between April and June (Vogel and Marine, 1991) and the juveniles typically rear in the stream through the summer before beginning their migration in the fall or winter (Fisher, 1994). Late fall-run juveniles generally leave the Sacramento River by December (Vogel and Marine, 1991), with peak emigration of smolts in October. Water temperatures in the lower Sacramento River are often too high in May and June to support fry survival, so later-emerging fry that migrate downstream likely suffer high rates of mortality and contribute little to the population. This suggests that a significant fraction of late fall-run juveniles rear in the upper Sacramento River throughout the summer before emigrating in the following fall and early winter as large subyearlings (Fisher, 1994). Summer rearing is made possible by the cold water releases from the Shasta-Trinity divisions of the CVP.

Estuarine Rearing

There is little information regarding the residence of the juvenile Chinook salmon in the estuary downstream of the Delta. Juveniles usually spend approximately 40 days migrating through the estuary to marine waters, and demonstrate little or no real estuarine dependence in their growth and development (MacFarlane and Norton, 2002).

Nearshore and Marine Residence

Juvenile fall-run Chinook salmon enter the ocean in spring and stay in nearshore waters in the vicinity of their natal rivers for the first few months of their lives in the ocean. Following this period, they remain between central California and southern Washington over the continental shelf. As described for winter-run, upwelling influences juvenile growth and survival.

12A.1.1.4 Upper Klamath and Trinity Rivers Spring-run Chinook Salmon

Status

The Upper Klamath and Trinity Rivers ESU contains fall-run, late fall-run, and spring-run fish that spawn in the Klamath and Trinity rivers upstream of the Trinity River's confluence with the Klamath. Although wild spring-run Chinook Salmon in the Klamath River system differ from fall-run Chinook Salmon genetically, as well as in terms of life history and habitat requirements (National Research Council [NRC], 2004), all are included within this ESU (Myers et al., 1998). The following profile pertains only to the spring-run, and focuses on the South Fork Trinity River (SFTR), which supports one of the few remaining stocks of wild spring-run Chinook Salmon within the greater Klamath Basin (Van Kirk and Naman, 2008).

A status review in 1999 concluded that Upper Klamath and Trinity Rivers ESU did not warrant listing (NMFS, 1999). A petition to list the Upper Klamath and Trinity Rivers ESU was submitted to NMFS in January 2011 (CBD et al., 2011); in April 2011, NMFS announced that listing was not warranted. Of primary importance in their decision was their conclusion that the spring-run and fall-run Chinook Salmon in the basin constitute a single ESU (Federal Register, 2012a). The genetic structure of Chinook Salmon populations in coastal basins (as opposed to the Central Valley) indicates that the spring- and fall-run life histories have evolved multiple times in different watersheds (Myers et al., 1998, Waples et al., 2004). Three hatchery stocks from the Iron Gate and Trinity River hatcheries are considered part of the ESU because they were founded using native, local stock in the watershed where fish are released (Federal Register, 2012a).

General Biology and Life History

General habitat requirements for Chinook Salmon are described earlier; the following describes life-history strategies and habitat requirements unique to the spring-run Chinook or of primary importance to its life history. Spring-run Chinook Salmon display a stream-type life-history strategy—adults migrate upstream while sexually immature, hold in deep cold pools over the summer, and spawn in late summer and early fall. Juvenile outmigration is highly variable, with some age 0+ juveniles outmigrating in their first spring, but others oversummering and then emigrating as yearlings the following spring.

Adult Upstream Migration, Holding, and Spawning

Adults spawn from September through early November in the South Fork Trinity River (State Coastal Conservancy, 2009). Within the South Fork Trinity River (SFTR) watershed, spring-run Chinook Salmon spawning takes place primarily between Hitchcock Creek and the East Fork of the SFTR on the mainstem SFTR, in Plummer Creek, in the mainstem of Hayfork Creek and the lower reaches of Salt and Tule creeks (U.S. Forest Service [USFS], 2001a; Reclamation, 1994), and possibly Big Creek (Chilcote et al., 2013). The East Fork of Hayfork Creek is used as summer holding habitat by adults, according to USFS (2001b), and adults have been observed during August in the lower SFTR below Surprise Creek and below Mule Bridge (USFS, 2011). In the Trinity River, spring-run start spawning approximately the second week of September and spawn through mid-October (USFWS and Hoopa Tribe, 1999).

Juvenile Rearing and Migration

Rearing in the SFTR basin takes place in the mainstem SFTR between Hitchcock Creek and the East Fork of the SFTR (USFS 2001a). This area was noted to be an oversummering area by USFS (2001a). Rearing also takes place in Plummer Creek (USFS 2001a).

Juvenile spring-run Chinook Salmon of the Upper Klamath and Trinity Rivers ESU generally remain in fresh water for a year or more. On the South Fork Trinity River, outmigration occurs in late April and May with a peak in May (Dean 1994, 1995); however, it is not possible to differentiate between spring and fall juveniles, so spring-run outmigration timing may differ somewhat from the fall run. Age-1 juveniles (Type III) have been found to outmigrate from the South Fork Trinity River during the following spring (Dean 1994, 1995).

12A.1.2 Steelhead (*Oncorhynchus mykiss*)

12A.1.2.1 Central Valley Steelhead

Status

The Central Valley Steelhead ESU was listed as a threatened species pursuant to FESA in March 1998 (Federal Register, 1998). In 2004, NMFS proposed that all west coast steelhead ESUs be reclassified to Distinct Population Segments (DPSs) and proposed to retain Central Valley Steelhead as threatened. In January 2006, after a status review (Good et al., 2005), NMFS issued its final decision to retain the status of Central Valley Steelhead as threatened (Federal Register, 2006a). The DPS includes naturally spawned anadromous O. mykiss (steelhead) populations below natural and manmade impassable barriers in the Sacramento and San Joaquin rivers and their tributaries, excluding steelhead from San Francisco and San Pablo bays and their tributaries and those from two artificial propagation programs: the Coleman Nimbus Fish Hatchery and Feather River Hatchery steelhead hatchery programs.

Critical habitat was designated on September 2, 2005 (Federal Register, 2005b). Critical habitat for the Central Valley Steelhead DPS includes stream reaches of the American, Feather, Yuba, and Bear rivers and their tributaries and tributaries of the Sacramento River including Deer, Mill, Battle, Antelope, and Clear creeks in the Sacramento River basin; the Mokelumne, Calaveras, Stanislaus, Tuolumne, and Merced rivers in the San Joaquin River basin; and portions of the Sacramento and San Joaquin rivers. Designated critical habitat in the Delta includes portions of the Delta Cross Channel Yolo Bypass, Ulatis Creek, and portions of the network of channels in the Sacramento River portion of the Delta as well as portions of the San Joaquin, Cosumnes, and Mokelumne rivers and portions of the network of channels in the San Joaquin portion of the Delta (Figure 12A-4). Critical habitat includes the river, river bottom, and the adjacent riparian zone. Riparian zones are considered essential for the conservation of steelhead because they provide important areas for fry and juvenile rearing.

Historically, Central Valley steelhead adult populations may have numbered between one and two million (McEwan, 2001). Populations of naturally spawned Central Valley Steelhead have declined and are composed predominantly of hatchery fish. The California Fish and Wildlife Plan of 1965 estimated the combined annual run size for Central Valley and San Francisco Bay tributaries to be about 40,000 during the 1950s (CDFG 1965b). The spawning population during the mid-1960s for the Central Valley basin was estimated at about 27,000 (CDFG 1965a). These numbers likely consisted of both hatchery and wild steelhead. McEwan and Jackson (1996) estimated the annual run size for the Central Valley basin to be less than 10,000 adults by the early 1990s. Much of the abundance data since the mid-1960s were obtained by visual fish counts at the RBDD fish ladders when gates were closed during much of the steelhead migration season. Current abundance estimates are not available for naturally spawned fish since RBDD gate operations were changed, so the extent to which populations have changed following the 1987−94 drought is unknown. NMFS' (2003) status review estimated the Central Valley Steelhead population at less than 3,000 adults.

The majority of historical steelhead spawning habitat is now inaccessible because of the construction of large dams; an estimated 80 percent of the spawning grounds in the Central Valley have been blocked because of hydropower, flood control, and water supply dams (Figure 12A-4) (CDFG, 1996, McEwan, 2001; Lindley et al., 2006).

General Biology and Life History

Steelhead are the anadromous form of rainbow trout (McEwan, 2001). Central Valley steelhead are found in the Sacramento River downstream of Keswick Dam and the major rivers and creeks in the Sacramento River watershed (Figure 12A-4). Naturally spawning steelhead populations have been found in the upper Sacramento River and tributaries below Keswick Dam; Battle, Mill, Deer, and Butte creeks; and the Feather, Yuba, American, and Mokelumne rivers (Comprehensive Monitoring, Assessment and Research Program for the CALFED Bay-Delta Program, 1998). Steelhead also occur in Stony and Thomes creeks (McEwan, 2001) and many of the other tributaries to the Sacramento River, including intermittent streams in the Redding area. The tributary creeks support naturally spawning populations, although Battle Creek populations are augmented by Coleman National Fish Hatchery. Recent monitoring programs have found steelhead in additional streams, such as Auburn Ravine, Dry Creek, and the Stanislaus River. It is possible that naturally spawning populations exist in many other streams but are undetected because of the lack of monitoring or research programs.

N

0 10 20 30 40 Miles

FIGURE 12A-4
Current and Historical Distribution of Steelhead in the Central Valley Drainages including Critical Habitat Designation
Sites Reservoir Project EIR/EIS

The populations in the Feather and American rivers are supported primarily by the Feather and Nimbus hatcheries, respectively. Eel River steelhead were included in the founding stock for the Nimbus Hatchery, and genetic studies have shown that American River steelhead are more closely related to Eel River steelhead than Central Valley stocks. In the San Joaquin River system, naturally producing populations are found in the eastside watersheds.

Steelhead exhibit two life history strategies: (1) stream maturing steelhead (summer steelhead); and (2) ocean maturing steelhead (winter steelhead) (McEwan, 2001). Stream maturing steelhead typically enter fresh water in spring, early summer, and fall. They ascend to headwater tributaries, hold over in deep pools until mature, and spawn in winter. Ocean maturing steelhead typically begin their spawning migration in fall, winter, and spring, and spawn relatively soon after entering fresh water. Ocean maturing steelhead generally spawn January through March, but spawning can extend into spring and possibly early summer months. This variability in life history patterns likely confers a survival advantage, especially in unstable variable climatic and hydraulic conditions (CDFG, 1996). All steelhead in the Central Valley are considered winter steelhead (ocean maturing) because spawning takes place a few weeks to a few months after entering fresh water.

Adult Migration

Central Valley Steelhead generally leave the ocean and migrate upstream from August through March (Busby et al., 1996), In the Sacramento River, steelhead migrate upstream nearly every month of the year, with the bulk of migration from August through November and the peak in late September (Hallock et al., 1961, McEwan, 2001). The peak of migration up the smaller tributary streams usually occurs in November and again in February (Hallock et al., 1961; Hallock, 1989; CDFG, 1996), with the onset of higher winter flows.

Spawning

Spawning in the upper Sacramento River generally occurs from December through April (Newton and Stafford, 2011). The majority of steelhead in the mainstem Sacramento River spawn downstream of Keswick Dam, with peak spawning from January through March when water temperatures throughout much of the Sacramento River are suitable to support egg incubation and emergence. The highest-density spawning within the mainstem is likely in the upstream portion of this area near Redding; however, the downstream extent of spawning is likely determined by the location of suitable water temperatures to support summer rearing of 0+ juveniles, which lack the swimming ability to move significant distances upstream to follow the upstream retreat of cold water in summer. Most Sacramento River steelhead are believed to spawn in the tributary streams.

Steelhead spawn in areas with suitable gravel and hydraulics. Work by Bovee (1978) found that steelhead prefer water depths of 14 inches (36 cm) for spawning, with a range between 6 and 24 inches (15 and 61 cm), and water velocities of 2 feet/second (61 cm/second), with a range of 1 to 3.6 feet/second (30 to 110 cm/second), which is similar to the hydraulic conditions preferred by Chinook Salmon in the Central Valley. Steelhead generally prefer to spawn in gravels, with optimal grain sizes ranging between 0.6 cm and 10 cm (Bjornn and Reiser 1991). As described for Chinook salmon, substrates with only a small amount of silt and sand (less than or equal to 5 percent) are important for successful spawning (CDFG, 1996). Unlike Pacific salmon, not all steelhead die after spawning. Adults may return to spawn as many as three times, but the percentage that repeat the spawning cycle is generally low (CDFG, 1996).

Eggs usually hatch within four weeks, depending on stream temperature (CDFG, 1996). From observations of more northern populations, preferred water temperatures for spawning and egg incubation are likely between 39°F and 52°F, and egg mortality likely begins at 56°F (CDFG, 1996; McEwan, 2001; Reiser and Bjornn, 1979). The yolk sac fry remain in the gravel after hatching for another four to six weeks (CDFG, 1996) before emerging.

Fry and Juvenile Rearing

Once the fry emerge, they inhabit shallow areas along the stream margin and seem to prefer areas with cobble substrates (CDFG, 1996). Further into development, juveniles will use a variety of habitats (CDFG, 1996). Habitat use is affected by the presence of predators, and juvenile steelhead survival increases when cover, such as wood debris and large cobble, is available (Mitro and Zale, 2002).

For juvenile steelhead to survive winter, they must avoid predation and high flows. Age 0+ steelhead can use shallower habitats and can find interstitial cover in gravel-size substrates, while age 1+ or 2+ steelhead, because of their larger size, need coarser cobble/boulder substrate for cover (Bustard and Narver 1975; Bisson et al., 1982, 1988; Fontaine, 1988; Dambacher, 1991). In winter, age 1+ steelhead typically stay within the area of streambed that remains inundated at summer low flows, while age 0+ fish frequently overwinter beyond the summer low flow perimeter along the stream margins (Everest et al., 1986).

Summer habitat can generally be assumed to be more limiting for age 1+ and 2+ juvenile steelhead than for age 0+ in many streams. Older age classes of juvenile steelhead (ages 1+ and 2+) prefer deeper water in summer than fry and show a stronger preference for pool habitats, especially deep pools near the thalweg with ample cover, as well as higher-velocity rapid and cascade habitats (Bisson et al., 1982, 1988; Dambacher, 1991). Fast, deep water, in addition to optimizing feeding versus energy expenditure, provides greater protection from avian and terrestrial predators (Everest and Chapman 1972).

Juvenile Central Valley steelhead typically migrate to the ocean after spending from one to three years in fresh water (CDFG, 1996). The majority of returning adult steelhead in the Central Valley have spent 2 years in fresh water before emigrating to the ocean (McEwan, 2001). A scale analysis conducted by Hallock et al. (1961) indicated that 70 percent emigrated after 2 years, 29 percent after 1 year, and 1 percent after 3 years in fresh water. Juvenile emigration from the upper Sacramento River occurs between November and late June, with a peak between early January and late March (Reclamation, 2004).

Juvenile Migration

Steelhead do not necessarily migrate at any set age or seemingly at any set season (CDFG, 1996). Some individuals will remain in a stream, mature, and even spawn without ever going to sea; others will migrate to sea at less than one year old, and some will return to fresh water after spending less than one year in the ocean (CDFG, 1996). Juvenile emigration from the upper Sacramento River occurs between November and late June, with a peak between early January and late March (Reclamation, 2004).

Estuarine Rearing

Estuaries can be important rearing areas for juvenile steelhead, especially in small coastal streams (CDFG, 1996). The Delta serves as an adult and juvenile migration corridor, connecting inland habitat to the ocean. The Delta may also serve as a nursery area for juvenile steelhead (McEwan and Jackson, 1996); however, much is unknown regarding historical and current role of the Delta as steelhead nursery habitat. Summer temperatures are moderated by the marine influence of the nearby San Francisco Bay and Pacific Ocean (Lindley et al, 2006). Due to these conditions, residency time in the Delta tends to be longer for the Central Valley steelhead than other salmonids. During their residency in the Delta, pumping operations of the CVP and the SWP can have a detrimental impact on smolt escapement to the ocean (CDFG, 1996). Based on fish facility salvage data, most steelhead move through the Delta from November through June, with the peak salvage during February, March, and April. The majority of steelhead salvaged range from 175 to 325 mm, with the most common size ranging from 226 to 250 mm.

12A.1.2.2 Klamath Mountains Province Steelhead

Trinity River steelhead populations are included in the Klamath Mountains Province Steelhead DPS. This DPS occupies river basins from the Elk River in Oregon to, and including, the Klamath and Trinity rivers in California. This DPS includes both winter and summer steelhead. Steelhead populations from this region are genetically distinct from populations to the north and south (NMFS, 1994). After a status review, NMFS concluded that the Klamath Mountains Province Steelhead DPS was not in danger of extinction or likely to become so in the foreseeable future; therefore, it was not warranted for listing as threatened or endangered (Federal Register, 2001).

Long-term data are not available to evaluate Klamath River steelhead population trends. CDFG (1965a) estimated a basin wide annual run size of 283,000 adult steelhead (spawning escapement + harvest). Busby et al. (1994) reported winter steelhead runs in the Klamath basin to be 222,000 during the 1960s. In the Trinity River Basin, returning adults were estimated to number approximately 50,000 in the 1960s. Hopelain (2001) used creel and gill net harvest data to estimate the winter-run steelhead population at 10,000 to 30,000 adults annually in the early 1980s. Population estimates of summer steelhead showed a steep decline during the 1990s (Reclamation, 2008), but Koch (2001) reported increasing runs on the Klamath and Trinity rivers following the late 1990s.

General Biology and Life History

General habitat requirements for steelhead are described in the Central Valley Steelhead profile; the following describes life history strategies and habitat requirements unique to steelhead of the Upper Klamath Mountains Province DPS or of primary importance to its life history. Both winter and summer runs of steelhead are included in the DPS. Winter steelhead become sexually mature during their ocean phase and spawn soon after arriving at their spawning grounds. Adult summer steelhead enter their natal streams and spend several months holding and maturing in fresh water before spawning. Throughout the entire year, at least one of the diverse life stages can be found present in the river (Israel, 2003). As with the Central Valley DPS, this DPS is composed predominantly of winter steelhead.

In addition to runs of adult steelhead, the Klamath and Trinity rivers also support a run of immature steelhead known as "half-pounders", which spend 2 to 4 months in the ocean before returning to the river in late summer and early fall (Barnhart, 1986). Half-pounders feed extensively in fresh water and are highly prized by sport anglers. Half-pounders overwinter in the river without spawning before returning to the ocean, and then return as mature adults during subsequent migrations. Half-pounders have a very limited geographic distribution and are known to exist only in the Rogue, Klamath-Trinity, Mad, and Eel river systems.

Winter-Run

Winter steelhead adults generally enter the Klamath River from July through October (fall run) and from November through March (winter run) (USFWS, 1997). Winter steelhead primarily spawn in tributaries from January through April (USFWS, 1997), with peak spawn timing in February and March (ranging from January to April) (NRC, 2004). Adults may repeat spawning in subsequent years after returning to the ocean. Half-pounders typically use the mainstem Klamath River until leaving the following March (NRC, 2004), although they also use larger tributaries such as the Trinity River (Dean 1994, 1995).

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 1+ juveniles have been captured in outmigrant traps in spring and summer in tributaries to the Klamath River above Seiad Creek (CDFG, 1990a, 1990b). These fish are likely rearing in the mainstem or non-natal tributaries before leaving as age-2+ outmigrants.

Juvenile outmigration primarily occurs between May and September with peaks between April and June, although smolts are captured in the estuary as early as March and as late as October (Wallace, 2004). Most adult returns (86 percent) originate from fish that smolt at age 2+, in comparison with only 10 percent for age-1 juveniles and 4 percent for age 3+ juveniles (Hopelain, 1998).

Summer-Run

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, 1997).

Juvenile summer steelhead in the Klamath Basin may rear in fresh water for up to 3 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 tributaries (particularly during periods of poor water quality) for 1 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. Juvenile outmigration can occur from spring through fall. Smolts are captured in the mainstem and estuary throughout 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 summer, especially upstream of Seiad Valley.

12A.1.3 Southern Oregon/Northern California Coast Coho Salmon ESU (*Oncorhynchus kisutch*)

12A.1.3.1 Status

The SONCC Coho ESU includes naturally spawning populations of Coho salmon between Punta Gorda, California and Cape Blanco, Oregon which includes the Klamath and Trinity rivers. Three artificial propagation programs are considered to be part of the ESU: the Cole Rivers Hatchery, Trinity River Hatchery, and Iron Gate Hatchery Coho Salmon programs. The SONCC Coho ESU is listed as threatened pursuant to FESA (Federal Register, 1997) and CESA (CDFG, 2002a).

Critical Habitat for the SONCC Coho Salmon ESU was designated by NMFS on May 5, 1999 (Federal Register, 1999b). Critical habitat for the SONCC Coho Salmon ESU encompasses accessible reaches of all rivers (including estuarine areas and tributaries) between the Mattole River in California and the Elk River in Oregon. Figure 12A-5 shows SONCC Coho salmon distribution and critical habitat in the Klamath River and Trinity River basins.

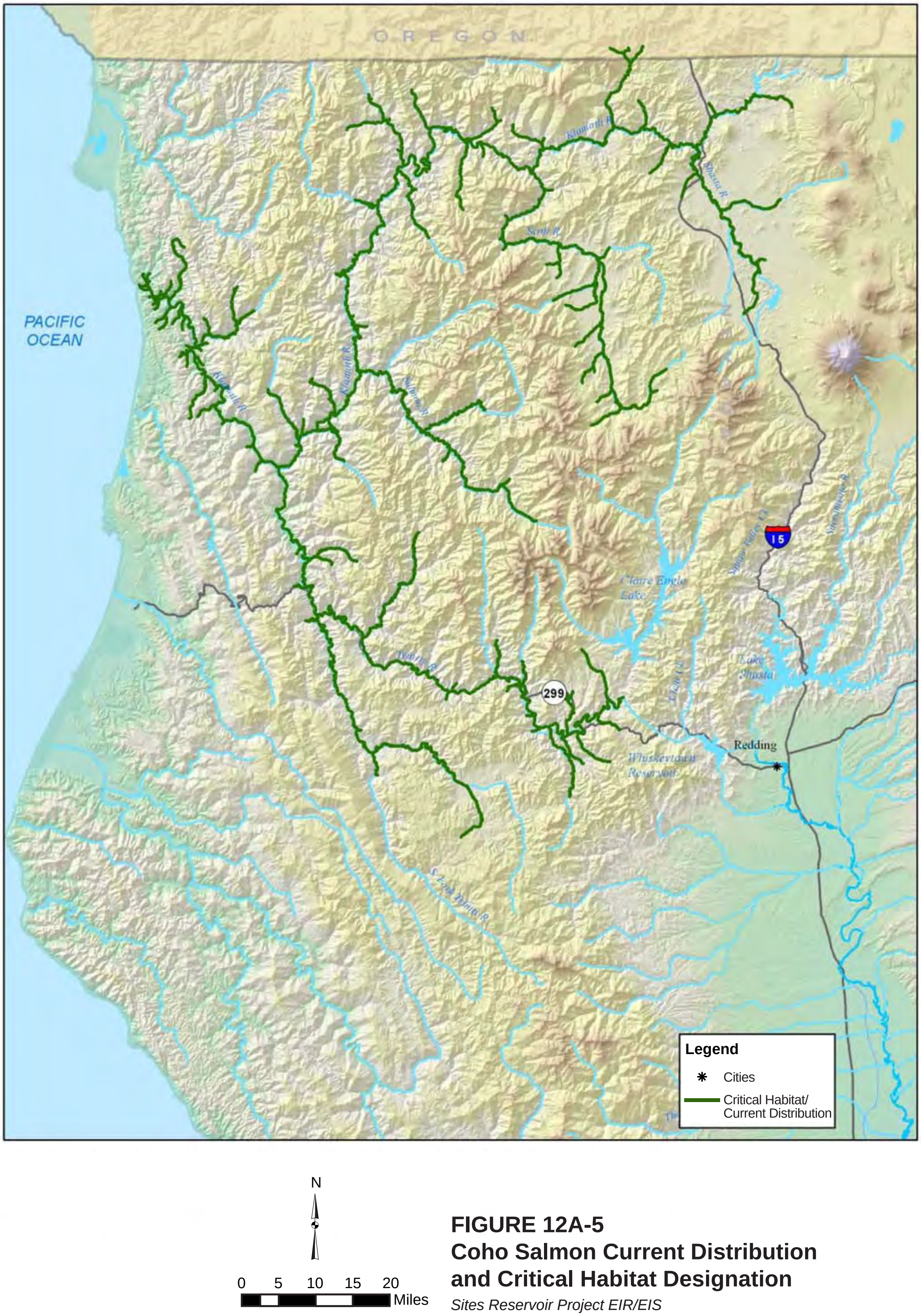


FIGURE 12A-5
Coho Salmon Current Distribution and Critical Habitat Designation
Sites Reservoir Project EIR/EIS

Coho Salmon were not likely the dominant species of salmon in the Trinity River before dam construction. However, Coho were widespread in the Trinity Basin ranging as far upstream as Stuarts Fork above Trinity Dam. Wild Coho in the Trinity Basin today are not abundant, and the majority of the fish returning to the river are of hatchery origin. An estimated 2 percent (200 fish) of the total Coho Salmon run in the Trinity River were composed of naturally produced Coho from 1991 through 1995 at a point in the river near Willow Creek (USFWS, 1998). This, in part, prompted the threatened status listing in 1997. These estimates included a combination of hatchery produced and wild Coho. About 10 percent of the Coho were naturally produced since 1995.

The population of Coho salmon has decreased significantly since the 1950s. Coho salmon abundance, including hatchery stocks, has declined at least 70 percent since the 1960s, and is currently six to 15 percent of its abundance during the 1940s (CDFG, 2004). It is estimated that in the 1940s, between 200,000 and 500,000 Coho returned to central and northern California streams each fall to spawn. Today, Coho populations in southern Oregon and northern California have fallen to approximately 10,000 naturally produced adults. This decline is reflected in the continued drop in the number of Coho salmon caught commercially. Commercially caught Coho salmon off the California and Oregon coasts ranged between 700,000 and three million in the 1970s. Catches in the 1980s and 1990s dropped, with catches in the 1980s being consistently below one million. Catches averaged less than 400,000 in the 1990s (Legislative Analyst's Office [LAO], 1997).

According to NMFS, a leading factor in the decline of the Coho salmon is the degradation of its habitat caused by various economic activities. These activities include timber harvesting, grazing, mining, water diversions, urbanization, and road and dam construction. Other activities that adversely affect Coho habitat include streambed alteration, unscreened water diversions, and loss of wetlands. Overfishing also contributed to the species' decline (LAO, 1997).

12A.1.3.2 General Biology and Life History

As an anadromous fish, Coho salmon spend most of their lives in the ocean and return to their native freshwater streams to spawn and die. California Coho salmon have a fairly strict three-year lifecycle, with approximately half spent in fresh water and half spent in saltwater (Moyle, 2002). Exceptions to the three-year rule are jack males, which return to fresh water as two-year-olds. The combination of a three-year lifecycle and a strong homing instinct means that each stream has three distinct Coho salmon cohorts (groups of fish that hatched during a given spawning season), which are isolated both temporally and spatially from one another. The jacks (early returning males), however, keep runs from being genetically isolated from one another, as do rare early returning females (Moyle, 2002).

Adult Migration and Spawning

Coho salmon migrate up and spawn mainly in streams that flow directly into the ocean or tributaries of large rivers (Moyle, 2002). Adult Coho salmon enter fresh water to spawn from August through January. On the Klamath and Trinity rivers, Coho salmon begin entering the river in early- to mid-September, and reach a peak in October to November. On coastal streams most Coho salmon return from November to January (Moyle, 2002).

The early part of the run is dominated by males, with females returning in greater numbers during the latter part of the run (Moyle, 2002). Spawning itself occurs mainly in November and December (USFWS, 1979). Females usually choose spawning sites near the head of a riffle, just downstream of a pool, where the water changes from a smooth to a turbulent flow and there is a medium to small gravel substrate (Shapovalov and Taft, 1954). Coho salmon typically spawn in small streams or side channels where the velocity is 1.0 to 3.4 feet per second and the stream depth ranges between 3.94 and 13.78 inches, depending on the velocity (Briggs, 1953; Bovee, 1978).

Coho salmon also prefer to construct their redds in areas where water upwells through the gravel bed, eliminating wastes and preventing sediments from filling the spaces between spawning gravel (CDFG, 2004). The flow characteristics of redd locations usually ensure good aeration, and the circulation facilitates fry emergence from the gravel (Moyle, 2002).

Each female builds a succession of redds in the same place, moving upstream as she does so and depositing a few hundred eggs in each (Briggs, 1953). Spawning takes approximately one week to complete, during which time each female lays 1,400 to 3,000 eggs. There is a positive correlation between the size of females and the number of eggs they produce, but California Coho salmon produce fewer eggs than fish from more northern populations (Sandercock, 1991).

The optimum temperature for Coho salmon egg incubation is between 40°F and 55°F (Bjornn and Reiser, 1991). In one study, Coho salmon embryos suffered 50 percent mortality at temperatures above 56.3°F (Beacham and Murray, 1990). In California, eggs incubate in the gravels from November through April. California Coho salmon eggs hatch in approximately 48 days at 48°F, and in 38 days at 51.3°F (Shapovalov and Taft, 1954).

Fry and Juvenile Rearing

After hatching, alevins[1] remain in the interstices of the gravel for two to 10 weeks until their yolk sacs have been absorbed (Shapovalov and Taft, 1954; Laufle et al., 1986; Sandercock, 1991). Coho salmon fry emerge from the gravel between March and July, with peak emergence occurring from March to May, depending on when the eggs were fertilized and the water temperature during development (Shapovalov and Taft, 1954). Juveniles prefer and presumably grow best at temperatures of 53.6°F to 57.2°F. Temperatures exceeding 77°F to 78.8°F are invariably lethal (Moyle, 2002).

Upon emerging, alevins seek shallow water along stream margins. Initially they form shoals (groups of juvenile fish), but as they grow bigger, the shoals break up and juveniles set up individual territories (Moyle, 2002). At this stage, the fish are termed parr. Rearing areas used by juvenile Coho salmon include low-gradient coastal streams, lakes, sloughs, side channels, estuaries, low-gradient tributaries to large rivers, beaver ponds, and large slackwaters. Smaller streams with low-gradient alluvial channels containing abundant pools formed by large woody debris are the most productive juvenile habitats (CDFG, 2004).

Habitat use by juvenile Coho salmon in some California streams is complex (Nielson, 1992). There are four distinct types of juveniles, termed estuarine, margin, thalweg, and early pulse juveniles. Estuarine juveniles move downstream into estuaries soon after emergence and rear in intertidal areas. Margin juveniles remain in stream margins and backwaters during summer, where growth is typically slow, so that yearling fish move downstream at less than 70 millimeters standard length. Thalweg juveniles are the "standard" juveniles that rear in the deeper parts of the main channel, feeding and growing steadily all season long; they are approximately 100 millimeters standard length when they smolt and head out to sea. Early pulse juveniles show two pulses of growth: in spring and in autumn, and transform into smolts at

[1] A larval salmonid that has hatched but has not completely absorbed its yolk sac, and generally has not emerged from the spawning gravel.

greater than 100 millimeters SL. Their behavior is “trout like” because they rest in deep cover during the day and forage on drifting invertebrates during dawn and dusk (Nielson, 1992).

Juvenile Migration

After one year in fresh water, smolts begin migrating downstream to the ocean in late March or early April. In some years, emigration can begin prior to March (CDFG, 2004) and can continue until July (Shapovalov and Taft, 1954; Sandercock, 1991). Peak downstream migration in California generally occurs from April to early June (CDFG, 2004). The timing of emigration is influenced by the size of the fish, flow conditions, water temperature, DO levels, day length, and the availability of food (CDFG, 2004).

The outmigrants are primarily one year old and measure 10 to 13 cm fork length, although a few larger two-year-olds may also be present. Parr marks are still prominent in early outmigrants, but later outmigrants are silvery, having transformed into smolts (Moyle, 2002). Most of this movement takes place at night and is interspersed with periods of holding and feeding in low velocity areas (Moyle, 2002).

Natural stream flow patterns are important in facilitating the downstream migration of Coho salmon smolts. Increases in stream flow trigger downstream movement of Coho salmon (CDFG, 2004). Short-term increases in stream flow are an important stimulus for smolt emigration (Spence, 1995). Artificial obstructions, such as dams and diversions of water, may impede emigration where they create unnatural flow patterns (CDFG, 2004).

Coho salmon have been observed throughout their range to emigrate at temperatures ranging from 36.6°F up to as high as 55.9°F (Sandercock, 1991). Water temperature affects timing of emigration, and rapid increases in temperature can trigger downstream migration (Spence, 1995). Coho salmon have been observed emigrating through the Klamath River Estuary in mid- to late-May when water temperature ranged from 53.6°F to 68°F (CDFG, 2004).

Estuarine Rearing

Adult Coho salmon use estuaries as a holding area as they prepare for their migration upstream. Juveniles use estuaries for rearing and completion of smoltification. Juveniles may occupy estuaries for several weeks before migrating out to sea. The phenomenon of smolts migrating is not a single unidirectional event; smolts may move in and out of an estuary a few times before finally remaining in the marine environment (CDFG, 2004).

Returning adults enter the freshwater environment through estuaries. Access to the estuaries, sufficient cover, and adequate flow and water quality (including suitable temperature) are all important factors for these fish. Once in the estuaries, upstream migration is generally associated with high outflow combined with high tides (Sandercock, 1991).

Nearshore and Marine

Upon entry into the ocean, immature Coho salmon remain in nearshore waters, congregating in schools as they move north along the continental shelf (Shapovalov and Taft, 1954; Anderson, 1995). Most remain in the ocean for two years. Data on ocean distribution of California Coho salmon are sparse, but it is believed that the Coho salmon scatter and join schools from Oregon and possibly Washington (Anderson, 1995).

12A.1.4 Green Sturgeon (*Acipenser medirostris*)

12A.1.4.1 Status

NMFS identified two DPSs for North American green sturgeon: the Northern DPS and the Southern DPS. The DPSs are based on the rivers in which the green sturgeon spawn and findings of preliminary genetic studies. The Southern DPS of North American Green Sturgeon includes all coastal and Central Valley populations south of the Eel River, including the Sacramento River basin (Federal Register, 2006b). After a status review was completed in 2002 (Adams et al., 2002), NMFS determined that the Southern DPS did not warrant listing as threatened or endangered but should be identified as a Species of Concern. This determination was challenged in April 2003, and NMFS was asked to consider new information on the species. NMFS updated its status review in February 2005 and determined that the Southern DPS should be listed as threatened under FESA. In April 2006, NMFS listed the Southern DPS of green sturgeon as threatened (Federal Register, 2006b). Green sturgeon are also considered a State Species of Special Concern by CDFW (2016). The listing of the Northern DPS pursuant to FESA was assessed, but was not warranted (Adams et al., 2002).

The Southern DPS green sturgeon population is located within the Primary, Secondary, and Extended study areas (Figure 12A-6). The Southern DPS is known to only spawn in the Sacramento River (NMFS, 2005). As of 2012, there is no documentation of green sturgeon spawning in the San Joaquin River. Young green sturgeon have been taken occasionally in the Santa Clara Shoal area in the San Joaquin Delta, but these fish likely originated from elsewhere, most likely the Sacramento River (NMFS, 2005).

NMFS designated critical habitat for Southern DPS green sturgeon on October 9, 2009 (Figure 12A-6). Critical habitat includes riverine, estuarine, and coastal marine habitats in California, Oregon, and Washington. Designated critical habitat in the Sacramento and San Joaquin river basins includes the Sacramento River downstream of Keswick Dam, the Feather River downstream of Oroville Dam, and the Yuba River downstream of Daguerre Point Dam; portions of the Sutter and Yolo bypasses; the legal Delta, excluding Five Mile Slough, Seven Mile Slough, Snodgrass Slough, Tom Paine Slough, and Trapper Slough; and San Francisco, San Pablo, and Suisun bays. Other designated areas include Humboldt Bay and coastal marine habitats extending from the California/Oregon border to Monterey. The lateral extent of critical freshwater habitat units is defined as the ordinary high-water line, as defined by the U.S. Army Corps of Engineers. In areas where the ordinary high-water line has not been defined, NMFS defined the width of the stream channel by its bankfull elevation (NMFS, 2009c).

The population size of Southern DPS green sturgeon is not known, but is considered substantially smaller than the Northern DPS (Adams et al., 2002). In the Sacramento-San Joaquin River Basin, Green sturgeon abundance is much lower than white sturgeon abundance. During tagging studies by CDFG, the majority of sturgeon captured were white sturgeon; an average of only one adult green sturgeon has been captured for every 134 adult white sturgeon. Preliminary green sturgeon genetics information for the Southern DPS confirms that numbers are low in the Sacramento-San Joaquin River system (Israel and May, 2010).

The abundance of North American green sturgeon has declined by 88 percent throughout much of its range (Musick et al., 2000). Although there is no direct evidence that populations of green sturgeon are declining in the Sacramento River, the small size of the population increases the risk that a decline in numbers would be difficult to detect until a collapse in the population occurs. The population is threatened by habitat loss or degradation, lethally high Delta temperatures, entrainment in water diversions, invasive species, and exposure to toxic materials (Moyle et al., 1995; NMFS, 2005).

N

0 10 20 30 40 Miles

FIGURE 12A-6
Current and Historical Distribution of Green Sturgeon the Central Valley including Critical Habitat Designation
Sites Reservoir Project EIR/EIS

12A.1.4.2 General Biology and Life History

Less is known about the biology and abundance of green sturgeon than the white sturgeon. Sturgeon live 40 to 50 years, delay maturation to large sizes (125 cm total length), and spawn multiple times over their lifespan. Adult Green Sturgeon do not spawn every year, and only a fraction of the population enters fresh water where they might be at risk of a catastrophic event (Beamesderfer et al., 2007). Though there are general descriptions of preferred habitat conditions for Green Sturgeon, much of this information is derived from Rogue River and Klamath River data, and little is known about specific spawning, rearing, or holding locations in the Sacramento River.

Adult Migration

Though Green Sturgeon spend most of their life in marine and estuarine environments, they periodically migrate into freshwater streams to spawn, spending up to 6 months in fresh water during their spawning migration. Upstream migration generally begins in February and may last until late July (Adams et al., 2002). In the Rogue River, telemetry studies have shown that adult Green Sturgeon hold in low-velocity, deep-water habitats prior to migrating upstream to spawn (Erickson et al., 2002). Green sturgeon congregate in pools greater than 16.4 feet in depth with variable water velocities and flow patterns (U.C. Davis [UCD] and DWR, 2010). The adults move around in the pools and may stray short distances, but the scope of their movement is limited. In the Sacramento River, adult Green Sturgeon begin their upstream spawning migrations into the San Francisco Bay in March and reach Knights Landing on the Sacramento River during April (Heublein et al., 2006).

Spawning

During spawning, green sturgeon show fidelity for individual rivers (Bemis and Kynard, 1997), and studies indicate that adults return to spawn every 3 to 5 years (Beamesderfer and Webb, 2002; Adams et al., 2002). Adult green sturgeon begin their upstream spawning migrations into the San Francisco Bay in March, reach Knights Landing during April, and spawn between March and July (Heublein et al., 2008). Based on the distribution of sturgeon eggs, larvae, and juveniles in the Sacramento River, CDFG (2002b) indicated that Green Sturgeon spawn in late spring and early summer above Hamilton City, possibly up to Keswick Dam (Brown, 2007). Israel and Klimley (2008) state that Green Sturgeon spawn in the mainstem from the confluence of Battle Creek to the area upstream of Molinos, but may also spawn below RBDD closer to GCID in some years. The upper and lower extent of the spawning area on the Sacramento River is not definitely known, but the lower extent is thought to be in the vicinity of Hamilton City. Opening of the RBDD gates during the winter run Chinook migration has likely benefited green sturgeon by re opening access to spawning areas (Adams et al., 2002), but the upper extent may be limited by coldwater temperatures in the Redding area. Embryos are negatively affected by temperatures at or below 57°F. In the laboratory, embryos thrived at temperatures between 62°F and 64°F, and hatching rates and the length of embryos began to decrease at 57°F (Van Eenennaam et al., 2001).

During flood flows in the Sacramento River system, returning adult green sturgeon are attracted by high flows in the Yolo and Sutter bypasses and move onto the floodplain and eventually concentrate behind Fremont and Tisdale Weirs, where they are blocked from further upstream migration. Agency biologists conduct rescues when fish become stranded behind the weirs (CDFG, 2011a).

The Feather River may also be an important spawning river (Moyle et al., 1995). Spawning in the Feather River was confirmed by DWR in 2011. Green sturgeon may have spawned elsewhere in the Sacramento-San Joaquin Basin before the development of major hydroelectric and water projects

(Adams et al., 2002). Habitat modeling identified potential habitat on the Feather River upstream of Oroville Dam that would have been suitable for sturgeon spawning and rearing prior to construction of the dam (Mora et al., 2009). This modeling also suggests sufficient conditions are present in the San Joaquin River to Friant Dam and in the tributaries, such as Stanislaus, Tuolumne, and Merced rivers upstream to their respective dams, although it is unknown whether green sturgeon ever inhabited the San Joaquin River or its tributaries. Other potential migration barriers include structures, such as the Red Bluff Diversion Dam (prior to its gates-open operation in 2012), Sacramento Deep Water Ship Channel locks, Sutter Bypass, and Delta Cross Channel gates on the Sacramento River, and Shanghai Bench and Sunset Pumps on the Feather River (Federal Register, 2006b).

Information on green sturgeon in the Trinity River system is limited. However, the Klamath River Basin is known to contain the largest spawning population of green sturgeon in California (Moyle, 2002). They have a complex anadromous life history, spending more time in the ocean than any other sturgeon. They migrate up the Klamath and Trinity rivers between late February and July to spawn. Gray's Falls (RM 43) is believed to be the upstream limit of sturgeon migration in the Trinity River. Klamath Basin green sturgeon spawn from March through July, peaking mid-April to mid-June (Emmett et al., 1991). Juveniles are found in the Trinity River near Willow Creek from June through September (USFWS, 1998), and appear to outmigrate during their first summer to the lower river or estuary, where they rear for some time before moving to the ocean (USFWS and Hoopa, 1999).

Little is known about sturgeon spawning habitat; they congregate in deep turbulent pools in the mainstem of rivers with gravel and sand substrates, but may also use areas with bedrock bottoms (UCD and DWR, 2010). Large numbers of eggs (6,000 to 140,000) are broadcast over the bottom where they settle and become entrained in the spaces between cobbles (Adams et al., 2002). Green sturgeon eggs are not as adhesive as white sturgeon eggs and likely depend more on pockets in the substrate to prevent getting swept downstream (Adams et al., 2002). Eggs sink rapidly to the bottom into cover; they do not drift (Kynard et al., 2005). Green sturgeon choose a spawning site based on fidelity for the site or its habitat characteristics. Eggs have been found (using artificial substrate mats) at depths ranging from 1.9 to 24.9 feet, with an average depth of 14.7 feet. In areas where eggs were found, the dominant substrate was medium-sized gravel (Poytress et al., 2009).

During incubation, water temperatures above 68ºF are lethal (Adams et al., 2002) and temperatures at or below 57ºF negatively affect embryos (Van Eenennaam et al., 2001). Eggs hatch in approximately seven to nine days at 59ºF, and the larvae develop into juvenile fish in approximately 45 days (Van Eenennaam et al., 2001). Green sturgeon juveniles are much less common in rotary screw traps in the Sacramento River in years when there is relatively low flow in the spring. This may be because fewer adults migrate upstream and spawn in low flow years (Poytress et al., 2009).

Rearing

Young Green Sturgeon appear to rear for the first 1 to 2 months in the Sacramento River between Keswick Dam and Hamilton City (CDFG, 2002b). Larval Green Sturgeon are captured at RBDD and the GCID fish facility between May and August, with peak capture at RBDD in June and July and at the GCID fish facility in July (Adams et al., 2002). Green Sturgeon larvae trapped at RBDD average 1.1 inches (2.9 cm) in length, while larvae trapped at the GCID fish facility average 1.4 inches (3.6 cm) (Adams et al., 2002), suggesting that larvae move downstream soon after hatching; however, it is not clear how long larval and juvenile Green Sturgeon remain in the middle Sacramento River.

Larvae and post-larvae are present in the lower Sacramento River and North Delta between May and October, primarily in June and July (CDFG, 2002b). Little is known of distribution and movements of young-of-the-year and riverine juveniles, but observations suggest they may be distributed primarily in the mainstem Sacramento River downstream of Anderson and in the brackish portions of the north and interior Delta (Israel and Klimley, 2008). Juvenile Green Sturgeon have been captured in the Delta during all months of the year (Borthwick et al., 1999, CDFG, 2002b). Catches of 1- and 2-year-old Southern DPS Green Sturgeon on the shoals in the lower San Joaquin River, at the CVP/SWP fish salvage facilities, and in Suisun and San Pablo bays indicate that some fish rear in the estuary for at least 2 years (CDFG, 2002b). Larger juvenile and subadult Green Sturgeon occur throughout the estuary, possibly temporarily, after spending time in the ocean (CDFG, 2002b, Kelly et al., 2006).

The rearing habitat preferences of Green Sturgeon larvae and juveniles in the Sacramento River are not well understood. Laboratory research has identified water temperature thresholds for larval Green Sturgeon. Water temperatures above 68°F (20°C) were found to be lethal to Green Sturgeon embryos by Cech et al. (2000), and temperatures above 63 to 64°F (17 to 18°C) were found to be stressful by Van Eenennaam et al. (2005). Cech et al. (2000) found that optimal growth of larvae occurred at 59°F (15°C), with growth slowing at temperatures below 52°F (11°C) and above 62°F (19°C).

While in the riverine environment, juveniles occupy low-light habitat and are active at night (Kynard et al., 2005). Older juveniles may be adapted to move through habitats with variable gradients of salinity, temperature, and dissolved oxygen (Kelly et al., 2006, Moser and Lindley, 2007). Their diet during their Sacramento River residence is unknown, but likely consists of drifting and benthic aquatic macroinvertebrates (Israel and Klimley, 2008).

Both larval and juvenile green sturgeon are susceptible to entrainment in pumps and diversions in the Delta and rivers. Screens designed to protect Chinook salmon and steelhead may not protect green sturgeon because of differences in swimming ability and size; however, the behavior of juvenile and larval green sturgeon in the river environment may decrease their encounters with diversions and pumps. For example, larval and juvenile sampling conducted at the RBDD experimental pumping plant (Reclamation, 1999 and 2001) indicates that entrainment of green sturgeon is rare. Screen criteria for green sturgeon have not been developed by NMFS or CDFG.

Estuarine Areas

Juveniles appear to spend one to four years in fresh water and estuarine water, and disperse into saltwater at lengths of 1 to 2.5 feet (Moyle et. al., 1995; Beamesderfer and Webb, 2002). Water temperatures of 59ºF are optimal for growth during this rearing stage (Adams et al., 2002). Green sturgeon juveniles feed on the abundant benthic invertebrates including shrimp and amphipods, small fish, and possibly mollusks.

Adults and subadults also occupy the San Francisco Bay, San Pablo Bay, Suisun Bay, and Sacramento-San Joaquin Delta. Adults and subadults primarily inhabit the Delta and bays during summer months, most likely for feeding and growth (Kelly et al., 2006; Moser and Lindley, 2007), but also enter the Delta and bays during their spring migration to the Sacramento River and during their winter outmigration from the Sacramento River to the ocean.

A diversity of depths is important to support different life stages and habitat uses for green sturgeon within estuarine areas. In a study of juvenile green sturgeon in the Delta, relatively large numbers of juveniles were captured primarily in shallow waters from 1 to 3 meters deep, indicating juveniles may require shallower depths for rearing and foraging (Radtke, 1966).

Nearshore and Marine

Subadult and adult sturgeon tagged in San Pablo Bay oversummer in bays and estuaries along the coast of California, Oregon, and Washington, between Monterey Bay and Willapa Bay, before moving farther north in the fall to overwinter north of Vancouver Island. Individual Southern DPS Green Sturgeon tagged by DFW in the San Francisco estuary have been recaptured off Santa Cruz, California; in Winchester Bay on the southern Oregon coast; at the mouth of the Columbia River; and in Grays Harbor, Washington (USFWS, 1996; Moyle, 2002). Most Southern DPS Green Sturgeon tagged in the San Francisco estuary have been returned from outside that estuary (Moyle, 2002).

Subadult and adult Green Sturgeon generally migrate north along the coast once they reach the ocean, concentrating in coastal estuaries like Willapa Bay, Grays Harbor, and the Columbia River estuary during summer (Adams et al., 2002). The strategy underlying summer visits to coastal estuaries is unclear because sampling indicates they have relatively empty stomachs, suggesting they may not be entering the estuaries to feed (Beamesderfer, 2000).

12A.1.5 Delta Smelt (*Hypomesus transpacificus*)

12A.1.5.1 Status

Currently, the delta smelt is listed as a Threatened species pursuant to the Endangered Species Act (ESA) by the USFWS (Federal Register, 1993b). In March 2006, a petition seeking to relist delta smelt as an endangered species was submitted to the USFWS. The USFWS issued a 12-month finding on the petition on April 7, 2010 indicating that reclassifying delta smelt from threatened to an endangered species is warranted, but precluded by other higher priority listing actions (Federal Register, 2010a).

Delta Smelt were historically one of the most common species in the San Francisco Estuary, but exhibited significant declines during the 1980s (CDFG, 2000). However, since 2000 the delta smelt, along with other pelagic[2] fish species, have experienced a substantial decline in population abundance (Sommer et al., 2007). The substantial declines in the delta smelt population in recent years, as well as declines in other pelagic fish species, have led to widespread concern regarding the pelagic fish community of the Bay-Delta. Several analyses by agencies and organizations, including the IEP, have focused on identifying the factors potentially influencing the status and abundance of delta smelt and other pelagic fish species within the Bay-Delta. Suspected causes being investigated by the IEP include: stock-recruitment effects, a decline in habitat quality, increased mortality rates, and reduced food availability.

Critical habitat for the delta smelt has been designated by USFWS within the Sacramento–San Joaquin River system (Federal Register, 1994b). Critical habitat for delta smelt is defined by the USFWS as:

> "Areas and all water and all submerged lands below ordinary high water and the entire water column bounded by and contained in Suisun Bay (including the contiguous Grizzly and Honker bays); the length of Goodyear, Suisun, Cutoff, First Mallard (Spring Branch), and Montezuma sloughs; and the existing contiguous waters contained within the Delta."

Upstream dams and Delta pumping plants affect delta smelt habitat by affecting flow, turbidity, and salinity within the Delta (Bay Delta Conservation Plan [BDCP], 2007). The upstream dams and the management of releases for flood control and water supply reduce the frequency and duration of high

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[2] Species occurring in the upper portion of open water, rather than close to the bottom or near the shore.

flows, which reduces turbidity and the transport of nutrients and organic matter. Low winter and spring outflow also increases the distance adult delta smelt must migrate to find suitable salinity levels for spawning. Low spring outflows also do not effectively transport larvae to downstream rearing areas. Water exports at the Delta SWP and CVP pumping plants reduce the abundance of zooplankton and phytoplankton by directly exporting them or reducing residence time in Delta channels. Delta SWP and CVP pumping plants also reduce the amount of rearing habitat available by shrinking the area having suitable salinity levels for delta smelt. Delta smelt juveniles are also susceptible to entrainment in the Delta pumping plants and mortality at fish salvage facilities. Other factors affecting delta smelt abundance include the introduction of non-native animal and plant species (e.g., *Corbula, Limnoitha, Egeria*), toxins, loss of habitat diversity, and Delta power plant cooling pumps (BDCP, 2007).

12A.1.5.2 General Biology and Life History

Delta smelt are a relatively small fish (2 to 4 inches long) and are endemic to the Sacramento-San Joaquin Delta. Typically, delta smelt live approximately one year. Some individuals live a second year and can reach lengths of 90 millimeters to 120 millimeters (Moyle, 2002). Overall, the Delta Smelt life cycle is completed in the brackish and tidal freshwater reaches of the upper San Francisco Estuary; however, salinity requirements vary by life stage (Moyle, 2002). They are a pelagic species, inhabiting open waters, away from the bottom and shore-associated structural features (Nobriga and Herbold, 2009). They live primarily in or just upstream of the low salinity zone between the freshwater and saltwater interface in the Bay-Delta. Suisun Bay is usually the vicinity of this mixing zone, although changes in stream flow can affect how far downstream low salinity waters occur (Moyle, 2002).

Distribution

Delta smelt are found within the Secondary and Extended study areas. Delta smelt spend their entire lifespan within the Bay-Delta. According to a recent review (Merz et al., 2011), the distribution of Delta Smelt includes an area from northern San Francisco Bay in the west, the confluence of the Sacramento and Feather rivers in the north, and the junction of Old and San Joaquin rivers in the south. The highest densities most frequently occur near the center of their range, which appears to extend from Suisun Marsh down through Grizzly Bay and east Suisun Bay through the confluence of the Sacramento and San Joaquin rivers, and into the lower portions of the Sacramento River, Cache Slough area, and the Sacramento Deepwater Ship Channel.

Their abundance and distribution have been observed to fluctuate substantially within and among years. Distribution and movements of all life stages are influenced by water transport associated with flows in the Bay-Delta, which also affect the quality and location of suitable open-water habitat (Feyrer et al., 2007; Nobriga et al., 2008). Smelt are short-burst swimmers that feed on plankton, and therefore, they are typically found in places with low water velocities where the water is cool and well oxygenated (Moyle, 2002). Water turbidity and salinity are also factors affecting their distribution.

Spawning

Delta Smelt are weakly anadromous and undergo a spawning migration from the low salinity zone to freshwater in most years (Grimaldo et al., 2009; Sommer et al., 2011). Spawning migrations occur between late December and late February, typically during “first flush” periods when inflow and turbidity increase on the Sacramento and San Joaquin Rivers (Grimaldo et al., 2009, Sommer et al., 2011). Notably, spawning movements are not always upstream. Under high outflow conditions, when total outflow exceeds 100,000 cubic feet per second (cfs), adult smelt tend to concentrate and spawn in Suisun

Bay, Cache Slough Complex, and Napa River (Hobbs et al., 2007; Sommer et al., 2011). During drier years, when total outflow is less than 20,000 cfs, smelt tend to concentrate and spawn in the Cache Slough Complex and western Delta.

Adult delta smelt begin their spawning migration into the upper Delta beginning in December or January. Adults migrate upstream from the brackish water estuarine areas into shallow fresh or slightly brackish waters in tidally influenced backwater sloughs and channel edge waters (Wang, 2010). Although the timing and duration varies, spawning generally takes place during March and April (Moyle, 2002). Although smelt can be found within a wide salinity range, from 0 to 18.4 parts per thousand (ppt) (Swanson et al., 2000), spawning occurs within in freshwater (Wang, 2010).

Delta Smelt are believed to spawn in shallow water along edges of rivers and sloughs subject to tidal influence (USFWS, 2001). Although the specific substrates or habitats used for spawning by Delta Smelt are not known, spawning habitat preferences of closely related species (Bennett, 2005) suggest that spawning may occur in shallow areas over sandy substrates. The adhesive eggs sink to the bottom and attach to substrates such as cattails, tules, tree roots, submerged branches, sand, and rocks in shallow waters (Moyle, 2002; Wang, 2010). Spawning apparently can occur at temperatures ranging from 45-72°F (7-22°C) (Moyle, 2002), but most often takes place between 45 and 59°F (7 and 15°C) (Wang, 2010). Temperatures optimal for embryo and larvae have not yet been determined, but it is likely that survival decreases as temperature increases beyond 64.4°F (Moyle, 2002). Embryonic development to hatching takes nine to 13 days at 58.64°F to 61.7°F (Moyle, 2002).

Newly hatched delta smelt have a large oil globule that makes them semi-buoyant, allowing them to maintain themselves just off the bottom (Moyle, 2002), where they feed on rotifers (microscopic crustaceans used by fish for food) and other microscopic prey. Once the swim bladder (a gas-filled organ that allows fish to maintain neutral buoyancy) develops, larvae become more buoyant and rise up higher into the water column. At this stage (16 millimeters to 18 millimeters [0.6 to 0.7 inch] total length), most are presumably washed downstream into the low salinity zone or the area immediately upstream of it (Moyle, 2002).

During high outflow periods, larvae are distributed more widely as the spawning range extends further west when Delta outflows are high (Hobbs et al., 2007). Dege and Brown (2004) found that larvae less than 20 mm rear 5 to 20 km upstream of X2 (Dege and Brown, 2004; Sommer and Mejia, 2013). As larvae grow and water temperatures increase in the Delta (to approximately 23°C), their distribution shifts towards the low salinity zone (Dege and Brown, 2004; Nobriga et al., 2008), where they circulate with the abundant zooplankton (Moyle, 2002). By fall, the centroid of Delta Smelt distribution is tightly coupled with X2 (Sommer et al., 2011; Sommer and Mejia, 2013).

Rearing

Larval and juvenile delta smelt rear within the Bay-Delta for a period of approximately 6 to 9 months (Moyle, 2002). Young smelt tend to feed on immature stages of calanoid copepods, and adult smelt may feed on all life stages, as well as other large planktonic organisms. Growth is rapid, and juvenile fish are 30 millimeters to 40 millimeters (1.2 to 1.6 inches) long after 70 days (Nobriga and Herbold, 2009). The most rapid growth occurs when they reach 30 millimeters fork length and are large enough to prey on a wider variety of food sources.

Larval and juvenile smelt need a shallow food-rich nursery habitat for survival., Adequate flow and suitable water quality is required for transport of juveniles downstream to rearing habitat (Moyle, 2002).

The specific geographic area critical to the maintenance of suitable rearing habitat for Delta Smelt extends eastward from Carquinez Strait, up the Sacramento River to its confluence with Three Mile Slough, and south along the San Joaquin River including Big Break (USFWS, 1996). Within this area, Delta Smelt typically rear in shallow (less than 10 feet [3 m]), open estuarine waters (Moyle, 2002), in salinities ranging from 2-7 ppt (Swanson and Cech, 1995) where "fresh and brackish water mix and hydrodynamics are complex as a result of the meeting of tidal and riverine currents" (Moyle, 2002). These conditions are typically most common in Suisun Bay, which provides vital nursery habitat for Delta Smelt. When the mixing zone is located in Suisun Bay, it provides optimal conditions for algal and zooplankton growth, an important food source for Delta Smelt (Moyle, 2002). When freshwater outflow is low, the mixing zone moves further up into the deeper, narrow channels of the Delta and Sacramento River, reducing food availability and total area available to the smelt (Moyle, 2002).

12A.1.6 Longfin Smelt (*Spirinchus thaleichthys*)

12A.1.6.1 Status

Longfin smelt are listed by CDFG as a threatened species pursuant to CESA. Its status remains unresolved at the federal level. In August 2007, USFWS was petitioned to list longfin smelt as endangered. On April 9, 2009, USFWS found that the Delta population did not meet the definition of a DPS, and as a result, did not warrant listing as a DPS. The Center for Biological Diversity challenged the merits of this determination. In 2011, USFWS entered into a settlement agreement with the Center for Biological Diversity and agreed to conduct a rangewide status review and prepare a 12-month finding to be published by September 30, 2011. The 12-month finding on the petition to list the San Francisco Bay-Delta population of the Longfin Smelt as endangered or threatened was completed in March 2012. USFWS determined that listing the Longfin Smelt rangewide was not warranted at the time, but that listing the Bay-Delta DPS of Longfin Smelt was warranted but precluded by other higher priority listing actions (Federal Register, 2012b).

Longfin smelt were once one of the most common fish species in the Delta. However, Longfin Smelt numbers in the Bay-Delta have declined significantly since the 1980s (Rosenfield and Baxter, 2007, Baxter et. al., 2010). Rosenfield and Baxter (2007) confirmed the positive correlation between Longfin Smelt abundance and freshwater flow that had been previously documented by others (Stevens and Miller 1983; Baxter, 1999a; Kimmerer, 2002), noting that abundances of both adults and juveniles were significantly lower during the 1987–94 drought than during either the pre- or post-drought periods. Abundance of Longfin Smelt has remained low since 2000, even though freshwater flows increased during several of these years (Baxter et al., 2010). Abundance indices derived from the FMWT, Bay Study Midwater Trawl, and Bay Study Otter Trawl show marked declines in Longfin Smelt populations from 2002 to 2009. Longfin Smelt abundance over the last decade is the lowest recorded in the 40-year history of CDFG's FMWT monitoring surveys (Federal Register, 2012b).

Research on declines of Longfin Smelt and other pelagic fish species in the Bay Delta since 2002 (referred to as pelagic organism decline) have most recently been summarized in the Interagency Ecological Program 2010 Pelagic Organism Decline Work Plan and Synthesis of Results (Baxter et al., 2010). Although there is substantial uncertainty about the causal mechanisms underlying the pelagic organism decline, reduced Delta freshwater flows have been identified as one of several key factors believed to contribute to recent declines in the abundance of Longfin Smelt (Baxter et al., 2010).

12A.1.6.2 General Biology and Life History

Longfin smelt in California are anadromous. Adults and juveniles can be found in the open waters of estuaries, mostly in the middle or at the bottom of the water column (Moyle, 2002). Most longfin smelt have a relatively short lifespan of two to three years. Longfin Smelt spend approximately 21 months of their life in brackish or marine waters (Baxter, 1999a; Dege and Brown, 2004). In the Bay-Delta, most Longfin Smelt spend their first year in Suisun Bay and Marsh. The remainder of their life is spent in the San Francisco Bay or the Gulf of Farallones (Moyle, 2008). Based on monthly survey results, Rosenfield and Baxter (2007) inferred that the majority of Longfin Smelt from the Bay-Delta migrate out of the estuary after the first winter of their life cycle and return during late fall to winter of their second year.

Longfin smelt can tolerate a broad range of salinity concentrations. Juvenile and adult Longfin Smelt have been found throughout the year in salinities ranging from pure fresh water to pure seawater, although once past the juvenile stage, they are typically collected in waters with salinities ranging from 14 to 28 ppt (Baxter, 1999a). Within the Delta, adult Longfin Smelt occupy water at temperatures from 16 to 20°C (61 to 68°F) and spawn in water with temperatures from 5.6 to 14.5°C (41 to 58°F) (Wang, 2010).

Distribution

Longfin smelt are found within the Secondary and Extended study areas. The Bay-Delta population of longfin smelt is the southernmost along the United States' Pacific coast (Moyle, 2002). In contrast to delta smelt, longfin smelt juveniles and adults are broadly distributed and inhabit the more saline regions of the Bay-Delta and nearshore coastal waters. Merz et al. (2013) utilized recently available sampling data (~1959-2012) from the Interagency Ecological Program and regional monitoring programs to provide a comprehensive description of the range and temporal and geographic distribution of Longfin Smelt by life stage within the San Francisco Estuary. Observations occurred as far west as Tiburon in Central San Francisco Bay and south as far as the Dumbarton Bridge in South San Francisco Bay; north as far as the town of Colusa on the Sacramento River and east as far as Lathrop on the San Joaquin River. Longfin smelt were also observed in seasonally-inundated habitat of the Yolo Bypass and in tributaries like the Napa and Petaluma rivers, Cache Slough, and the Mokelumne River (Merz et al., 2013).

Spawning

Longfin Smelt congregate in deep waters near the low salinity zone near X2 during the spawning period, and they likely make short runs upstream, possibly at night, to spawn from these locations (CDFG, 2009; Rosenfield, 2010). Longfin Smelt have been observed in their winter and spring spawning period as far upstream as Isleton in the Sacramento River, Santa Clara shoal in the San Joaquin system, Hog Slough off the South-Fork Mokelumne River, and Old River south of Indian Slough (CDFG, 2009). Merz et al. (2013) found that adults were frequently detected in the central regions (from Carquinez Straight upstream to the Confluence), adults were also detected relatively frequently upstream of the Sacramento-San Joaquin confluence.

Both adult and larval Longfin Smelt were detected relatively frequently upstream of the confluence, unlike the juvenile and subadult life stages, likely indicating that Longfin Smelt spawning habitat extends further upstream into freshwater areas than rearing habitat. Spawning adults appear to be able to disperse into upper Delta reaches and into San Francisco Bay as well. The presence of adult Longfin Smelt in San Francisco Bay during the spawning period likely relates to years with high Delta inflows, when low salinity habitat shifted westward (Merz et al., 2013).

Longfin Smelt in the Delta may spawn as early as November and as late as June, although spawning typically occurs from January to April (CDFG, 2009, Moyle, 2002). The adhesive eggs are deposited on rocks or aquatic plants in the freshwater sections of bays and river deltas. Baxter et al. (2010) found that female Longfin Smelt produced between 1,900 and 18,000 eggs, with fecundity greater in fish with greater lengths. The embryos hatch in approximately 40 days at 44.6°F (Moyle, 2002). Newly hatched larvae are 5 millimeters to 8 millimeters long and are buoyant.

Rearing

Larval Longfin Smelt less than 12 mm (0.5 inch) in length are buoyant because they have not yet developed an air bladder; as a result, they occupy the upper one-third of the water column. Longfin Smelt develop an air bladder at approximately 12 to 15 mm (0.5 to 0.6 inch) in length and are able to migrate vertically in the water column. At this time, they shift habitat and live in the bottom two-thirds of the water column (CDFG, 2009). Longfin Smelt are dispersed broadly in the Delta by high flows and currents, which facilitate transport of larvae and juveniles long distances. Longfin Smelt larvae are dispersed farther downstream during high freshwater flows (Dege and Brown, 2004). Longfin Smelt larvae were detected relatively frequently upstream of the Sacramento-San Joaquin confluence; greater than 73 percent of the time in the Lower Sacramento, Upper Sacramento, Cache Slough and Ship Channel, and Lower San Joaquin regions, and greater than 31 percent of the time in the East Delta and South Delta regions during the smelt larval surveys (Merz et al., 2013).

The distribution of young-of-the year smelt largely coincides with that of the larvae (Baxter, 1999a; Moyle, 2002). There is a strong positive correlation between winter and spring Delta outflow and longfin smelt abundance the following year. There is also a strong correlation between juvenile survival and Delta outflow, as well as the position of X2 (the location in the Delta at which salinity equals 2 ppt) (Moyle, 2002). Strong Delta outflow appears to benefit longfin smelt survival because higher flows transport longfin smelt young to more suitable rearing habitat in Suisun and San Pablo bays (Moyle, 2002).

12A.1.7 Pacific Lamprey (*Lampetra tridendata*)

The Pacific Lamprey is a widely distributed anadromous species found in river systems along the northern margin of the Pacific Ocean from central Baja California north along the west coast of North America to the Bering Sea in Alaska (Ruiz-Campos and Gonzales-Guzman 1996, Lin et al., 2008). The Pacific lamprey is found within the Primary, Secondary, and Extended study areas.

12A.1.7.1 Status

The USFWS received a petition to list the Pacific lamprey pursuant to FESA as either threatened or endangered in January 2003 (Klamath-Siskiyou Wildlands Center et al., 2003). The petition was declined by USFWS in 2004 because of insufficient evidence that listing was warranted (Federal Register, 2004c). The Pacific lamprey is considered a species of special concern by CDFW (2016).

In recent years, state, federal, and tribal agencies have expressed concern at the apparent decline of lamprey populations in the Northwestern United States (Close et al., 2002; Moser and Close, 2003; CRBLTW, 2005). Widespread anecdotal accounts of decreased Pacific Lamprey spawning and carcasses have been supported by a substantial reduction in counts of migrating individuals at dams since the late 1960s (Moser and Close, 2003, Klamath-Siskiyou Wildlands Center et al., 2003). Very few data on Pacific Lamprey populations are available to assess status in the Sacramento-San Joaquin Basin; however, loss of access to historical habitat throughout California indicates that populations may be greatly suppressed compared with historical levels (Moyle et al., 2009).

12A.1.7.2 General Biology and Life History

Pacific Lamprey are anadromous, rearing in freshwater before outmigrating to the ocean, where they grow to full size prior to returning to their natal streams to spawn. Pacific Lamprey are thought to remain in the ocean for approximately 18 to 40 months before returning to freshwater as sexually immature adults, typically from late winter until early summer (Kan, 1975, Beamish, 1980). After entering freshwater from the ocean, adult Pacific Lamprey typically spend approximately 1 year in freshwater prior to spawning (Robinson and Bayer, 2005; Clemens et al., 2009; Stillwater Sciences, 2010; Lampman, 2011).

Ocean Residence

Pacific lampreys are predatory as adults in the ocean and estuary, latching onto large fish and extracting blood and body fluids through a hole it creates with its rasp like tongue. adult Pacific Lamprey feed parasitically on a variety of marine and anadromous fishes such as salmon, flatfish, rockfish, and pollock. Pacific Lamprey are preyed upon by sharks, sea lions, and other marine animals (Richards and Beamish, 1981; Beamish and Levings, 1991; Close et al., 2002), and have been captured in depths from 300 to 2,600 feet and as far as 62 miles off the coast (USFWS, 2007).

Freshwater Residence

The adult freshwater residence period can be divided into three distinct stages: (1) Initial migration from the ocean to holding areas, (2) pre-spawning holding, and (3) secondary migration to spawn (Robinson and Bayer, 2005; Clemens et al., 2010, 2012).

The initial migration from the ocean to upstream holding areas occurs from approximately January until early August (Stillwater Sciences, 2010; McCovey, 2011; Clemens et al., 2012). In the Eel River and the nearby Klamath River, where ample information exists, entry into freshwater from the ocean generally begins in January and ends by June (Petersen-Lewis, 2009; McCovey, 2011; Stillwater Sciences, 2010). Most individuals cease upstream migration by mid-July, although some individuals continue moving into August (McCovey, 2011). Data from mid-water trawls in Suisun Bay and the lower Sacramento and San Joaquin rivers indicate that adults likely migrate into the Sacramento-San Joaquin Basin from late winter through early summer (Hanni et al., 2006).

The pre-spawning holding stage begins when individuals cease upstream movement in the summer, and continues until fish began their secondary migration to spawn, generally in late winter or early spring (Robinson and Bayer, 2005; McCovey, 2011). During this holding period, most fish remain stationary throughout the summer and fall, but some individuals undergo additional upstream movements in the winter following high flow events (Robinson and Bayer, 2005; McCovey, 2011). In the Sacramento River, adults, likely either in the holding or spawning stage, have been detected at GCID from December through July and nearly year-round at RBDD (Hanni et al., 2006). It is expected that adult Pacific Lamprey with varying levels of sexual maturity are present in the Sacramento-San Joaquin Basin throughout the year.

After the pre-spawning holding period, individuals undergo a secondary migration from holding areas to spawning areas. This migration generally begins in late winter and continues through July, by which time most individuals have spawned and died (Robinson and Bayer, 2005; Stillwater Sciences, 2010;

Lampman, 2011). During this secondary migration, movement to spawning areas can be both upstream and downstream (Robinson and Bayer, 2005; Lampman, 2011).

Spawning

Spawning typically takes place from March through July depending on water temperature and local conditions such as seasonal flow regimes (Kan, 1975; Brumo et al., 2009; Gunckel et al., 2009). Hannon and Deason (2007) have documented Pacific Lamprey spawning in the American River between early January and late May, with peak spawning typically occurring in early April. Spawning occurs in both the mainstem of medium-sized rivers and smaller tributaries (Luzier et al., 2006, Brumo et al., 2009, Gunckel et al., 2009), and generally takes place in pool and run tailouts and low gradient riffles. Spawning substrate size typically ranges from approximately 25 to 90 mm (1.0 to 3.5 inches), with a median of 48 mm (1.9 inches) (Gunckel et al., 2009). Water velocity above redds ranges from 0.2 to 1.0 meters per second (m/s) (median 0.6 m/s), and depth varies from approximately 0.2 to 1.1 meter (m) (0.7 to 3.6 feet) (Gunckel et al., 2009).

Depending on water temperature, hatching occurs in approximately 2 to 3 weeks, and yolk-sac larvae known as prolarvae remain in redd gravels for approximately 2 to 3 more weeks before emerging at night as 8-to-9-mm larvae, and drift downstream to rear in depositional areas (Meeuwig et al., 2005, Brumo 2006). Pacific Lamprey typically die soon after spawning (Kan, 1975; Brumo 2006), although there is some anecdotal evidence that this is not always the case (Moyle, 2002; Michael, 1980; Michael, 1984).

Juvenile Rearing and Outmigration

After larvae emerge from redds drifting downstream, the eyeless, toothless larvae known as ammocoetes settle out of the water column and burrow into fine silt and sand substrate in low-velocity, depositional areas such as pools, alcoves, and side channels (Moore and Mallatt, 1980; Torgensen and Close, 2004; Stone and Barndt, 2005). Ammocoete presence has also been shown to be associated with presence of woody debris (Roni, 2003; Graham and Brun, 2006). Rearing Pacific Lamprey ammocoetes appear to prefer rearing temperatures below 68°F (20 degrees Celsius [°C]) (BioAnalysts, Inc., 2000); and temperatures above 82.4°F (28°C) result in mortality of ammocoetes (van de Wetering and Ewing, 1999). Depending on factors influencing their growth rates, they remain in this habitat from 4 to 10 years, filter-feeding on algae and detrital matter prior to metamorphosing into an adult form (Pletcher, 1963; Moore and Mallatt, 1980; Beamish and Levings, 1991; van de Wetering, 1998). During the ammocoete stage, individuals may periodically move and relocate in response to changing water levels, channel adjustments, or substrate movements (Umpqua Land Exchange Project [ULEP], 1998). These factors generally result in a gradual downstream movement that may lead to higher densities in downstream reaches (Richards, 1980).

During metamorphosis, individuals develop eyes, a suctoral disc, sharp teeth, and more-defined fins (McGree et al., 2008). After metamorphosis, smolt-like individuals known as macropthalmia migrate to the ocean—typically in conjunction with high-flow events between fall and spring (van de Wetering 1998). Data from rotary screw trapping at sites in the Sacramento-San Joaquin Basin indicate that emigration of Pacific Lamprey macropthalmia peaks from early winter through early summer; however, some outmigration has been observed year-round in the mainstem Sacramento River at both RBDD and GCID (Hanni et al., 2006). When abundant, outmigrating Pacific Lamprey may act to buffer predation on juvenile and smolt salmon because they are easier to capture than salmonids (Close et al., 2002).

12A.1.8 River Lamprey (*Lampetra ayresi*)

River Lamprey are found in large coastal streams from just north of Juneau, Alaska, to the San Francisco Bay (Vladykov and Follett, 1958, Wydoski and Whitney, 1979). The Sacramento and San Joaquin basins are at the southern edge of their range (Moyle et al., 2009). The river lamprey is found within the Primary, Secondary, and Extended study areas.

12A.1.8.1 Status

USFWS received a petition to list river lamprey pursuant to FESA as either threatened or endangered in January 2003 species (Klamath-Siskiyou Wildlands Center et al., 2003). In December 2004, USFWS found that there was not substantial information that listing of river lamprey was warranted (Federal Register, 2004c). The river lamprey is considered a species of special concern by CDFW (2016).

Little is known regarding their abundance and distribution within California; they seem to be primarily associated with the lower portions of certain large river systems, and most records for the state are from the lower Sacramento-San Joaquin system, especially the Stanislaus and Tuolumne rivers (Moyle et al., 1995, Moyle, 2002). In the Sacramento River, they have been documented upstream to at least Red Bluff Diversion Dam (RBDD) (Hanni et al., 2006; Moyle et al., 2009). River Lamprey have also been collected in the Feather River, American River, Mill and Cache creeks (Vladykov and Follett, 1958; Hanni et al., 2006; Moyle et al., 2009). River Lamprey have not been documented during rotary screw trapping efforts in Clear, Battle, and Deer creeks, or in the Yuba River (Hanni et al., 2006). Other streams where they have been found in California outside of the Central Valley include the Napa and Russian rivers, and Alameda, Sonoma, and Salmon creeks (DWR et al., 2013). Quantitative data on populations are extremely limited, but loss and degradation of historical habitats suggest populations may have declined (Moyle et al., 2009).

12A.1.8.2 General Biology and Life History

Adult River Lamprey migrate from the ocean into spawning areas in the fall. Adults of both sexes construct nests in gravel at the upstream end of riffles (Wydoski and Whitney, 1979; Beamish and Youson, 1987; Moyle, 2002). Eggs are deposited and fertilized in these depressions, after which the adults typically die, similar to other species of lampreys. In the Sacramento-San Joaquin basin of California, most spawning is believed to occur in April and May (Vladykov and Follett, 1958; Scott and Crossman, 1973) at temperatures of about 55 to 56°F (Wang, 2010).

After hatching, young ammocoetes drift downstream to settle in the silt-sand substrates of backwaters, eddies, and pools, where they remain burrowed for approximately 3 to 5 years (Moyle, 2002). At this stage, they are filter feeders, with a diet consisting of algae (primarily diatoms) and other organic detritus and microorganisms (Wydoski and Whitney, 1979). Good water quality and temperatures not exceeding 77°F are believed to be necessary for their survival (Moyle, 2002). Their metamorphosis into adults begins in July when they reach about 12 cm (4.7 in) (Beamish, 1980), and is not complete for about 9 to 10 months until around April the following spring. This is a more extended period of metamorphosis than observed in other lamprey species. During this time, they are believed to live in deep waters of the river channel. Just prior to the completion of metamorphosis, the juvenile lampreys (macropthalmia) congregate immediately upstream of salt water and enter the estuary or ocean from May to July (Beamish and Youson, 1987).

Adults spend 3 to 4 months in salt water, remaining close to shore and growing to lengths of about 25 to 31 cm. In the estuary or ocean, River Lamprey are obligate parasites, typically killing their host in the process of feeding. They most commonly parasitize fishes 10 to 30 cm long, feeding near the surface on smelt, herring, and mid-size salmonids (Beamish, 1980; Roos et al., 1973; Beamish and Neville, 1995). In the fall, adults migrate back upstream into spawning areas and cease to feed. Fidelity to the streams in which they were spawned remains unknown.

The species is expected to use Delta habitats primarily as a migration corridor (DWR et al., 2013), and have been collected in Suisun Bay, Montezuma Slough, and Delta sloughs during California Department of Fish and Wildlife (DFW) plankton sampling efforts. CVP and SWP salvage data indicate that they are found in the salvage primarily from December through March (DWR et al., 2013). Juveniles are weak swimmers, frequently becoming entrained in water diversions or turbine intakes of hydroelectric projects or becoming impinged on screens meant to bypass juvenile salmonids or other fish (USFWS, 2007).

12A.1.9 Sacramento Splittail (*Pogonichthys macrolepidotus*)

12A.1.9.1 Status

USFWS listed Sacramento Splittail as a threatened species on March 10, 1999, because of the reduction in its historical range and because of the large population decline during the 1987-93 drought (USFWS, 1996, Federal Register, 1999c). On June 23, 2000, the Federal Eastern District Court of California found the final rule to be unlawful and on September 22, 2000, remanded the determination back to USFWS for a reevaluation of the final decision. After a thorough review, USFWS removed the Sacramento Splittail from the list of threatened species (Federal Register, 2003) and reaffirmed this decision in 2010 (Federal Register, 2010b).

12A.1.9.2 General Biology and Life History

Distribution

Sacramento Splittail are endemic to the Sacramento and San Joaquin River systems of California, including the Delta and the San Francisco Bay. Historically, splittail were found in the Sacramento River as far upstream as Redding, in the Feather River to Oroville, and in the American River upstream to Folsom. In the San Joaquin River, they were once documented as far upstream as Friant (Rutter 1908). Splittail are thought to have originally ranged throughout the San Francisco estuary, with catches reported by Snyder (1905) from southern San Francisco Bay and at the mouth of Coyote Creek.

Splittail are largely absent from the upper river reaches where they formerly occurred, residing primarily in the lower parts of the Sacramento and San Joaquin rivers and tributaries and in Central Valley lakes and sloughs (Moyle, 2002, Moyle et al., 2004). In wet years, however, they have been known to ascend the Sacramento River as far as RBDD and into the lower Feather and American rivers (Baxter et al., 1996; Sommer et al., 1997; Baxter, 1999b, 2000). The Sutter and Yolo bypasses along the lower Sacramento River appear to be important splittail spawning areas (Sommer et al., 1997). In wet years, Sacramento Splittail have been found in the San Joaquin River as far upstream as Salt Slough (Saiki, 1984, Baxter, 1999b, Brown and Moyle, 1993, Baxter, 2000) and in the Tuolumne River as far upstream as Modesto (Moyle, 2002), where the presence of both adults and juveniles during wet years in the 1980s and 1990s indicated successful spawning.

Non-breeding Adults

Non-reproductive adult splittail are most abundant in moderately shallow, brackish areas, but can also be found in freshwater areas with tidal or riverine flow (Moyle et al., 2004). Because splittail are adapted for living in brackish waters with fluctuating conditions, they are tolerant of high salinities and low dissolved oxygen (DO) levels. Splittail are often found in salinities of 10 to 18 ppt, although lower salinities may be preferred (Meng and Moyle, 1995) and can survive low DO levels (0. 6 to 1.2 milligrams per liter for young-of-the-year, juveniles, and subadults) (Young and Cech, 1995, 1996). Non-breeding splittail are found in temperatures ranging from 5 to 24°C, depending on the season, and acclimated fish can survive temperatures up to 33°C for short periods (Young and Cech, 1996). Juveniles and adult splittail demonstrate optimal growth at 20 degrees Celsius (ºC) and signs of physiological distress only above 29ºC (Young and Cech, 1995).

Spawning

Adults typically migrate upstream from brackish areas in January and February and spawn in fresh water on inundated floodplains in March and April (Moyle et al., 2004). Foraging in flooded areas along the main rivers, bypasses, and tidal freshwater marsh areas of Montezuma and Suisun sloughs and San Pablo Bay before the onset of spawning may contribute to spawning success and survival of adults after spawning (Moyle et al., 2004). Splittail are adapted to the wet-dry climatic cycles of Northern California and thus concentrate their reproductive effort in wet years when potential success is enhanced by the availability of inundated floodplain (Meng and Moyle, 1995, Sommer et al., 1997).

When spawning, splittail can be found in the lower reaches of rivers and flooded areas. Otherwise they are primarily confined to the Delta, Suisun Bay, Suisun Marsh, the lower Napa River, the lower Petaluma River, and other parts of the San Francisco estuary (Meng et al., 1994, Meng and Moyle, 1995). In general, splittail are most abundant in Suisun Marsh, especially in drier years (Meng and Moyle, 1995), and reportedly rare in southern San Francisco Bay (Leidy, 1984). Splittail abundance appears to be highest in the northern and western Delta when population levels are low, and they are more evenly distributed throughout the Delta during successful year classes (Sommer et al., 1997, Moyle, 2002).

Rising flows appear to be the major trigger for splittail spawning, but increases in water temperature and day length may also be factors (Moyle et al., 2004). Spawning typically occurs on inundated floodplains from February through June, with peak spawning in March and April. Information indicates that splittail spawn in open areas with moving, turbid water less than 5 feet (1.5 m) deep, among dense annual vegetation and where water temperatures are below 15°C (Moyle et al., 2004).

Splittail eggs are deposited in flooded areas among submerged vegetation, to which they adhere until hatching. Splittail eggs begin to hatch within 3 to 7 days, depending on temperature (Bailey, 1994). Eggs laid in clumps hatch more quickly than individual eggs (Moyle et al., 2004). Little is known regarding the tolerance of splittail eggs and developing larvae to DO, temperature, pH, or other water quality parameters, or to other factors such as physical disturbance or desiccation.

Larvae and Juveniles

Within 5 to 7 days after hatching, swim bladder inflation occurs, and larvae begin active swimming and feeding (Moyle, 2002). After emergence, most larval splittail remain in flooded riparian areas for 10 to 14 days, most likely feeding among submerged vegetation before moving off floodplains into deeper water as they become stronger swimmers (Sommer et al., 1997, Wang, 2010). Floodplain habitat offers high food quality and production and low predator densities to increase juvenile growth. Although juvenile splittail rear in upstream areas for a year or more (Baxter, 1999b), most move to tidal waters after only a few weeks, often in response to flow pulses (Moyle et al., 2004). The majority of juveniles move downstream into shallow, productive bay and estuarine waters from April to August (Meng and Moyle, 1995). Growth likely depends on the availability of high-quality food, especially in the first year of life (Moyle et al., 2004).

12A.1.10 Hardhead (*Mylopharodon concephalus*)

Hardhead are a California Species of Special Concern (CDFW, 2016). They are a member of the minnow family, Cyprinidae, and are similar in appearance to the Sacramento pikeminnow (Moyle, 2002). Hardhead exist throughout the Sacramento-San Joaquin River Basin and are fairly common in the Sacramento River and in the lower reaches of the American and Feather rivers, but in other parts of their range, populations have declined or have become increasingly isolated (Moyle, 2002). Hardhead can also inhabit reservoirs and are abundant in a few impoundments where water level fluctuations prevent bass from reproducing in large numbers (Moyle, 2002). Hardhead tend to be absent from areas that have been highly altered (Moyle et al., 1995) or that are dominated by introduced fish species, especially centrarchids (species of the sunfish family) (Moyle et al., 1995). Hardhead are omnivorous; their diet consists mostly of benthic invertebrates and aquatic plants, but also includes drifting insects. In reservoirs, hardhead also prey upon zooplankton (Moyle et al., 1995).

Hardhead spawn mainly in April and May, but some may spawn as late as August in the foothill regions of the upper San Joaquin River (Wang, 2010). They migrate upstream and into tributary streams as far as 45 miles to spawning sites. Spawning behavior has not been documented, but it is assumed to be similar to that of the pikeminnow, which deposit their eggs over gravel-bottomed riffles, runs, and at the head of pools (Moyle et al., 1995). Spawning substrates may also include sand and decomposed granite (Wang, 2010).

Optimal temperatures for hardhead appear to be between 75°F and 82°F (Moyle et al., 1995), although hardhead inhabit portions of the Sacramento River upstream of RBDD (USFWS, 2002) where temperatures are maintained at approximately 56°F.

12A.1.11 Eulachon (*Thaleichthys pacificus*)

Eulachon are anadromous fish that occur 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 (Scott and Crossman, 1973, Willson et al., 2006). Spawning occurs in gravel riffles, with hatching about a month later. The larvae generally move downstream to the estuary following hatching.

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 (Federal Register, 2009). On March 18, 2010, NMFS listed the southern DPS of Pacific Eulachon as threatened under the ESA (Federal Register, 2010c); critical habitat was designated in 2011 (Federal Register, 2011). The Klamath River is near the southern limit of the range of Eulachon (Eulachon BRT, 2010).

Large spawning aggregations of Pacific Eulachon used to regularly occur in the Klamath River (Fry, 1979), migrating in March and April to spawn, but they rarely moved more than 8 miles inland (NRC, 2004). DFW sampled in the Klamath River from 1989 to 2003 with no Pacific Eulachon captures (U. S. Department of the Interior [USDI] and CDFG, 2011). The Yurok Tribe sampled extensively for Pacific Eulachon in early 2011, and although tribal fishermen did not capture Pacific Eulachon from the Klamath River itself, they did recover Pacific Eulachon from the surf zone at the mouth of the river (USDI and CDFG, 2011).

12A.1.12 Southern Resident Killer Whale (*Orcinus orca*)

12A.1.12.1 Status

Three distinct forms of Killer Whales, termed residents, transients, and offshores, are recognized in the northeastern Pacific Ocean. Resident Killer Whales in U.S. waters are distributed from Alaska to California, with four distinct communities recognized: Southern, Northern, Southern Alaska, and Western Alaska (Krahn et al., 2002, 2004). Some evidence suggests that until the mid- to late-1800s, the Southern Resident Killer Whale population may have numbered more than 200 animals (Krahn et al., 2002). This estimate was based, in part, on a recent genetic analysis of microsatellite DNA, which found that the genetic diversity of the Southern Resident population resembles that of the Northern Residents (Barrett-Lennard, 2000, Barrett-Lennard and Ellis, 2001), and concluded that the two populations were possibly once similar in size. Recent efforts to assess the Killer Whale population during the past century have been hindered by an absence of empirical information prior to 1974 (NMFS, 2006).

Of the four distinct communities of resident killer whales recognized, only the Southern Resident Distinct DPS is listed as endangered (Federal Register, 2005c). The Southern DPS primarily occurs in the inland waters of Washington state and southern Vancouver Island, particularly during the spring, summer, and fall, but members of the 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, Federal Register, 2005c).

Designated critical habitat for Southern Resident DPS Killer Whale (Federal Register, 2006c) does not overlap with the study areas for this EIR/EIS, nor are there any discernible changes to the physical environment that occur within designated critical that could be correlated to Project operations. The only potential effects of Project operations on the identified physical or biological features essential to conservation would be to prey quantity, quality, and availability. Project operations have the potential to affect only a portion of juvenile salmon originating in California’s Central Valley streams. Salmon originating in California streams are estimated to contribute between 3 and 5 percent of the salmon population off the Washington coast based on analysis of troll catches. These estimates were made based on data collected during the time of year when the Southern Residents are present. The majority of the fish attributed to California streams that are affected by the Project are expected to be hatchery fish.

12A.1.12.2 General Biology and Life History

Southern Resident Killer Whales spend a significant portion of the year in the inland waterways of the Strait of Georgia, Strait of Juan de Fuca, and Puget Sound, particularly during the spring, summer, and fall, when all three pods are regularly present in the Georgia Basin (defined as the Georgia Strait, San Juan Islands, and Strait of Juan de Fuca) (Heimlich-Boran, 1988, Felleman et al., 1991, Olson, 1998, Osborne, 1999). The Southern Resident population consists of three pods, identified as J, K, and L pods. Typically, K and L pods arrive in May or June and spend most of their time in this core area until departing in October or November. During this time, both pods also make frequent trips lasting a few days to the outer coasts of Washington and southern Vancouver Island (Ford et al., 2000). J pod continues to spend intermittent periods of time in the Georgia Basin and Puget Sound during late fall, winter, and early spring.

While the Southern Residents are in inland waters during the warmer months, all of the pods concentrate their activities in Haro Strait, Boundary Passage, the southern Gulf Islands, the eastern end of the Strait of Juan de Fuca, and several localities in the southern Georgia Strait (Heimlich-Boran, 1988, Felleman et al., 1991, Olson, 1998, Ford et al., 2000). In general, they spend less time elsewhere, including other sections of the Georgia Strait, Strait of Juan de Fuca, and San Juan Islands, Admiralty Inlet west of Whidbey Island, and Puget Sound. Individual pods are similar in their preferred areas of use (Olson, 1998), although there are some seasonal and temporal differences in certain areas visited by each pod (Hauser, 2006). For example, J pod visits Rosario Strait more frequently than K or L pods (Hauser, 2006). The movements of Southern Resident Killer Whales relate to those of their preferred prey—salmon. Pods commonly seek out and forage in areas where salmon occur, especially those associated with migrating salmon (Heimlich-Boran, 1986, 1988; Nichol and Shackleton, 1996). Notable locations of particularly high use include Haro Strait and Boundary Passage, the southern tip of Vancouver Island, Swanson Channel off North Pender Island, and the mouth of the Fraser River delta, which is visited by all three pods in September and October (Felleman et al., 1991; Ford et al., 2000). These sites are major corridors for migrating salmon.

Wild female Southern Resident Killer Whales give birth to their first surviving calf between the ages of 12 and 16 years (mean = about 14.9 years) (Olesiuk et al., 1990; Matkin et al., 2003). Females produce an average of 5.4 surviving calves during a reproductive life span lasting about 25 years (Olesiuk et al., 1990). Males become sexually mature at body lengths ranging from 5.2 to 6.4 meters, which corresponds to between the ages of 10 and 17.5 years (mean = about 15 years) (Christensen, 1984; Perrin and Reilly, 1984; Duffield and Miller, 1988; Olesiuk et al., 1990), and are presumed to remain sexually active throughout their adult lives (Olesiuk et al., 1990).

Southern Resident Killer Whales are known to consume 22 species of fish and one species of squid (Scheffer and Slipp, 1948; Ford et al., 1998, 2000; Ford and Ellis, 2005; Saulitis et al., 2000). Ford and Ellis (2005) found that salmon represent over 96 percent of the prey consumed during the spring, summer, and fall. Chinook Salmon were selected over other species, comprising over 70 percent of the identified salmonids taken. This preference occurred despite the much lower abundance of Chinook in the study area in comparison to other salmonids and is probably related to the species' large size, high fat and energy content, and year-round occurrence in the area. Other salmonids eaten in smaller amounts include chum (22 percent of the diet), pink (3 percent), coho (2 percent), sockeye (less than 1 percent), and steelhead (less than 1 percent) (Ford and Ellis, 2005). This work suggested an overall preference of these whales for Chinook during the summer and fall, but also revealed extensive feeding on chum salmon in the fall.

Southern Resident Killer Whale survival and fecundity are correlated with Chinook Salmon abundance (Ward et al., 2009, Ford et al., 2010). Southern Resident Killer Whales could potentially be affected by changes in salmon populations caused by the Project, because their survival and fecundity appear dependent on the abundance of Chinook Salmon (Ward et al., 2009; Ford et al., 2010).

Chinook Salmon originating from the Fraser River are the dominant prey of resident Killer Whales in the summer months when they are usually in inland marine waters (Hanson et al., 2010). Less is known of their diet during the remainder of the year (September through May), when they spend much of their time in outer coastal waters, and may range from central California to northern British Columbia (Hanson et al., 2010). However, it is believed likely that they preferentially feed on Chinook Salmon when available, and roughly in proportion to their relative abundance (Hanson et al., 2010). Hanson et al. (2010) found Southern Resident stomachs to contain several different ESUs of salmon, including Central Valley fall-run Chinook Salmon.

NMFS (2008) estimated the biological requirements of Southern Resident Killer Whales including the diet composition and number of salmon the population requires in their coastal range. NMFS estimated that the current population of Southern Residents at the time (87) would be required to consume between 392,555 and 470,288 salmon based on diet compositions and bioenergetic needs in their coastal range. These estimates were based on Chinook Salmon comprising 70 to 88 percent of their diet.

Based on observations of captive Killer Whales, studies have extrapolated the energy requirements of wild Killer Whales and estimate an average size value for the five salmon species combined. Osborne (1999) estimated that adult Killer Whales would consume 28 to 34 adult salmon per day, and that younger Killer Whales (less than 13 years of age) would consume about 15 to 17 salmon per day to meet their daily energy requirements. Extrapolating these results, the Southern Resident population (approximately 90 individuals) would consume about 750,000 to 850,000 adult salmon per year.

12A.1.13 White sturgeon (*Acipenser transmontanus*)

12A.1.13.1 Status

White Sturgeon have a marine distribution spanning from the Gulf of Alaska south to Mexico, but a spawning distribution ranging only from the Sacramento River northward. Currently, self-sustaining spawning populations are only known to occur in the Sacramento, Fraser, and Columbia rivers. In California, the largest numbers are in the San Francisco Bay estuary, with spawning occurring mainly in the Sacramento and Feather rivers. White sturgeon are considered a California species of special concern (CDFW, 2016).

12A.1.13.2 General Biology and Life History

White sturgeon, similar to the green sturgeon, are anadromous fish that spend most of their lives within an estuary, usually returning to fresh water only to spawn (Beamesderfer and Webb, 2002). White Sturgeon are long-lived, late maturing, and have a high fecundity (Israel et al., 2015). Because White Sturgeon require a long time to mature, large year classes are typically associated with years of high outflow (Kohlhorst et al., 1991; Schaffter and Kohlhorst, 1999), and population size can fluctuate to extremes (Schaffter and Kohlhorst, 1999). There is a relatively strong relationship between Delta outflow and year class strength during the period when white sturgeon are spawning and young white sturgeon are migrating downstream (March-July). There is a threshold at about 50,000 cfs such that year classes are generally strong when flows are above the threshold (Gingras et al., 2014).

Adult Migration and Spawning

White sturgeon reside in estuaries of large rivers for much of their lives. They are found in brackish portions of the estuary and they may move around a bay or estuary to find optimal brackish water areas (Kohlhorst et al., 1991). Male sturgeon reach sexual maturity before the females, although time of onset of maturity for both varies with photoperiod[3] and temperature. Males are sexually mature as early as three to four years. Females mature as early as five years (Wang, 2010). White sturgeon do not necessarily breed annually, and only a small percentage of the adult population spawns in a given season. Males may spawn every one to two years, and females may spawn every two to four years. The sturgeon begin migrating in streams during winter, with large peak flows triggering spawning between February and early June. Upstream migration is usually initiated by a large pulse flow (Schaffter, 1997).

[3] The duration of an organism's daily exposure to light.

In the Central Valley, white sturgeon spawn in the Sacramento River between Knights Landing and Colusa and possibly farther upstream; most White Sturgeon spawn downstream of the Glenn-Colusa Irrigation Dam. In some years, white sturgeon may also spawn in the Feather and San Joaquin rivers (Moyle, 2002). White Sturgeon spawning has recently been confirmed in the lower San Joaquin River (Jackson and Van Eenennaam, 2013), and the U.S. Geological Survey (USGS) is currently mapping and characterizing White Sturgeon spawning habitat in the lower portion of the river (USGS, 2015).

Spawning occurs over deep gravel riffles or in deep pools with swift currents and rock bottoms between late February and early June when temperatures are between 8°C and 19°C. White Sturgeon have high fecundities, and typical females may have as many as 200,000 eggs. Eggs become adhesive subsequent to fertilization, and adhere to the substrate until they hatch 4 to 12 days later, depending on temperature (Wang, 2010). Once the eggs have been deposited, the adults move back downstream to the estuary. Larvae hatch in 1 to 2 weeks, depending on temperature. Once the yolk sac is absorbed (approximately 1 week after hatching), the larvae can begin to actively forage along the benthos.

Rearing

Juvenile sturgeon are often found in upper reaches of estuaries in comparison to adults, which suggests that there is a correlation between size and salinity tolerance. White Sturgeon are opportunistic predators and may feed on many introduced species. The diet of young sturgeon consists primarily of different types of crustaceans, although they begin to increase the diversity of food items with age. Most food is taken from the bottom of the estuary where the sturgeon may pick up clams, crabs, and shrimp. Larger sturgeon begin to feed on other fish, such as anchovies, starry flounder, smelt, and striped bass (Moyle, 2002). They grow quickly in their first year, up to 30 cm FL in the Bay Delta, and the growth rate generally decreases with age (Moyle, 2002).

Both larval and juvenile green sturgeon are susceptible to entrainment in pumps and diversions in the Delta and rivers. Periodic high flows in the 1990s produced small increases in White Sturgeon salvage catches, but salvage numbers were much lower than prior to 1985. USFWS (1996) reported that juvenile sturgeon are probably more vulnerable to entrainment at the SWP and CVP at low to intermediate flows during those years when river and Delta inflow are normal or below normal.

Estuarine and Ocean Residence

In the ocean, White Sturgeon have been known to migrate long distances, but spend most of their life in brackish portions of large river estuaries. White Sturgeon primarily live in brackish portions of estuaries where they tend to concentrate in deep sections having soft substrate. They move according to salinity changes, and may swim into intertidal zones to feed at high tide.

Recent stomach content analysis of White Sturgeon from the San Francisco Bay estuary indicates that the invasive overbite clam, Corbula amurensis, may now be a major component of the White Sturgeon diet (Zeug et al., 2014), and unopened clams were often observed throughout the alimentary canal (Kogut, 2008). Kogut's study found that at least 91 percent of clams that passed through sturgeon digestive tracts were alive. This suggests sturgeon are potential vehicles for transport of adult overbite clams and also raise concern about the effect of this invasive clam on sturgeon nutrition and contaminant exposure.

12A.1.14 Striped Bass (*Morone saxatilis*)

Striped bass occur in the Sacramento River, its major tributaries, and the Delta. Striped Bass move regularly from salt to fresh water. They require a large body of water for foraging on fish (usually estuaries or large reservoirs) and large cool rivers for spawning. Substantial striped bass spawning and rearing occurs in the Sacramento River and Delta, although their range extends up into tributary rivers and creeks. Striped bass are native to the Atlantic coast. They were first introduced to the Pacific coast in 1879, when they were planted in the San Francisco Bay Estuary (Moyle, 2002).

Adult Striped Bass are distributed mainly in the lower bays and ocean during the summer, and in the Delta during fall and winter. Adult striped bass inhabit Central Valley streams throughout the year, with peak abundance occurring in the spring months coincident with the spawning period. Spawning begins in April, and peaks in May and early June. In the Yolo Bypass, Harrell and Sommer (2003) observed that flow pulses immediately preceding floodplain inundation triggered upstream movement of Striped Bass, resulting in successful spawning. Striped bass spawn in warmer temperatures ranging from 59ºF to 68ºF. In the Sacramento River, most spawning is believed to occur between Colusa and the mouth of the Feather River (Moyle, 2002). During low flow years, spawning occurs within the Delta itself.

Eggs are free-floating and negatively buoyant, and hatch in about two days as they drift downstream, with larvae occurring in shallow and open waters of the lower reaches of the Sacramento and San Joaquin rivers, the Delta, Suisun Bay, Montezuma Slough, and Carquinez Strait. Larvae in the Sacramento River migrate into the water column from April to mid-June (Stevens, 1966). In the Sacramento River, embryos and larvae are carried into the Delta and Suisun Bay (Moyle, 2002). In the San Joaquin River, embryos remain in the same general area where spawning took place, as freshwater outflow is balanced by tidal currents (Moyle, 2002). When larval bass from both rivers begin to feed, they are concentrated in the most productive part of the estuary—where freshwater and salt water meet or near X2 (Moyle, 2002).

Striped Bass are tolerant of a wide range of environmental conditions, surviving temperatures up to 25°C (77ºF) (and up to 34°C [93ºF] for shorter periods), rapid temperature swings, low oxygen levels between 3 and 5 milligrams per liter (mg/L), and high turbidity (Moyle, 2002). Hassler (1988), in a summary of environmental tolerance studies, reported that Striped Bass could tolerate dissolved oxygen concentrations ranging from 3 to 20 mg/L, and a pH range of 6 to 10, although the optimum level ranged from 6 to 12 mg/L and 7 to 9, respectively. The information compiled by Hassler (1988) suggested juveniles preferred rearing temperatures of 24 to 26°C (60.8 to 66.2°F). As Striped Bass grow, their temperature preference shifts towards cooler water (Hill et al., 1989). Adult Striped Bass appear to prefer water temperatures ranging from 20 to 24°C (68 to 75.2°F) (Emmett et al., 1991).

Typical of an anadromous species, salinity tolerance of Striped Bass also changes with age (Lal et al., 1977; Hill et al., 1989). Eggs and larvae reportedly thrive at salinities less than 3 practical salinity units (psu) (Mansueti, 1958; Dovel, 197l), and can tolerate salinities of 8 to 9 psu without ill effects (Morgan and Rasin, 1973). Adults can apparently tolerate salinities from 0 to 34 psu or more (Rogers and Westin, 1978), with a range of 10 to 20 psu reported as optimal for larger juveniles (Bogdanov et al., 1967).

Striped Bass are a top predator in the Delta and are considered major predators on fish (Thomas 1967). Fish become important in the diet of juveniles, especially late in the summer when young-of-the-year Striped Bass and shad become available (Moyle, 2002). Striped Bass are primarily piscivorous as subadults, (approximately age 2+). Stevens (1966) found that the importance of fish in the diet of subadult and adult Striped Bass in the Sacramento-San Joaquin estuary varied seasonally. Fish were most prevalent in the diet of subadults in fall, and occurred most frequently in the diet of adults in fall and winter. Adult Striped Bass feed primarily on smaller Striped Bass, threadfin shad, and juvenile salmonids, as well as pelagic ocean fishes (Moyle, 2002). Striped Bass are considered important predators on juvenile salmon in the Sacramento River (Tucker et al., 1998; Moyle, 2002). The impact of Striped Bass on Delta Smelt and Sacramento Splittail is not known (Moyle, 2002). Delta Smelt were occasional prey fish for Striped Bass in the early 1960s (Turner and Kelley, 1966) but went undetected in a recent study of predator stomach contents (Nobriga and Feyrer, 2008). Striped Bass are likely the primary predator of juvenile and adult Delta Smelt given their spatial overlap in pelagic habitats (NMFS, 2009d).

Though Striped Bass may commonly exhibit a roving school foraging strategy (Pickard et al., 1982), they appear to take advantage of prey that is concentrated at screened diversions or pumps, and may be partially responsible for the decline of some native fishes, including salmon, thicktail chub, and Sacramento perch (Tucker et al., 1998). Striped Bass are considered to be a primary cause of juvenile salmon mortality at the state water-export facility in the south Delta (USFWS, 1995). Tucker et al. (1998) observed Striped Bass preying heavily on juvenile Chinook Salmon that passed through the diversion facilities at Red Bluff Diversion Dam on the Sacramento River. Juvenile Chinook Salmon were found by Thomas (1967) to be a major food item in the diet of Striped Bass in the spring and early summer during smolt outmigration through the Sacramento and San Joaquin rivers and Delta.

12A.1.15 American Shad (*Alosa sapidissima*)

American shad are found within the Primary, Secondary, and Extended study areas. American shad occur in the Sacramento River, its major tributaries, the San Joaquin River, and the Delta. Because of its importance as a sport fish, American shad have been the subject of investigations by CDFG. American shad are native to the Atlantic coast, and were planted in the Sacramento River in 1871 and 1881 (Moyle, 2002).

Adult American shad typically enter Central Valley streams from the ocean from late March through early July, with the spawning migration peaking from mid-May through June (Moyle, 2002). Water temperature is an important factor influencing the timing of spawning. American shad are reported to spawn at water temperatures ranging from approximately 46ºF to 78.8ºF (Wang, 2010), although optimal spawning temperatures are reported to range from approximately 60ºF to 70ºF. When suitable spawning conditions are found, American shad school and broadcast their eggs throughout the water column. Spawning takes place mostly in the main channels of rivers. At 62ºF, eggs hatch in six to eight days. Larval American shad have been found in off-channel floodplain habitats. Approximately 70 percent of the spawning run is comprised of first time spawners (Moyle, 2002).

In contrast to salmonids, distribution of spawning American shad are determined by river flow rather than homing[4] behavior (Moyle, 2002). Shad have the ability to navigate and to detect minor changes in their environment (Moyle, 2002).

12A.1.16 Black Bass (*Micropterus* sp.)

Largemouth and smallmouth bass mostly spawn in the spring and summer. They are more successful in disturbed environments than native species. In general, they are adapted to warm, slow-moving, and nutrient rich waters (Moyle, 2002). Largemouth and smallmouth bass are important sportfish in lakes, reservoirs, and rivers. These species spawn in the nearshore, shallow littoral zone in reservoirs and are susceptible to reduced spawning success from reservoir fluctuations. Each of these non-native species is found within the Primary, Secondary, and Extended study areas.

[4] Ability of some species to return to a specific area or location, such as a natal stream.

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