OROVILLE FERC RELICENSING
(PROJECT NO. 2100)

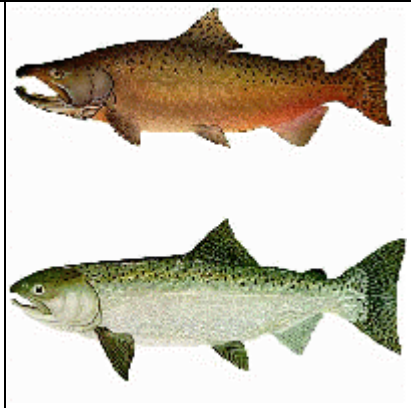
INTERIM REPORT
SP-F3.2 TASK 2
SP-F21 TASK 1

APPENDIX A
MATRIX OF LIFE HISTORY AND HABITAT REQUIREMENTS FOR FEATHER RIVER FISH SPECIES

LITERATURE REVIEW OF LIFE HISTORY AND HABITAT REQUIREMENTS FOR FEATHER RIVER FISH SPECIES

CHINOOK SALMON

JANUARY 2003

Element	Element Descriptor	General	Feather River Specific
General			
common name (s)	English name (usually used by fishers and laypeople).	Chinook salmon, King salmon	
scientific name (s)	Latin name (referenced in scientific publications).	*Oncorhynchus tshawytscha*	
taxonomy (family)	Common name of the family to which they belong. Also indicate scientific family name.	Salmon, trout, and char - *Salmonidae* Chinook salmon are most closely related to coho salmon. Within the Chinook salmon species, there are many distinct populations, usually recognized as "runs" or "stocks" (Moyle 2002b).	
depiction	Illustration, drawing or photograph.	  Courtesy Shedd Aquarium	

Element	Element Descriptor	General	Feather River Specific
range	Broad geographic distribution, specifying California distribution, as available.	Chinook salmon are distributed from Alaska (north to Kotzebue Sound) to California, with the southernmost spawning runs occurring in the Central Valley, specifically in the San Joaquin and King Rivers of Fresno County. Chinook salmon are widely distributed in the pelagic zone of the north Pacific Ocean. The extent of distribution depends on temperature, with the greatest number of Chinook salmon found north of 40°N, except those occurring off the coast of California which is about 35°N (Moyle 2002b). In the Central Valley, spawning occurs in all major streams in the Sierra Nevada drainage, although the distribution of spawning fish has been severely truncated by dams blocking access to upstream areas. Along the Sacramento River, spawning occurs in numerous tributary creeks, streams and major rivers including the American River, Feather River, Yuba River, as well as the mainstem Sacramento River (Moyle 2002b). Generally, ocean-type (or fall-run) Chinook salmon are predominant south of 55°N, while spring-type Chinook salmon are predominant north of 55°N parallel (Myers et al. 1998). In Sacramento-San Joaquin River drainages, 10–18% of Chinook salmon are reported to be stream type (spring-run and late-fall-run) and 82–90% of Chinook salmon are reported to be ocean type (fall-run) (U.S.Fish and Wildlife Service 1995)	Historical upstream extent of Chinook salmon distribution in Feather River drainage is reported as (Yoshiyama et al. 2001): -West Branch Feather River: vicinity of Stirling City -North Fork Feather River: 6 miles above Lake Almanor, 3 miles up Hamilton Branch, and to Indian Falls on East Branch of North Fork. -Middle Fork Feather River: Bald Rock Falls -South Fork Feather River: Upper limit of Lake Oroville (6 miles above former mouth of South Fork)
native or introduced	If introduced, indicate timing, location, and methods.	Native	

Element	Element Descriptor	General	Feather River Specific
ESA listing status	Following the categories according to California Code of Regulations and the Federal Register, indicate whether: SE = State-listed Endangered; ST =State-listed Threatened; FE = Federally listed Endangered; FT = Federally-listed Threatened; SCE = State Candidate (Endangered); SCT = State candidate (Threatened); FPE = Federally proposed (Endangered); FPT = Federally proposed (Threatened); FPD = Federally proposed (Delisting); the date of listing; or N = not listed.	NMFS identified five Ecologically Significant Units (ESU) of Chinook salmon in California, based on genetic and life history similarities: 1) Southern Oregon and California ESU 2) Upper Klamath and Trinity Rivers ESU 3) Central Valley fall-run ESU 4) Central Valley spring-run ESU 5) Sacramento River winter-run ESU (Myers et al. 1998).	Two ESUs specific to Feather River (Myers et al. 1998) 1) Central Valley spring-run ESU 2) Central Valley fall-run ESU. The Central Valley spring-run Chinook salmon ESU includes spawning populations in the Sacramento River and its tributaries (including the Feather River). Spring-run chinook salmon were federally-listed as Threatened on September 16, 1999 (NMFS 1999). The Central Valley fall-run Chinook salmon ESU includes spawning populations in the Sacramento River and its tributaries (including the Feather River). Fall-run Chinook salmon were designated a candidate for listing on September 16, 1999 (NMFS 1999).
species status	If native, whether: Extinct/extirpated; Threatened or Endangered; Special concern; Watch list; Stable or increasing. If introduced, whether: Extirpated (failed introduction); highly localized; Localized; Widespread and stable; Widespread and expanding.	Stable. Although Chinook salmon are in long-term decline in California, they are not, *as a species,* in immediate danger of extinction (Moyle 2002b).	Central Valley fall-run Chinook salmon: Watchlist. Central Valley fall-run Chinook salmon are considered a candidate species for Threatened status by NMFS. (Moyle 2002b). Central Valley spring-run Chinook salmon: Threatened/Endangered. Central Valley spring-run Chinook salmon were federally listed as Threatened by NMFS in 1999.
economic or recreational value	Indicate whether target species sought for food or trophy. Whether desirable by recreational fishers, commercial fishers, or both.	The commercial Chinook salmon fishery in California started about 1850 in the San Francisco Bay and the Sacramento-San Joaquin Delta region, where it formed the nucleus of the first major fishery conducted by Euro-American immigrants (Yoshiyama et al. 1998).	In the Feather River, a significant recreational fishery persists.
warmwater or coldwater	Warmwater if suitable temperature range is similar to basses; coldwater if suitable temperature range is similar to salmonids.	Coldwater.	

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pelagic or littoral	Environment: Pelagic - living far from shore; Littoral - living near the shore.	Chinook salmon tend to stay along the California coast, with a general northward movement off Washington state where there is high productivity. High productivity is caused by upwelling generated by the complex phenomenon known as the California Current, a southward-moving current originating in the Gulf of Alaska (Moyle 2002b) (Allen et al. 1986).	
bottom or water column distribution	Environment: bottom (benthic) or along water column.	Vertical distribution of Chinook salmon in the water column varies with season, ranging from 0–328 ft (0–100 m). Vertical distribution of Chinook salmon is typically deeper than the distribution of other salmonids and typically ranges from 65.6–147.6 ft (20–45 m) (Moyle 2002b).	
lentic or lotic	Environment: Lentic - pertaining to stagnant water, or lake-like; Lotic - moving water, or river-like.	In freshwater, nearshore orientation moving into swifter, deeper water as larger juveniles.	
Adults			
life span	Approximate maximum age obtained.	Maximum reported life span is 9 years (Froese et al. 2002).	
adult length	Indicate: Length at which they first reproduce; average length and maximum length the fish can attain.	Chinook salmon are the largest in average size of the five species of Pacific salmon (Raleigh et al. 1986). The angling record for Chinook salmon is 59.1 inches (150 cm) total length (Froese et al. 2002). Spawning adults are the largest Pacific salmon, typically ranging from 29.5–31.5 inches (75–80 cm) standard length, with lengths in excess of 55.1 inches (140 cm) (Moyle 2002a). Sacramento River fall-run Chinook salmon average 21.7 inches (55 cm) fork length at 2 years of age, 27.6 inches (70 cm) at 3 years of age, 35.4 inches (90 cm) at 4 years of age, and 39.4 inches (100 cm) at 5 years of age (Moyle 2002b). Spring-run Chinook salmon reach 29.5–39.4 inches (75–100 cm) standard length (Moyle et al. 1995). Spring-run Chinook salmon mostly spawn at age 3. Fall-run Chinook salmon mostly spawn as 4- or 5-year-olds. (Moyle 2002b).	

Element	Element Descriptor	General	Feather River Specific
		After summarizing various data, average age at maturity for all Chinook salmon runs in Sacramento-San Joaquin River drainages was reported as 3 years (Myers et al. 1998).	
adult weight	Indicate: Weight at which they first reproduce; average weight and maximum weight the fish can attain.	The angling record for Chinook salmon is 135.4 pounds (61.4 kg) (Froese et al. 2002). The largest Chinook salmon reported in California weighed 85.1 pounds (38.6 kg) (Moyle 2002a). Spring-run Chinook salmon weigh up to 19.8–22 pounds (9-10 kg) or more (Moyle et al. 1995). Spawning adult Chinook salmon can weigh in excess of 99 pounds (45kg) (Moyle 2002a).	
physical morphology	General shape of the fish: elongated, fusiform, laterally compressed, etc.	Fusiform (streamlined).	
coloration	Indicate color, and color changes, if any, during reproduction phase.	Spawning adult Chinook salmon are olive brown to dark maroon. Spawning males are darker than females (Moyle 2002b). Chinook salmon can be distinguished from other spawning salmon by color pattern, particularly the spotting on the caudal fin and the black gums of the lower jaw (Moyle 2002a).	
other physical adult descriptors	Unique physical features for easy identification.	Spawning males have hooked jaws and slightly humped backed. Numerous small spots on the back, dorsal fin and both lobes of the tail exist in both sexes (Moyle 2002b).	
adult food base	Indicate primary diet components.	After juvenile Chinook salmon enter the ocean, they become voracious predators on small fish and crustaceans. Small Chinook salmon feed heavily on invertebrates such as crab larvae and amphipods. As they grow larger, fish increasingly dominate their diet (Moyle 2002b).	
adult feeding habits	Indicate whether plankton eater, algae eater, bottom feeder, piscivorous, active hunter, ambush predator, filter feeder. Night, day, dusk or dawn feeder.	Adult Chinook salmon typically feed on the most abundant pelagic planktivore. This generally includes herrings, anchovies, juvenile rockfish, and sardines off California (Moyle 2002b).	

Element	Element Descriptor	General	Feather River Specific
adult in-ocean residence time	For anadromous species, age when they migrate to the ocean and duration spent in the ocean before returning to freshwater to spawn.	The ocean stage of the Chinook salmon life cycle lasts 1–5 years. Chinook salmon enter the ocean as juveniles (Moyle 2002b). In-ocean residence ranges from 1–6 years, and is more commonly 2–4 years, with the exceptions of a small proportion of yearling males which matures in freshwater or return after 2 or 3 months in saltwater (Myers et al. 1998).	
adult habitat characteristics in-ocean	For anadromous species, description of the ocean habitat utilized: whether along major current systems, gyres, pelagic (beyond continental shelves) and neritic (above continental shelves) zones, etc.	When juveniles first enter the ocean, they tend to stay along California coast. They may exhibit general northward movement off WA where there is high productivity caused by upwelling generated by the complex phenomenon known as the California Current, a southward-moving current originating in the Gulf of Alaska (Moyle 2002b) (Allen et al. 1986).	
Adult upstream migration (immigration)			
range of adult upstream migration timing	Time of year adults migrate upstream. If applicable, indicate for various runs.	Sacramento River Basin spring-run Chinook salmon adults immigrate from March through September (Yoshiyama et al. 1998). Sacramento River spring-run Chinook salmon adults immigrate from mid-March through July (Myers et al. 1998). Spring-run Chinook salmon can be classified as *stream-type Chinook salmon* (Healey 1991). Spring-run Chinook salmon adults typically enter rivers as immature fish in spring and early summer, remain in freshwater until they spawn in early fall (Moyle 2002b). Sacramento River Basin fall-run Chinook salmon adults immigrate from June through December (Yoshiyama et al. 1998). Sacramento River fall-run Chinook salmon adults immigrate from mid-August through September (Myers et al. 1998). Fall-run Chinook salmon adults enter rivers in summer or fall as adults and spawn soon after (Moyle	Spring-run Chinook salmon enter the Feather River from March through June (and spawn the following autumn) (Sommer et al. 2001). Fall-run Chinook salmon return to the Feather River to spawn from September through December (and spawn immediately) (Sommer et al. 2001). Fall-run Chinook salmon enter the Feather River from October through early December, while spring-run Chinook salmon enter the Feather River from March through June (California Department of Water Resources 1982).

Element	Element Descriptor	General	Feather River Specific
		2002b). Fall-run Chinook salmon can be classified as *ocean-type Chinook* (Healey 1991).	
peak adult upstream migration timing	Time of year most adults migrate upstream. If applicable, indicate for various runs.		Fall-run Chinook salmon immigration peaks from mid-October through early December (Sommer et al. 2001).
adult upstream migration water temperature tolerance	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	Adult spring-run Chinook salmon tolerate water temperatures ranging from 38°F–56°F (3.3°C–13.3°C) (Bell 1991). Adult fall-run Chinook salmon tolerate water temperatures ranging from 51°F–67°F (10.6°C–19.4°C) (Bell 1991). In the San Joaquin River, adult Chinook salmon initiated immigration as water temperatures fell from 72°F–66°F (22°C–18.9°C) (U.S.Fish and Wildlife Service 1995). Water temperatures ranging from 70°F–72°F (21.1°C–22.2°C) were reported as incipient lethal water temperatures for adult summer-run Chinook salmon and early fall-run Chinook salmon in the Columbia River (Becker 1973). The upstream migration of adult Chinook salmon from the Delta to the San Joaquin River is reported to have been prevented by water temperatures above 70°F (21.1°C). Upstream migration of adult Chinook salmon was reported to resume when temperature cooled to 65°F (18.3°C) (Boles et al. 1988). In the Columbia River, adult Chinook salmon tend to cease upstream migration if water temperatures are greater than 70°F (21.1°C) (Becker 1973).	

Element	Element Descriptor	General	Feather River Specific
adult upstream migration water temperature preference	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental.	Water temperature preference for adult fall-run Chinook salmon immigration has been reported as ranging from 45ºF–60ºF (7.2°C–15.6°C) in the Columbia River (Becker 1973; Burrows 1963).	
Adult holding (freshwater residence)			
water temperature tolerance for holding adults	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	Mean water temperatures in pools where adult spring-run Chinook salmon held during the summer of 1986 in Deer and Mill creeks were 60.8°F (16°C) (range 53.1°F–64.4°F or 11.7°C–18°C) and 68°F (20°C) (range 64.9°F–70°F or 18.3°C–21.1°C) (Moyle et al. 1995). Records indicate that spring-run Chinook salmon in the Sacramento-San Joaquin River system spend the summer holding in large pools where summer temperatures are usually below 69.8°F–77°F (21°C–25°C) (Moyle et al. 1995). Sustained water temperatures above 80.6°F (27°C) are lethal to adult Spring Chinook salmon (Moyle et al. 1995). In the Sacramento River, adult immigrants held at hatcheries at water temperatures greater than 60°F (15.6°C) and less than 38°F (3.3°C) exhibited poor survival (Boles et al. 1988). Water temperature range for post-spawning adults is reported as 37°F–60°F (2.8°C–15.6°C) (Boles et al. 1988). Pools in holding areas need to be sufficiently deep, cool, and oxygenated to allow over-summer survival of Chinook salmon (DWR et al. 2000).	
water temperature preference for holding adults	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental.	*[See water temperature tolerance for holding adults, above.]*	

Element	Element Descriptor	General	Feather River Specific
water depth range for holding adults	Reported range of observed (minimum and maximum) water depth utilization.	Spring-run Chinook salmon hold in pools that are at least 3.3–9.8 ft (1–3 m) deep (Moyle et al. 1995). Pools in holding areas need to be sufficiently deep, cool, and oxygenated to allow over-summer survival of Chinook salmon (DWR et al. 2000).	
water depth preference for holding adults	Reported range of most frequently observed water depth utilization.	Spring-run Chinook salmon select large deep pools, usually >6.6 ft (>2 m) deep (Moyle 2002b).	
substrate preference for holding adults	If bottom dwellers, indicate substrate: mud, sand, gravel, boulders, aquatic plant beds, etc. If gravel, indicate range or average size of gravel.	Spring-run Chinook salmon select pools with bedrock bottoms (Moyle 2002b).	
water velocity range for holding adults	Reported range of observed (minimum and maximum) water velocity utilization.	Spring-run Chinook salmon adults prefer mean water column velocities of 0.49–2.6 ft/sec (15–80 cm/sec) (Moyle 2002b). Holding pools for adult spring-run Chinook salmon have been characterized as having moderate water velocities ranging from 0.5–1.3 ft/sec (15.2–39.6 cm/sec) (DWR et al. 2000).	
water velocity preference for holding adults	Reported range of most frequently observed water velocity utilization.	In Deer Creek, adult spring-run Chinook salmon preferred mean water velocities ranging from 2.0–2.6 ft/sec (60–80 cm/sec) during a 1988 survey (Moyle et al. 1995).	
other habitat characteristics for holding adults	General description of habitat (e.g. turbid or clear waters, lentic or lotic, presence of aquatic plant beds, debris, cover, etc.).	Holding pools usually have a large bubble curtain at the head, underwater rocky ledges, and shade cover throughout the day. Adult spring-run Chinook salmon also seek cover in smaller “pocket” water behind large rocks in fast water (Moyle et al. 1995). Holding pools for adult Spring-run Chinook salmon have been characterized as having cover such as bubble curtains (DWR et al. 2000).	
timing range for adult holding	Time of year (earliest-latest) and duration of stay from upstream migration to spawning.	Adult spring-run Chinook salmon may hold in their natal tributaries for up to several months before spawning (DWR et al. 2000).	Adult fall-run Chinook salmon holding occurs for a relatively short time period, ranging from a few days to a few months (Sommer et al. 2001).

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			Adult spring-run Chinook salmon holding occurs for a longer duration of time than holding for adult fall-run Chinook salmon, with the holding period ranging from arrival in freshwater until the following autumn (Sommer et al. 2001).
timing peak for adult holding	Time of year when maximum number of adults are present before spawning.		Adult spring -run Chinook salmon hold throughout the summer until approximately late-September or mid-October when they spawn (California Department of Water Resources 1982).
Spawning			
fecundity	Average or range in the number of eggs females lay in a spawning season.	Generally, fecundity of Chinook salmon ranges from 2,000–17,000 eggs per female. The number of eggs increases with body size and may vary among populations and runs (Moyle 2002b). A regression model developed by DFG that predicted fecundity of spring-run Chinook salmon females based on form length estimated that Central Valley spring-run Chinook salmon fecundity ranged from 1,350-7,193 eggs per female, with a weighted average of 4,161 eggs per female. Estimates of fecundity made in the latter 19th century at Baird Hatchery using the number of females spawned and total egg take estimated fecundity of spring-run Chinook salmon ranged from 3,278–4,896 eggs per female, and averaged 4,159 eggs per female between 1877 and 1901 (DWR et al. 2000).	Sacramento fall-run Chinook salmon have exceptionally high fecundity for a given size. Spring-run Chinook salmon and fall-run Chinook salmon, fecundity estimates averaging 4,900 eggs per female and 5,500 eggs per female, respectively (Moyle 2002b). Average fecundity of Feather River Chinook salmon females is 5,522 eggs per female (DWR 2002).
nest construction	Location and general description of nest -- substrates, aquatic plants, excavations, crevices, habitat types, etc.	Nests are predominantly constructed in loose gravels or small cobbles. Redd sites are chosen in part by the presence of subsurface flow, and thus redds from previous spawners are desirable places for later fish to spawn, a phenomenon known as redd superimposition (Moyle 2002b). Various studies have demonstrated the importance of subgravel flow during redd site selection. Tailspill gravel mounds are created to stimulate subgravel flow. Redds are generally located at the head of a riffle. Spawning can occur below logjams, which can increase rate of subgravel flow. Adult Chinook	

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		salmon may spawn in sites upstream of large gravel dunes to take advantage of the subgravel flow stimulated by the dunes (Healey 1991).	
nest size	Size and average dimensions of the nest.	Redds average approximately 64.6 ft^2 (6 m^2) in size, in areas relatively free of silt (Burner 1951) (Raleigh et al. 1986). In the Sacramento-San Joaquin drainages, redd size ranges from 22–486 ft^2 (2.01 m^2–45.2 m^2) (U.S.Fish and Wildlife Service 1995). In a review of several studies, redd area was reported to range from 26–43 ft^2 (2.4–4.0 m^2), 42–70 ft^2 (3.9–6.5 m^2), 43–161 ft^2 (4.0–15.0 m^2), 5.4–296 ft^2 (0.5–27.5 m^2), and from 23–482 ft^2 (2.1–44.8 m^2). Mean redd area was reported in once reviewed study as 102 ft^2 (9.5 m^2) and in another reviewed stud as 183 ft^2 (17.0 m^2) (Healey 1991).	
spawning process	Indicate whether nest builder, broadcast spawner, or other.	A female Chinook salmon digs a shallow depression in the gravel of the stream bottom in an area of relatively swift water by performing vigorous cavdal flexions. The female deposits a pocket of eggs and covers it with gravel. Over a course of one or several days, the female deposits 4 or 5 pockets of eggs in a line running upstream, enlarging the excavation (redd) (U.S.Fish and Wildlife Service 1995). Adult female Chinook salmon dig a redd (nest) and deposit eggs within the stream sediment where egg incubation, hatching, and subsequent emergence take place following fertilization (DWR et al. 2000).	
spawning substrate size/characteristics	Range of substrates used during spawning (e.g. mud, sand, gravel, boulders, beds of aquatic plants). Indicate presence of plant/wood debris, crevices at spawning sites. If gravel, indicate range of average size.	Spawning substrate typically includes a mixture of gravel and small cobbles (Moyle 2002b). Substrate size ranges from 0.11–5.9 inches (0.3–15.0 cm) gravel (Raleigh et al. 1986).	Redds were constructed in substrate containing less than 60% fines in 0.2- to 1-inch (0.5–2.54 cm) to 6- to 9-inch (15.2–22.9 cm) gravel size classes (Sommer et al. 2001).
preferred spawning substrate	Indicate preferred spawning substrate (e.g. mud, sand, gravel, boulders, plant bed, etc).	Chinook salmon spawned over gravel with an average size of 1.7 inches (4.2 cm) in California (Raleigh et al. 1986).	Redds were constructed in substrate containing less than 60% fines in 0.2- to 1-inch (0.5–2.54 cm) to 6- to 9-inch (15.2–

Element	Element Descriptor	General	Feather River Specific
		Preferred spawning substrate size ranged from 0.8–4.2 inches (2.0–10.6 cm) gravel (Raleigh et al. 1986). Preferred spawning substrate size ranged from ravel 1–6 inches in diameter (2.54–15.2 cm) (U.S.Fish and Wildlife Service 1995). Reported optimal spawning gravel size ranges from 0.5–4.02 inches (1.3–10.2 cm) diameter; with 80% of the spawning gravel ranging from 0.5–2.01 inches (1.3–5.1 cm) and with 20% of the spawning gravel larger than 2.01 inches (5.1 cm) in diameter (Allen et al. 1986). Suitable substrate for embryos is a gravel/cobble mixture with a mean diameter of 1–4 inches in diameter and a composition including less that 5% fines (particles less that 0.3 inch in diameter) (DWR et al. 2000).	22.9 cm) gravel size (Sommer et al. 2001).
water temperature tolerance for spawning	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	Spawning occurs in a range of water temperatures extending from 39.9°F–64.4°F (4.4°C–18°C), although water temperatures greater than 55°F (12.8°C) increased mortality to females prior to spawning (Raleigh et al. 1986). Spring-run Chinook salmon reportedly spawned in water temperatures ranging from 40.1°F–55°F (4.5°C–12.8°C), and fall-run Chinook salmon reportedly spawned at water temperatures ranging from 41°F–56.1°F (5.0°–13.4°C) (Raleigh et al. 1986). Mature females subjected to prolonged exposure to water temperatures above 60°F (15.6°C) or below 38°F (3.3°C) results in poor adult survival and egg viability (U.S.Fish and Wildlife Service 1995). Chinook salmon spawned in water temperatures ranging from 42.1°F–57°F (5.6°C–13.9°C) (Reiser and Bjornn 1979) (Allen et al. 1986).	

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water temperature preference for spawning	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental derivation.	In Columbia River, recommended water temperatures range from 45–55°F (7.2–12.8° C) for spawning areas (Becker 1973).	
water velocity range for spawning	Minimum and maximum speed of water current the spawning fish can tolerate.	Chinook salmon spawn in water velocities ranging from a few centimeters per second to several meters per second (0.49–6.2 ft/sec or 15–190 cm/sec) (Moyle 2002b). Spawning water velocity ranges from 1.5–2.5 ft/sec (0.46–0.76 m/sec) for spring-run Chinook salmon and from 1.15–3.8 ft/sec (0.35–1.15 m/sec) for fall-run Chinook salmon (Raleigh et al. 1986). Chinook salmon spawning occurs in water velocities ranging from 1.2–3.5 ft/sec (36.5–107cm/sec) (DWR et al. 2000).	Water velocity for Chinook salmon spawning in the Feather River ranged from 0.04–4.8 ft/sec (1.15–146.3 cm/sec) (Sommer et al. 2001).
water velocity preference for spawning	Preferred water current (flow velocity) during spawning.	Water velocity preferences for spawning range from 0.98–2.6 ft/sec (30–80 cm/sec) (Moyle 2002b). Water velocity preferences for spawning range from 1.5–2.5 ft/sec (45.7–76.2 cm/sec) (Vogel et al. 1991). Reported optimal range of water velocities for spawning ranges from 0.98–3.0 ft/sec (0.3–0.91 m/sec) (Allen et al. 1986).	The central 50% of water velocity measured during observations of spawning Chinook salmon in the Feather River occurred at water velocities ranging from 1.5–2.7 ft/sec (45.7–82.3 cm/sec) (Sommer et al. 2001).
water depth range for spawning	Reported range of observed (minimum and maximum) water depth utilization.	Chinook salmon spawn in water depths ranging from a few centimeters to several meters (Moyle 2002b). Chinook salmon spawn in water depths greater than 0.8 ft (0.24 m) (Allen et al. 1986).	Chinook salmon spawners observed in the Feather River utilized water depths ranging from 0.4–4 ft (0.1–1.2 m) (Sommer et al. 2001).
water depth preference for spawning	Reported range of most frequently observed water depth utilization.	Chinook salmon prefer spawning at water depths of 0.8–3.3 feet (25–100 cm) depth (Moyle 2002b). Chinook salmon prefer to spawn in water depths exceeding 0.5 ft (15.2 cm) (U.S.Fish and Wildlife Service 1995).	The central 50% of water depths measured during observations of spawning Chinook salmon in the Feather River ranged from 1.6–2.6 ft (0.5–0.8 m) (Sommer et al. 2001).

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range for spawning timing	Earliest and latest time of season or year in which spawning occurs.	In the Sacramento River Basin, spring-run Chinook salmon spawning occurs from late August through October, while fall-run Chinook salmon spawning occurs from late September through December (Yoshiyama et al. 1998). In the Sacramento River, spring-run Chinook salmon spawning occurs from August through October, while fall-run Chinook salmon spawning occurs from October through December (Myers et al. 1998).	Fall-run Chinook salmon return to the Feather River to spawn from September through December (and spawn immediately) (Sommer et al. 2001). Spring-run Chinook salmon spawning timing is the autumn following their adult migration (Sommer et al. 2001).
peak spawning timing	Time of year most fish start to spawn.	In the Sacramento River Basin, peak spawning of spring-run Chinook salmon occurs in mid-September, while peak spawning of fall-run Chinook salmon occurs from October–November (Yoshiyama et al. 1998). In the Sacramento River, peak spawning of spring-run Chinook salmon occurs from late August through mid-September, while peak spawning of fall-run Chinook salmon occurs in November (Myers et al. 1998).	Fall-run Chinook salmon spawning in the Feather River peaks in mid- to late-November (Myers et al. 1998).
spawning frequency (iteroparous/ semelparous)	Semelparous - producing all offspring at one time, such as in most salmon. Usually these fish die after reproduction. Iteroparous - producing offspring in successive, e.g., annual or seasonal batches, as is the case in most fishes.	Semelparous.	
Incubation/early development			
egg characteristics	Shape, size, color, in clusters or individuals, stickiness, and other physical attributes.	Chinook salmon egg size and weight in the Pacific Southwest ranges from 0.2–0.3 inch (6.3–7.9 mm) in diameter and 0.012–0.014 ounces (0.35–0.40 grams) in weight (Allen et al. 1986).	
water temperature tolerance for incubation	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	High survival rates of eggs and fry were observed at constant water temperatures of 50°F (10.0°C), 45°F (7.2°C) and 40.1°F (4.5°C). Very low survival was observed at water temperatures greater than 60.8°F (16°C) and at water temperatures less than 33.8°F (1°C) (Raleigh et al. 1986). Water temperatures greater than 59°F (15°C) were	

Element	Element Descriptor	General	Feather River Specific
		lethal to embryos and fry (Raleigh et al. 1986). At water temperatures above 56°F (13.3°C), egg survival rate decreases. At water temperatures above 62°F (16.7°C), no survival of eggs was observed (U.S.Fish and Wildlife Service 1995). Chinook salmon eggs have been successfully incubated and hatched at water temperatures ranging from 39.2°F–60.8°F (4–16°C). However, lower water temperatures can be tolerated in the later stages of embryonic development. Water temperature tolerance ranges from 42.4°F–57.6°F (5.8°C–14.2°C) in the later stages of embryonic development (Allen et al. 1986). Controlled laboratory experiments with British Columbia Chinook salmon stocks on effects of temperature were conducted at 35.6°F, 39.2°F, 46.4°F, 53.6°F–59°F (2°C, 4°C, 8°C, 12°C, and 15°C) on early development phase survival. Survival rate from fertilization to hatching is zero at 35.6°F (2°C). Average survival rate is 0.88 at 39.2°F (4°C), 0.994 at 46.4°F (8°C); 0.988 at 53.6°F (12°C); and 0.933 at 59°F (15°C) (Beacham et al. 1989). In the Sacramento River, at water temperatures ranging from 55°F–57.5°F (12.8–14.1°C), egg mortality was low, but produced fry mortality in excess of 50 %. Fry mortality was reduced to lower levels when eggs were incubated at constant temperatures ranging from 50°F–55°F (10–12.8°C), or when water temperatures declined during incubation when initial incubation temperatures ranged up to 60°F (15.5C) (Boles et al. 1988). In the American River, Chinook salmon egg survival was highest when water temperatures ranged from 53°F– 54°F (11.7–12.2°C) (DWR et al. 2000).	
water temperature preference for incubation	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or	Maximum embryo survival occurs at water temperatures ranging from 41°F–55.4°F (5°C–13°C) (Moyle 2002b).	

Element	Element Descriptor	General	Feather River Specific
	experimental derivation.	Water temperatures ranging from 35°F–58°F (1.7°C–14.4°C) are recommended for successful egg incubation (Yoshiyama et al. 2001). Maximum survival of incubating eggs and yolk-sac larvae occurs at water temps between 41°F–56°F (5°C–13.3°C) (U.S.Fish and Wildlife Service 1995). Controlled laboratory experiments with British Columbia Chinook salmon stocks on effects of water temperature were conducted at 35.6°F, 39.2°F, 46.4°F, 53.6°F, 59°F (2°C, 4°C, 8°C, 12°C, and 15°C) on early development phase survival. The highest average survival rate (0.994) from fertilization to hatching occurs at 46.4°F (8°C). Incubation time at this temperature averages 70 days (Beacham et al. 1989).	
time required for incubation	Time duration from fertilization to hatching. Note: Indicate at which temperature range. Incubation time is temperature-dependent.	The time required for egg incubation ranges from 40–60 days in water temperatures ranging from 41°F–55.4°F (5°C–13°C) and in saturated oxygen conditions (Moyle 2002b). 900–1,000 thermal units is required for incubation of Chinook salmon eggs (1 T.U. = 1°C above freezing x 24 hours) (Raleigh et al. 1986). In the Sacramento-San Joaquin River drainages, approximately 6–9 weeks is required for egg incubation (U.S.Fish and Wildlife Service 1995). Controlled laboratory experiments with British Columbia Chinook salmon stocks on the effects of water temperature was conducted at 35.6°F, 39.2°F, 46.4°F, 53.6°F, 59°F (2°C, 4°C, 8°C, 12°C, and 15°C) on early development phase incubation and survival. At a water temperature of 39.2°F (4°C) egg incubation averages 129 days. At 46.4°F (8°C), egg incubation averages 70 days. At 53.6°F (12°C), egg incubation averages 44 days, and at 59°F (15°C) egg incubation averages 35 days. The survival rates is highest at 46.4°F (8°C) (Beacham et al. 1989).	
size of newly hatched larvae	Average size of newly hatched larvae.	In controlled laboratory experiments with British Columbia Chinook salmon stocks, the average size of alevins incubated at different temperatures	

Element	Element Descriptor	General	Feather River Specific
		39.2°F–59°F (4°C–15°C) averaged (0.83 inch) 21 mm (Beacham et al. 1989).	
time newly hatched larvae remain in gravel	Time of year of hatching, and duration between hatching and emergence from gravel.	After hatching, larvae remain in gravel for approximately 4–6 weeks until yolk sac is absorbed. After absorption, alevins emerge (Moyle 2002b). The number of days between hatching and emergence depend on the temperature. Controlled laboratory experiments with British Columbia Chinook salmon stocks on the effects of water temperature suggest that, depending upon the acclimation temperature, the average number of days to emergence ranges from 62 to 214 days, as illustrated below (Beacham et al. 1989): Acclim. temp (°C) Ave. time to emergence (days) 39.2°F (4°C) 214 46.4°F (8°C) 119 53.6°F (12°C) 77 59.0°F (15°C) 62	
other characteristics of larvae	Alevin -- early life history phase just after hatching (larva) when yolk-sac still present.	Fry remain in the gravel for 2–4 weeks until the yolk is absorbed (U.S.Fish and Wildlife Service 1995). After hatching, alevins remain in the gravel interstices for a month or longer. Salmon alevins are negatively phototactic and positively geotactic (movement as reaction to gravity) and thigmotactic (reaction to solid object or touch). These characteristics serve to prevent premature emergence. Alevins remain inactive unless forced to disperse in response to excessive levels of carbon dioxide or metabolic waste, or in order to avoid desiccation during low flow (Allen et al. 1986).	In the upper Sacramento River, fry growth ranged from 0.009–0.015 inch/day (0.24–0.40 mm/ day), with mean growth of 0.012 inch/day (0.33 mm/day). During the same period, growth of fry in the San Francisco Bay estuary ranged from 0.02–0.03 inch/day (0.4–0.69 mm/day), with mean growth of 0.02 inch/day (0.53 mm/day) (Allen et al. 1986).
timing range for emergence	Time of year (earliest-latest) hatchlings (larvae and alevins) leave or emerge from the nesting/hatching (gravel) sites.	Juvenile emergence in the Sacramento River Basin occurs approximately 4–6 weeks after hatching and generally occurs from November through March for spring-run Chinook salmon and from December through March for fall-run Chinook salmon (Yoshiyama et al. 1998).	
timing peak for emergence	Time of year most hatchlings emerge.		Spring-run Chinook salmon and fall-run Chinook salmon fry emerge from spawning gravel as early as November

Element	Element Descriptor	General	Feather River Specific
			spawning gravel as early as November and remain there for at least several weeks (Sommer et al. 2001).
size at emergence from gravel	Average size of hatchlings at time of emergence.	Fall-run Chinook salmon in the Sacramento-San Joaquin River drainages are typically less than 2 inches (5.1 cm) in length(U.S.Fish and Wildlife Service 1995). Chinook salmon fry newly emerged from the redd are approximately 1.4–1.7 inches (35–44 mm) long and weigh as much as 0.018 ounce (0.5 g) (Allen et al. 1986). Controlled laboratory experiments with British Columbia Chinook salmon stocks incubated and reared at water temperatures ranging from 39.2°F–59°F (4°C-15°C). Average size of fry was approximately 1.4 inches (35.5 mm) (Beacham et al. 1989).	
Juvenile rearing			
general rearing habitat and strategies	General description of freshwater environment and rearing behavior.	Fall-run Chinook salmon juveniles emerge from the gravel and move downstream within a few months to rear in mainstem rivers or before emigrating to sea (Moyle 2002b). Spring-run Chinook salmon may rear in streams for 3-15 months, depending on flow conditions (Moyle 2002b). Larger fry tend to be most likely to disperse from the redd earliest. Movement occurs mostly at night and tends to cease after a few weeks, when fry settle into rearing habitat in streams. In general, there is a shift in microhabitat utilization by juvenile Chinook salmon to deeper and faster water as they grown larger. Microhabitat use and foraging behavior can be influenced by the presence of predators which may result in fish selection of habitat with heavy cover. Additionally, during the night, juvenile Chinook salmon may abandon foraging areas in swift-moving water in factor of quiet edgewaters or pools (Moyle 2002b).	

Element	Element Descriptor	General	Feather River Specific
water temperature tolerance for juvenile rearing	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	Rearing juvenile Chinook salmon can tolerate water temperatures ranging from 32°F–75.2°F (0°C–24°C) (Raleigh et al. 1986). Lethal temperature limits of young Chinook salmon, based on lab experiments are listed below (Brett 1952): Acclim. temp — Lower lethal limit — Upper lethal limit 75.2°F (24°C) — 45.3°F (7.4°C) — 77.2°F (25.1°C) 68°F (20°C) — 40.1°F (4.5°C) — 77.2°F (25.1°C) 59°F (15°C) — 36.5°F (2.5°C) — 77°F (25.0°C) 50°F (10°C) — 33.4°F (0.8°C) — 75.7°F (24.3°C) 41°F (5°C) — —— — 70.7°F (21.5°C) For Washington Chinook salmon fry, the most rapid growth at constant water temperature occurred at 55°F (12.8°C). At variable water temperatures, maximum growth rate occurs at water temperatures near 60°F (15.6°C) (Seymour 1956). At Nimbus Hatchery, juvenile Chinook salmon achieve optimum growth under lab conditions at maximum ration at water temperatures ranging from 54°F–60°F (12.2°C–15.6°C) (Rich 1987b). Juvenile fall-run Chinook salmon in a Washington lab study had optimum propagation at 60°F (15.6°C) (Banks 1971). Juvenile Chinook salmon in a British Columbia lab study achieve optimum growth under lab conditions at max ration at water temperatures averaging 66°F (18.9°C). Optimum food conversion efficiency under lab conditions occurred at water temperatures ranging from 67°F–68°F (19.4°C–20°C) (Brett et al. 1982). In the Sacramento River, the upper lethal temperature for long-term exposure to increased water temperatures is 78.5°F (25.8°C), although higher temperature can be tolerated for brief periods of time (Boles et al. 1988).	The upper lethal limit for juvenile Chinook salmon in a lab study at Nimbus and Feather River hatcheries and at Tracy pumping station was 78.5°F (25.8°C) for juveniles acclimated at 55º–73°F (12.8°C–22.8°C) (Orsi 1971).

Element	Element Descriptor	General	Feather River Specific
water temperature preference for juvenile rearing	Range of suitable, preferred, or reported optimal water temperatures. Indicate whether literature, observational, or experimental derivation.	Rearing Chinook salmon fingerlings at hatcheries preferred water temperatures ranging from 53.6°F–57.2°F (12°C–14°C) (Banks 1971; Brett 1952). Water temperature of 60°F (15.6°C) was reported as optimal for growth of fingerling Chinook salmon based on lab experiments comparing growth at 50°F (10°C), 55°F (12.8°C), 60°F (15.6°C) and 65°F (18.3°C) (Banks 1971). Reported optimal water temperatures for Chinook salmon fry rearing range from 50°F–54°F (10°C–12.2°C) (Rich 1997) . In the Sacramento River, preferred water temperatures for fry rearing range from 53°F–57.5°F (11.7°C–14.2°C) (Boles et al. 1988). In the Sacramento River, the preferred water temperature of Chinook salmon fingerlings ranges from 53.6°F–57.2°F (12°C–14°C). Maximum growth occurs at 55°F (12.8°C) (Boles et al. 1988). For Washington spring-run Chinook salmon fry, preferred water temperature at constant temperature ranges from 54°F (12.2°C) to 55°F (12.8°C) (Brett 1952). In the Columbia River, preferred water temperature for rearing Chinook salmon ranges from 50°F–60°F (10°C–15.6°C) (Becker 1973). In a lab study, juvenile American River Fall-run chinook salmon achieved maximum growth at a water temperature range of 55°F–60°F (12.8°C–15.6°C) (Rich 1987a). In a lab study, juvenile American River Fall-run Chinook salmon achieved maximum growth and food conversion efficiency at a water temperature of 66°F (19°C). The experiments were conducted at oxygen levels greater than 90% of saturation levels and pathogen free waters (Cech et al. 1999).	

Element	Element Descriptor	General	Feather River Specific
water velocity ranges for rearing juveniles	Reported range of observed (minimum and maximum) water velocity utilization.	YOY Chinook salmon tend to select water velocities 0–2.0 ft/sec (0–60 cm/sec) (Raleigh et al. 1986).	
water velocities preferred by rearing juveniles	Reported range of most frequently observed water velocity utilization.	YOY Chinook salmon tend to prefer water velocities ranging from 0–<1.3 ft/sec (0–<40 cm/sec) (Raleigh et al. 1986). Chinook salmon juveniles prefer water velocities ranging from 0.20–.79 ft/sec (0.06–0.24 m/sec) (Allen et al. 1986).	
water depth range for juvenile rearing	Reported range of observed (minimum and maximum) water depth utilization.	Chinook salmon fry and juveniles have been observed in pools at depths of greater than 0.5 ft (15 cm) (Raleigh et al. 1986). Juvenile Chinook salmon utilize deep, low-velocity pools (Raleigh et al. 1986). Based on habitat suitability curves, Chinook salmon fry utilize depths ranging from 0.1 ft (3.0 cm) to approximately 4.9 ft (150 cm) (Raleigh et al. 1986).	
water depth preference for juvenile rearing	Reported range of most frequently observed water depth utilization.	Based on habitat suitability curves, Chinook salmon fry prefer depths ranging from approximately 0.9 ft (27.4 cm) to approximately 2.0 ft (61.0 cm) (Raleigh et al. 1986).	
cover preferences for rearing juveniles	Type of cover for protection from predators used by rearing juveniles (e.g. crevices, submerged aquatic vegetation, overhanging vegetation, substrate cover, undercover bank, small woody debris, large woody debris).	After emerging from gravel, fry are generally washed downstream into back- or edge-water areas, where velocities are low, cover is dense and small food items abundant (Moyle 2002b). Juvenile rearing habitat should provide adequate space, cover, and food supply. Preferred upstream habitat includes abundant instream and overhead cover (for example, undercut banks, submerged and emergent vegetation, logs, roots, other woody debris, and dense overhead vegetation) to provide refuge from predators, and a sustained, abundant supply of invertebrate and larval fish prey. Further downstream, rearing fry use low velocity areas where substrate irregularities and other habitat features	

Element	Element Descriptor	General	Feather River Specific
		create velocity refuges and they may increasingly rely on turbidity as cover (DWR et al. 2000).	
food base of juveniles	Indicate primary diet components. Also indicate the diet changes, if any, as growth occurs.	In streams, Chinook salmon fry feed mainly on drifting terrestrial and aquatic insects, but zooplankton become more important in the lower river reaches and estuaries (U.S.Fish and Wildlife Service 1995). Chironmidae (midges) are typically cited as an important prey sources for juvenile Chinook salmon upstream of the Delta, whereas crustaceans may be more important in the western Delta. Juvenile Chinook salmon diets often differ by habitat type, resulting in differences in caloric intake and growth rate (DWR et al. 2000).	In the Sacramento River and American River, small salmon (1.6–3.1 inches [40-80 mm] FL) feed mainly on larvae and pupae of chironomid midges, baetid mayfly larvae and adults, hydropsychid caddisfly (Moyle 2002b). In the Sacramento-San Joaquin Delta, terrestrial insects are the most important food item for rearing juveniles, but crustaceans are also eaten (Moyle 2002b).
feeding habits of rearing juveniles	Indicate whether plankton eater, algae eater, bottom feeder, piscivorous, active hunter, ambush predator, filter feeder. Night, day, dusk or dawn feeder. Also indicate change of feeding habits growth occurs.	Juvenile Chinook salmon are opportunistic drift feeders and eat a wide variety of terrestrial and aquatic insects. They feed mostly during the day, with peak feeding at dawn and during the afternoon (Moyle 2002b).	
predation of juveniles	Indicate which species prey on juveniles.	Sacramento pikeminnow constitutes a serious problem for native Salmonid populations. Rearing conditions in the Sacramento River including warm water, low and irregular flow, standing water, and water diversions are more conductive to warmwater species such as Sacramento pikeminnow and striped bass than to native salmonids. Striped bass *(Morone saxatilis*) is also thought to be a significant predator of juvenile salmon (National Marine Fisheries Service (NMFS) 1998).	
timing range for juvenile rearing	Range of time of year (months) during which rearing occurs.	In the Sacramento River Basin, juvenile stream residency, from emergence to prior emigration, ranges from 3–15 months for spring-run Chinook salmon and 1–7 months for fall-run Chinook salmon (Yoshiyama et al. 1998).	Juvenile Chinook salmon rearing occurs for several weeks after emergence (Sommer et al. 2001).

Element	Element Descriptor	General	Feather River Specific
timing peak for juvenile rearing	Time of year (months) during which most rearing occurs.		
Juvenile emigration			
time spent in fresh water prior to emigrating	Duration (in years and/or months) from emergence to emigration to the ocean.	In the Sacramento River Basin, juvenile stream residency, from emergence to prior emigration, ranges from 3–15 months for spring-run Chinook salmon and 1–7 months for fall-run Chinook salmon (Yoshiyama et al. 1998). For Chinook salmon runs in the Sacramento-San Joaquin River drainages, Chinook salmon spend less than 1 year in fresh water prior to emigrating to the ocean. Juvenile Chinook salmon emigrate (age of smoltification) as subyearling, i.e. age less than 1 year (Myers et al. 1998).	
water temperature tolerances during emigration	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	Based on studies of steelhead and coho salmon, water temperature ranging from 50°F–55°F (10°C–12.8°C) has been recommended as the optimal thermal range for smoltification and emigration (DWR et al. 2000). Juvenile Chinook salmon prefer water temperatures less than 71.6°F (22°C). The emigration of fry, subyearling, and juvenile Chinook salmon are typically completed prior to occurrence of high water temperatures. Water temperatures in the Sacramento-San Joaquin Delta can exceed 71.6°F (22°C) in summer (Myers et al. 1998).	
water temperature preferences during emigration	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental derivation.	Chinook salmon achieve reported optimal smoltification at water temperatures ranging 50°F–55°F (10°C–12.8°C) (Rich 1997). In a British Columbia lab study, fall-run Chinook salmon had the best osmoregulatory preadaptation at water temperatures ranging from 50°F–63.5°F (10°C–17.5°C) (Clarke et al. 1985).	
emigration timing range	Time of year juveniles commence emigration and duration of emigration	In the Sacramento River Basin, spring-run Chinook salmon emigrate from March-June and from November through March, while fall-run Chinook salmon emigration occurs from March through July	Emigration of juvenile Chinook salmon occurs in the Feather River from December through June (Sommer et al. 2001).

Element	Element Descriptor	General	Feather River Specific
		(Yoshiyama et al. 1998).	Emigration of juvenile Chinook salmon occurs in the Feather River from November through June (DWR 2002).
emigration timing peak	Time of year most juveniles are emigrating.		Most juvenile Chinook salmon emigrate from February through April (Sommer et al. 2001). These juveniles typically emigrate as fry. Rearing locations for Feather River juvenile Chinook salmon is largely unknown, but in wetter years juveniles rear for weeks to months in Yolo bypass floodplain immediately downstream of the Feather River before migrating to the estuary (Sommer et al. 2001). Emigration of fall-run Chinook salmon peaks in February. Rotary screw trap data from 1998-2000 on the Feather River illustrates that 96% of the Chinook salmon were caught in January through March. Nearly all fall-run Chinook salmon juveniles (>95%) emigrate from the reach of the Feather River extending from the Fish Barrier Dam to the Thermalito Afterbay Outlet within few weeks after emergence (DWR 2002). Emigration of spring-run Chinook salmon peaks in December based on 1998-2000 rotary screw trap data on the Feather River. Another pulse of juvenile emigrants appear at Live Oak in April and May, presumably after rearing in the river to a larger size (DWR 2002).
size range of juveniles during emigration	Minimum and maximum sizes (inches or mm) of emigrating juveniles. Indicate average size.	Average size sampled at ocean entrance for subyearling fall-run Chinook salmon smolts was 3.5 inches (88 mm), while average size for subyearling spring-run Chinook salmon smolts was 3.3 inches (83 mm) (Myers et al. 1998). Emigrating juveniles in the upper Sacramento River are greater than 2.8 inches (70 mm) in size. Fry greater than 2.8 inches (70 mm) are observed in the Sacramento-San Joaquin estuary	96.6% of the fall-run Chinook salmon caught at the Thermalito Afterbay Outlet rotary screw trap were less than 2 inches (50 mm) long, and 81.4 % of the fall-run Chinook salmon caught at the Live Oak rotary screw trap were less than 2 inches (50 mm). Emigrating salmon ranged from 0.9–8.3 inches (24–210 mm) fork length

Element	Element Descriptor	General	Feather River Specific
		rearing for 2 months before entering ocean (Myers et al. 1998). Fry emigrants range from 1.2–1.8 inches (30–45 mm) in fork length and fingerling emigrants range from 2–4.7 inches (50–120 mm) in fork length (Healey 1991). Fall-run Chinook salmon smolts average 3.15 inches (8 cm) total length when they leave the Sacramento-San Joaquin Estuary and are as long as 11.8 inches (30 cm) by the end of their first year (Allen et al. 1986).	(DWR 2002). Majority of Chinook salmon emigrants are "pre-smolt" (i.e., are less than 2 inches (<50 mm) (DWR 2002).
factors associated with emigration	Pulse flows, water temperature changes, turbidity levels, photoperiod, etc.		
Other potential factors			
DO	Levels of dissolved oxygen in water expressed in mg/l tolerated by fish.	Survival from embryo to fry is highest at 10.5 mg/l O_2 and lowest at 3.5 mg/l for all water temperatures tested including 50.9°F, 53.6°F, 56.3°F, and 59°F (10.5°C, 12.0°C, 13.5°C and 15.0°C) (Raleigh et al. 1986). Minimum dissolved oxygen concentration required is reported as 8 mg/l. Chinook salmon juveniles can survive short term exposure to 3 mg/l O_2 at temperatures 41°F (≤5°C). Reported optimal levels of dissolved oxygen are greater than 9 mg/l at water temperatures less than 50°F (10°C) and 13 mg/l at water temperatures greater than 50°F (10°C) (Raleigh et al. 1986). Egg incubation is reported as optimal when water is saturated with dissolved oxygen. Dissolved oxygen concentrations of less than 1.6 mg/l are lethal (Allen et al. 1986).	
pH	Alkalinity/acidity of water (expressed in pH) that fish can tolerate.	pH range of 5.5–9.0, with reported optimal range of 6.8–8.0 (Raleigh et al. 1986).	

Element	Element Descriptor	General	Feather River Specific
turbidity	Indicate turbidity or state of water (e.g., clear water or presence of siltation or organic/inorganic matter in water) that fish can tolerate.	Juvenile salmon are capable of tolerating turbidity as high as 1,000 ppm. The migration of adult salmon may be inhibited at turbidities greater than 4,000 ppm. Given a choice, Chinook salmon will avoid turbid waters (Allen et al. 1986).	
factors contributing to mortality	e.g. fishing/angling mortality, drastic habitat alterations, unfavorable climatic changes, etc.	The decline of the Central Valley Chinook salmon resource was caused by several factors: overfishing, blockage and degradation of streams by mining activities, and reduction of salmon habitat and streamflows by dams and water diversions (Yoshiyama et al. 1998). Overharvesting in the Central Valley is contributory to the decline of Chinook salmon. Overall ocean harvest rate indices for 1990-94 range 71-79% and freshwater recreational harvest is increasing and approaching 25% (Index = catch / [catch + escapement]) (National Marine Fisheries Service (NMFS) 1998).	

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