State of California
The Resources Agency
Department of Water Resources

MATRIX OF LIFE HISTORY AND HABITAT REQUIREMENTS FOR FEATHER RIVER FISH SPECIES SP-F15 TASK 1 SP-F21 TASK 1

STEELHEAD

Oroville Facilities Relicensing FERC Project No. 2100

APRIL 2004

ARNOLD SCHWARZENEGGER Governor State of California	**MIKE CHRISMAN** Secretary for Resources The Resources Agency	**LESTER A. SNOW** Director Department of Water Resources

State of California
The Resources Agency
Department of Water Resources

MATRIX OF LIFE HISTORY AND HABITAT REQUIREMENTS FOR FEATHER RIVER FISH SPECIES SP-F15 TASK 1 SP-F21 TASK 1

STEELHEAD

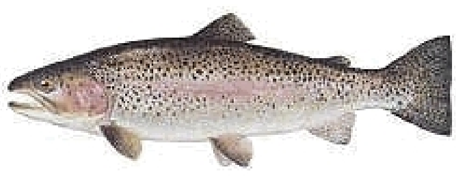
Oroville Facilities Relicensing FERC Project No. 2100

This report was prepared under the direction of

Terry J. Mills.. Environmental Program Manager I, DWR

by

Paul Bratovich ....Principal/Fisheries Technical Lead, SWRI
David Olson................................ Senior Environmental Scientist/Project Manager, SWRI
Adrian Pitts.. Environmental Scientist/Author, SWRI
Meryka Atherstone ....Associate Environmental Planner/Author, SWRI
Allison Niggemyer ....Associate Environmental Scientist/ Author, SWRI
Amanda O'Connell .... Environmental Planner/Author, SWRI
Karen Riggs .... Environmental Planner/Author, SWRI

Element	Element Descriptor	General	Feather River Specific
General			
Common name (s)	English name (usually used by fishers and laypeople).	Steelhead (anadromous populations), coastal rainbow trout (migratory or anadromous populations) (Moyle 2002).	Steelhead (migratory or anadromous populations), rainbow trout (non-anadromous populations) (Moyle 2002).
Scientific name (s)	Latin name (referenced in scientific publications).	*Oncorhynchus mykiss*	
Taxonomy (family)	Common name of the family to which they belong. Also indicate scientific family name.	Salmon, trout, char – *Salmonidae* The flexibility in steelhead life history patterns engendered many local populations to be distinct and awarded taxonomic recognitions. Major controversies arose regarding subspecies designations for various evolutionary groups in non-anadromous populations (rainbow trout) and designations for ESUs in anadromous populations (steelhead) and their resident derivatives (Moyle 2002). Two ecotypes of steelhead have been identified (McEwan 2001): ▪ Stream-maturing steelhead (summer-run), which enter freshwater with immature gonads and must spend several months in the stream. ▪ Ocean-maturing steelhead (winter-run), which mature in the ocean and hold in freshwater for a relatively short time.	Rivers of the Central Valley contain mostly winter-run steelhead (Moyle 2002) but summer-run steelhead may have been more common before dam construction (McEwan 2001).
Depiction	Illustration, drawing or photograph.		
Range	Broad geographic distribution, specifying	Rainbow trout are the most abundant and widespread native salmonid in western North	

Element	Element Descriptor	General	Feather River Specific
	California distribution, as available.	America, and are likely the most widely distributed fish in California. Steelhead are originally native to Pacific coast streams from the Kuskokwim River in Alaska to the streams of Baja California. In Asia, rainbow trout are native mainly to the north Pacific coast south of the Kamchatka Peninsula. In salt water, steelhead are found throughout the North Pacific ocean (Moyle 2002).	
Native or introduced	If introduced, indicate timing, location, and methods.	Native.	Native.
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.	Central Valley steelhead were federally listed as Threatened (FT) on March 19, 1998 (NOAA 1998). The Sacramento and San Joaquin rivers and their tributaries were designated as Critical Habitat on March 17, 2000. Non-anadromous rainbow trout are excluded from the listing (DFG 2002). On April 30, 2002, the U.S. District Court for the District of Columbia approved a NMFS consent decree withdrawing critical habitat designations for 19 salmon and steelhead populations on the West Coast, including Central Valley Steelhead (NOAA 2002a).	Feather River steelhead belong to the Central Valley steelhead ESU (Moyle 2002).
Species status	If native, whether: Extinct/Extirpated; Threatened or Endangered; Special Concern; Watch List; Stable or Increasing. If	Central Valley steelhead are included in Moyle's (2002) class IB designation (Threatened or Endangered) (Moyle 2002). Apparent wild steelhead are found in the	Steelhead populations are supported within the Feather River system by a hatchery program (DFG 2002).

Element	Element Descriptor	General	Feather River Specific
	introduced, whether: Extirpated (failed introduction); Highly Localized; Localized; Widespread and Stable; Widespread and Expanding.	Sacramento River system (e.g., substantial, but not quantified, population of wild steelhead exist in the lower Yuba River) (DFG 2002).	
Economic or recreational value	Indicate whether target species is sought for food or trophy. Whether desirable by recreational fishers, commercial fishers, or both.	Prized recreational species (Moyle 2002). There is a regulated recreational fishery on hatchery-produced steelhead however, the regulations vary by stream (DFG 2002; McEwan and Jackson 1996). In the Sacramento and Klamath river systems, steelhead account for over $20 million annually (16% of the total salmonid commercial and sport fish revenues for these systems) (McEwan and Jackson 1996).	A recreational fishery for steelhead exists on the Feather River (Moyle 2002).
Warmwater or coldwater	Warmwater if suitable temperature range is similar to basses; coldwater if suitable temperature range is similar to salmonids.	Coldwater.	
Pelagic or littoral	Environment: Pelagic - living far from shore; Littoral - living near the shore.	Steelhead have a pelagic ocean residence. In fresh water, they have a nearshore orientation as fry and move into swifter, deeper water as larger juveniles (DFG 2002).	
Bottom or water column distribution	Environment: bottom (benthic) or along water column.	Steelhead are both free-swimming and positively rheotactic at various freshwater lifestages (DFG 2002).	
Lentic or lotic	Environment: Lentic - pertaining to stagnant water, or lake-like; Lotic - moving water, or river-like.	Lotic.	
Adults			
Life span	Approximate maximum age obtained.	Steelhead may live for up to 9 years (Moyle 2002). Rainbow trout rarely reach 5 years old, but may	

Element	Element Descriptor	General	Feather River Specific
		reach 6 to 7 years (Moyle 2002).	
Adult length	Indicate: Length at which they first reproduce; average length and maximum length the fish can attain.	Sacramento River basin steelhead immigrants range in size from 12 to 18 inches (30.5 to 45.7 cm) Fork length (FL) for adults returning after 1 year in the ocean, to 18 to 23 inches (45.7 to 58.4 cm) FL for adults returning after 2 years in the ocean (S.P. Cramer & Associates 1995). Rainbow trout reach lengths of 11.8 to 13.8 inches (30 to 35 cm) FL in the McCloud River, California at an age of 6 to 7 years (Moyle 2002). The growth rate of steelhead is highly variable. In relatively large streams, steelhead reach 3.9 to 4.7 inches (10 to12 cm) FL at year 1, and reach 6.3 to 6.7 inches (16 to 17 cm) FL at year 2. In relatively small streams with low summer flows, steelhead reach 1.9 to 3.5 inches (4.8 to 16 cm) FL at year 1, and 3.9 to 6.3 inches (10 to 16 cm) at FL year 2 (Moyle 2002). Steelhead typically reach maturity at 3 to 4 years of age. Age at maturity depends on the combination of the number of years in freshwater (1 to 3 yrs) and the number of years in the ocean (1 to 4 yrs). In Waddel Creek, California most fish sampled were of the following types: 2:1 (30%), 2:2 (27%), 3:1 (11%), and 1:2 (8%) (expressed as years in freshwater:years in the ocean) (Moyle 2002). Approximately 57% of Sacramento River steelhead spawn after 1 year in the ocean, and approximately 43% spawn after 2 years in the ocean (Busby et al. 1996). Age at spawning can be estimated by adding the number of years spent in freshwater to the number of years spent in the ocean. Thus, the age at first spawning is typically 2 to 4 years	

Element	Element Descriptor	General	Feather River Specific
		(Busby et al. 1996).	
Adult weight	Indicate: Weight at which they first reproduce; average weight and maximum weight the fish can attain.	The reported largest steelhead caught in California, weighing 27.3 pounds (12.4 kilograms), was caught in the Smith River. The reported largest steelhead on record was caught in Alaska, and weighed 42.1 pounds (19.1 kilograms) (Moyle 2002).	The largest non-steelhead rainbow trout reported in California was caught in the Feather River and weighed 21.2 pounds (9.6 kilograms), (Moyle 2002).
Physical morphology	General shape of the fish: elongated, fusiform, laterally compressed, etc.	Steelhead have fusiform (streamlined) bodies (Moyle 2002).	
Coloration	Indicate color, and color changes, if any, during reproduction phase.	Steelhead tend to have a more greenish appearance in freshwater. They have small black spots on their back and most of their fins (Pacific States Marine Fisheries Commission 1996). Broad red lateral bands are apparent during steelhead spawning (Pacific States Marine Fisheries Commission 1996).	
Other physical adult descriptors	Unique physical features for easy identification.	Steelhead have teeth on the tip of their tongue but not on base of the tongue (Fry 1973).	
Adult food base	Indicate primary diet components.	Stream-dwelling rainbow trout feed on terrestrial and aquatic insects, insect larvae, amphipods, snails, and small fish. During the winter, they feed primarily on bottom-dwelling invertebrates (Moyle 2002). The diet of adult steelhead in the ocean is comprised of fish, squid, and crustaceans in surface waters (Moyle 2002).	
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 steelhead in streams feed opportunistically, but individuals may have specialized diets (i.e., feeding primarily on one organism) (Moyle 2002). Adult rainbow trout feed during the day or at night, but peak feeding typically occurs at dawn and dusk (Moyle 2002). Adult steelhead actively feed in freshwater (Moyle 2002).	

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.	Steelhead smolts migrate out to sea at 1 to 3 years of age, and stay there for 1 to 2 years (Moyle 2002). Adults spend 1 to 2 years in the ocean; the proportion of "2-salt" (i.e., 2 years in ocean) individuals, relative to "1-salt" individuals, increases with a northward movement in latitude (S.P. Cramer & Associates 1995).	
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.	Adult steelhead habitat utilization in the ocean is poorly known, but it is reported that it is likely that most California steelhead do not move far from the California coast (Moyle 2002).	
Adult Upstream Migration (Immigration)			
Range of adult upstream migration timing	Time of year adults migrate upstream. If applicable, indicate for various runs.	Winter-run Central Valley steelhead begin entering freshwater in August (Moyle 2002). Central Valley steelhead adult migration ranges from July through May (McEwan 2001). Central Valley steelhead adult migration occurs from August through April (Busby et al. 1996).	Based on 1953-1959 data from immediately upstream of the confluence of the Sacramento River and Feather River, steelhead immigrate into the Feather River from July to March (McEwan 2001). Feather River steelhead begin entry into freshwater from September through June (Busby et al. 1996).
Peak adult upstream migration timing	Time of year most adults migrate upstream. If applicable, indicate for various runs.	Peak Central Valley steelhead immigration occurs from late September through October (Moyle 2002). Peak Central Valley steelhead immigration occurs from September through March. Adult steelhead tend to migrate during high-flow periods (McEwan 2001).	Upstream migration of adult steelhead to the Feather River confluence with the Sacramento River peaks in October and November (S.P.Cramer & Associates 1995).
Adult upstream migration water temperature tolerance	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	Water temperatures lethal to adult steelhead have been reported to be 70°F (21.1°C) (Rich 2000 *in* McEwan 2001).	

Element	Element Descriptor	General	Feather River Specific
		For adult trout, especially adult steelhead, lethal water temperatures are approximately 73.4°F to 75.2°F (23°C to 24°C) (Moyle 2002).	
Adult upstream migration water temperature preference	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental.	Based on northern stocks, the reported optimal water temperature range for migrating adult steelhead is 46°F to 52°F (7.8°C to 11.1°C) (DWR and USBR 2000). The preferred water temperature range for the spawning migration of steelhead is reported to be 46°F to 52°F (7.8°C to 11.1°C) (NOAA 2000a).	
Adult Holding (Freshwater Residence)			
Water temperature tolerance for holding adults	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	Water temperatures <39.2°F (<4°C) and >73.4°F (>23°C) are reportedly lethal to unacclimated fish. For adult trout, especially adult steelhead, lethal water temperatures are reported to be approximately 73.4°F to 75.2°F (23°C to 24°C) (Moyle 2002). Summer-run steelhead can reportedly survive exposure to water temperatures from 77°F to 80.6°F (25°C to 27°C) for short periods (Moyle 2002). Rainbow trout are reportedly found in streams in which daytime water temperatures range from 32°F (0°C) in the winter to 80.6°F (27°C) in the summer (Moyle 2002). The following water temperature ranges and stress levels are reported for steelhead: ▪ Chronic low stress: 52.1°F to 57.5°F (11.2°C to 14.7°C); ▪ Chronic medium stress: 57.6°F to 61.0°F (14.2°C to 16.1°C); and, ▪ Chronic high stress: Greater than 61.0°F (16.1°C) (USFWS 1995).	
Water temperature preference for holding adults	Range of suitable, preferred or reported optimal water temperatures. Indicate	Reported optimal water temperatures for growth of rainbow trout range from approximately 59°F to 64.4°F (15°C to 18°C). In summer, when	

Element	Element Descriptor	General	Feather River Specific
	whether literature, observational, or experimental.	water temperatures fluctuate, reported optimal water temperatures are from approximately 3°F to 5°F (2°C to 3°C), lower than in streams with more constant conditions (Moyle 2002). Summer-run steelhead prefer cold pools in the range of 50°F to 59°F (10°C to 15°C) during summer months (Moyle 2002).	
Water depth range for holding adults	Reported range of observed (minimum and maximum) water depth utilization.	The minimum depth requirement for passage of adults is reported to be 7 inches (17.8 cm) (DWR and USBR 2000).	
Water depth preference for holding adults	Reported range of most frequently observed water depth utilization.	Summer-run steelhead reportedly prefer holding in deep pools of 9.8 feet (3 meters) or more (Moyle 2002).	
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.	Microhabitat occupied by steelhead during daylight hours in the New River, California included cover provided by bedrock ledges and boulders; fish also occupied areas with riparian shading (Nakamoto 1994).	
Water velocity range for holding adults	Reported range of observed (minimum and maximum) water velocity utilization.	Adult steelhead are reported to withstand maximum water velocities of 10 to 13 ft/sec (3.0 to 3.10 m/sec) (DWR and USBR 2000). Microhabitat occupied during daylight hours in the New River, California included water velocities that ranged from 0.4 to 13.4 in/sec (1 to 34 cm/sec) (Nakamoto 1994).	
Water velocity preference for holding adults	Reported range of most frequently observed water velocity utilization.	Microhabitat occupied during daylight hours in the New River, California included water velocities that averaged 3.7 in/sec (9.3 cm/sec); steelhead densities were highest at the higher water velocities (Nakamoto 1994).	
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.).	Adults occupied areas in the New River, California with cover and moderate water velocities (Nakamoto 1994).	

Element	Element Descriptor	General	Feather River Specific
Timing range for adult holding	Time of year (earliest-latest) and duration of stay from upstream migration to spawning.	Central Valley winter-run steelhead mature in the ocean and arrive on the spawning grounds nearly ready to spawn. Summer steelhead, or stream-maturing steelhead, enter freshwater with immature gonads and typically spend several months in freshwater before spawning (DWR and USBR 2000). Summer steelhead in the New River, California are reportedly found from July through October (Nakamoto 1994). Summer-run steelhead enter freshwater of the Columbia River, Washington from May to October and remain in the river all winter (often more than six months), and spawn the following spring (Robards and Quinn 2002). Winter-run steelhead enter freshwater of the Columbia River from November to April and spawn shortly afterwards (Robards and Quinn 2002).	Because Feather River steelhead are reported to be believed to be ocean-maturing (winter-run), they likely exhibit a relatively short holding duration (DFG 2002).
Timing peak for adult holding	Time of year when maximum number of adults are present before spawning.	Adult summer steelhead reportedly enter the New River as early as June, but most do not reach the pools in which they oversummer until August (Nakamoto 1994).	
Adult Immigration and Holding (combined life stage water temperature index values)			
Immigration and holding timing	Time of year adults migrate upstream and hold in rivers. If applicable, indicate for various runs.	Movements of adult steelhead from freshwater holding areas to spawning grounds can occur any time from December to March, with peak activities occurring in January and February (Moyle 2002).	In the Feather River, the adult immigration and holding time period lasts from September through April with peak migration extending from October through November (pers. com., B. Cavallo, 2004; McEwan 2001; Moyle 2002; S.P.Cramer & Associates 1995).
Water temperature index values for adult immigration and holding life stage.	Index water temperatures synthesized from examination of water temperature ranges reported in the literature. Indicate	**Index Value**	**Supporting Literature**

Element	Element Descriptor	General	Feather River Specific
	stressful or lethal levels.		
		52°F	The preferred water temperature range for adult steelhead immigration reportedly is 46.0°F to 52.0°F (NOAA 2000a; NOAA 2002b; State Water Resources Control Board 2003); The optimum water temperature range for adult steelhead immigration reportedly is 46.0°F to 52.1°F (USBR 1997); The recommended adult steelhead immigration water temperature range is 46.0°F to 52.0°F (USBR 2003).
		56°F	To produce rainbow trout eggs of good quality, brood fish reportedly must be held at water temperatures not exceeding 56.0°F (Leitritz and Lewis 1980; Bruin and Waldsdorf 1975 *in* Smith et al. 1983). Holding migratory fish at constant water temperatures above 55.4°F to 60.1°F reportedly may impede spawning success (EPA 2001; Billard and Breton 1977 *in* McCullough 1999; Billard and Gillet 1981 *in* McCullough 1999).
		70°F	Migration barriers have frequently been reported for pacific salmonids when water temperatures reach 69.8°F to 71.6°F (EPA 2001); Snake River adult steelhead immigration reportedly was blocked when water temperatures reached 69.8°F (Strickland 1967 in McCullough 1999).
Spawning			
Fecundity	Average or range in the number of eggs females lay in a spawning season.	Fecundity in steelhead is highly variable, ranging from 200 to 12,000 eggs per female. Steelhead contain approximately 2,000 eggs per pound (900 eggs per kilogram) of body weight. Rainbow trout under 11.8 inches (30 cm) Total Length (TL) contain fewer than 1,000 eggs (Moyle 2002). In the American River, mature female steelhead	

Element	Element Descriptor	General	Feather River Specific
		reportedly produce from 1,500 to 4,500 eggs, with an average of approximately 3,500 eggs per female. In the Sacramento River, the average number of eggs per female is reportedly approximately 1,500 (USFWS 1995).	
Nest construction	Location and general description of nest -- substrates, aquatic plants, excavations, crevices, habitat types, etc.	Steelhead construct nests (redds) in coarse gravels with relatively swift water (Moyle 2002).	
Nest size	Size and average dimensions of the nest.	Steelhead redds can contain up to 1,000 eggs, and 6 to 7 redds are required to complete spawning. The average redd size for Sacramento River basin steelhead is reported to be 56 feet^2 (5.2 meters^2), which is smaller than the average redd size in most California streams (USFWS 1995). Based on field observations of 54 redds in the Clearwater and Salmon river watersheds in Idaho, the average redd size was 17.7 feet^2 (5.4 meters^2), with a range of 6.9 to 44 feet^2 (2.09 to 11.2 meters^2) (Orcutt et al. 1968).	
Spawning process	Indicate whether nest builder, broadcast spawner, or other.	Steelhead are nest builders. Males remain at the nest sight two weeks longer than females after spawning and surviving spawners return to sea between April and June (USFWS 1995).	
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.	Steelhead spawning occurs over coarse gravel 0.5 to 5.1 inches (1 to 13 cm) in diameter in the tail of a pool or in a riffle (Moyle 2002). Approximately 70% of spawning gravels sampled in 68 redds in the Clearwater and Salmon river watersheds in Idaho were between 0.5 to 4 inches (1 to 10.6 cm) in diameter (Orcutt et al. 1968).	

Element	Element Descriptor	General	Feather River Specific
Preferred spawning substrate	Indicate preferred spawning substrate (e.g. mud, sand, gravel, boulders, plant bed, etc).	The preferred gravel particle size for steelhead spawning ranges from 0.25 to 3.0 inches (0.6 to 7.6 cm) in diameter, with less than 5% sand and silt by weight (USFWS 1995).	
Water temperature tolerance for spawning	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	Water temperatures ranged from 36°F to 47°F (2.2°C to 8.3°C) during peak spawning (mid April to mid May), in the Clearwater and Salmon river watersheds in Idaho (Orcutt et al. 1968). The preferred water temperature range for steelhead spawning is reported to be 30°F to 52°F (1.1°C to 11.1°C) (DFG 2000).	
Water temperature preference for spawning	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental derivation.	The reported optimum water temperature range for Central Valley steelhead spawning is 46.0°F to 52.0°F (7.8°C to 11.1°C) (USFWS 1995). Based on a literature review, the reported preferred water temperature range for spawning Central Valley steelhead is 39°F to 52°F (3.9°C to 11.1°C) (Interagency Ecological Program Steelhead Project Work Team 1998).	
Water velocity range for spawning	Minimum and maximum speed of water current the spawning fish can tolerate.	Water velocities over steelhead redds reportedly typically range from 0.65 to 5.1 ft/sec (0.2 to 1.6 m/sec) (Moyle 2002). The reported water velocity range for steelhead spawning is 0.5 to 3.6 ft/sec (0.2 to 1.1m/sec) (USFWS 1995).	
Water velocity preference for spawning	Preferred water current (flow velocity) during spawning.	The reported preferred water velocity for steelhead spawning is 1.5 ft/sec (0.5 m/sec) to 2.0 ft/sec (0.6 m/sec) (USFWS 1995).	

Element	Element Descriptor	General	Feather River Specific
Water depth range for spawning	Reported range of observed (minimum and maximum) water depth utilization.	Steelhead redds are reported as typically constructed at a depth of 0.3 to 4.9 feet (0.09 to 1.5 meters) (Moyle 2002). Steelhead redds are reportedly constructed at depths of 5 to 28 inches (12.7 to 71.1 cm)(USFWS 1995). In the Clearwater and Salmon river watersheds in Idaho, the shallowest water recorded over a redd was 0.7 feet (0.2 meters); while maximum depth was not measured in this study, redds *"were observed in depths exceeding 5 feet (1.5 meters)"* (Orcutt et al. 1968).	
Water depth preference for spawning	Reported range of most frequently observed water depth utilization.	The average water depth for spawning is reportedly 14 inches (35.6 cm) (USFWS 1995).	
Range for spawning timing	Earliest and latest time of season or year in which spawning occurs.	Central Valley winter-run steelhead reportedly spawn from December through March (Moyle 2002). Central Valley winter-run steelhead spawning reportedly can occur from October through June (McEwan 2001).	Central Valley steelhead in the Feather River reportedly spawn from November through June (Busby et al. 1996).
Peak spawning timing	Time of year most fish start to spawn.	Peak spawning for Central Valley winter-run steelhead reportedly occurs from January through February (Moyle 2002). The peak spawning range for Central Valley winter-run steelhead reportedly occurs from December through April (McEwan 2001). Peak spawning for California steelhead reportedly occurs from December through April (Interagency Ecological Program Steelhead Project Work Team 1998).	Peak spawning for Central Valley steelhead in the Feather River reportedly occurs from January through February (Busby et al. 1996).

Element	Element Descriptor	General	Feather River Specific
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.	Steelhead are reportedly iteroparous spawners. Both rainbow trout and steelhead spawn annually, but can skip a year between spawning efforts. Steelhead can spawn up to four times, but mortality rates of adults increase with subsequent spawning (50–75%) (Moyle 2002). Steelhead in California and Oregon are reportedly primarily 2-time spawners and in these regions, rarely spawn three or more times. Iteroparous steelhead are reportedly predominantly female (Busby et al. 1996).	
Incubation/Early Development			
Egg characteristics	Shape, size, color, in clusters or individuals, stickiness, and other physical attributes.	Steelhead eggs are pink to orange in color, generally spherical or slightly irregular, ranging in size from 0.12 to 0.24 inches (0.3 to 0.6 cm). The eggs are deposited in loose clusters or piles, and have been reported to range from adhesive during the water hardening process to not adhesive. Steelhead eggs are demersal (Wang 1986).	
Water temperature tolerance for incubation	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	Total mortality of steelhead eggs is believed to occur at water temperatures of approximately 63°F (17.2°C) or higher (Moyle 2002). Water temperatures suitable for steelhead egg incubation and emergence reportedly ranged from 48°F to 52°F (8.9°C to 11.1°C) (NOAA 2000a). There was substantial steelhead egg and alevin loss reportedly at water temperatures $\geq$ 56°F (13.3°C) (Placer County Water Agency and USBR 2002). Central Valley steelhead eggs can reportedly survive at water temperature ranges of 35.6°F to 59°F (2°C to 15°C) (Myrick and Cech 2001).	
Water temperature preference for	Range of suitable, preferred or reported optimal water	At water temperatures of 50°F to 59°F (10°C to 15°C), eggs reportedly will hatch in 3 to 4 weeks	

Element	Element Descriptor	General	Feather River Specific
incubation	temperatures. Indicate whether literature, observational, or experimental derivation.	(Moyle 2002). The water temperature range of 48°F to 52°F (8.9°C to 11.1°C) is reportedly preferred for steelhead egg incubation and emergence (Interagency Ecological Program Steelhead Project Work Team 1998). Central Valley steelhead eggs reportedly have the highest survival rates at water temperature ranges of 44.6 to 50 (7 to 10) (Myrick and Cech 2001).	
Time required for incubation	Time duration from fertilization to hatching. Note: Indicate at which temperature range. Incubation time is temperature-dependent.	Steelhead eggs will reportedly hatch in 3 to 4 weeks at water temperatures of 50°F to 59°F (10°C to 15°C) (Moyle 2002). Steelhead eggs will reportedly hatch in 19 days when incubated at 60°F (15.6°C), and in 80 days when incubated at 40°F (4.4°C)] (USFWS 1995). Steelhead eggs will reportedly hatch in approximately 4 weeks at water temperatures of 48°F to 52°F (8.9°C to 11.1°C) (DWR and USBR 2000) Hatchery steelhead will reportedly hatch in 30 days at 51°F (10.6°C) (McEwan and Jackson 1996).	
Size of newly hatched larvae	Average size of newly hatched larvae.	Larval steelhead are approximately 0.55 to 0.61 inches (1.4 to 1.6 cm) TL at hatching (Wang 1986).	
Time newly hatched larvae remain in gravel	Time of year of hatching, and duration between hatching and emergence from gravel.	Newly hatched steelhead reportedly remain in gravel for 2 to 3 weeks (Moyle 2002). Steelhead fry reportedly emerge from gravel 2 to 8 weeks after hatching(USFWS 1995). After hatching, the yolk-sac fry or alevins reportedly remain in gravel for 4 to 6 weeks (DWR and USBR 2000).	

Element	Element Descriptor	General	Feather River Specific
Other characteristics of larvae	Alevin -- early life history phase just after hatching (larva) when yolk-sac still present.		
Timing range for emergence	Time of year (earliest-latest) hatchlings (larvae and alevins) leave or emerge from the nesting/hatching (gravel) sites.	Emergence of steelhead reportedly ranges from January through April, based on 3 weeks of incubation and 3 weeks post-hatch residence time in gravel (i.e., 6 weeks added to the spawning timing range) (Moyle 2002). Central Valley winter-run steelhead incubation and emergence reportedly occurs from December through August (McEwan 2001).	
Timing peak for emergence	Time of year most hatchlings emerge.	Peak emergence of steelhead reportedly ranges from mid-February through March, based on 3 weeks of incubation and 3 weeks post-hatch residence time in gravel (i.e., 6 weeks added to the peak spawning range) (Moyle 2002). Central Valley winter run steelhead incubation and emergence reportedly peaks in January through June (McEwan 2001). Under laboratory conditions, young steelhead emerged from the gravel from 25 June to 8 July, and 75% of fish had absorbed their yolk sacs by 16 July; young steelhead also emerged from 10 July to 28 July, and 75% of fish had absorbed their yolk sac by 2 August (Chandler and Bjornn 1988).	
Size at emergence from gravel	Average size of hatchlings at time of emergence.	Average total lengths of steelhead at emergence, as observed under laboratory conditions, ranged from 1.1 to 1.2 inches (2.8 to 2.9 cm) (Chapman et al. 1986). Under laboratory conditions, steelhead weighed an average of 0.025 grams at emergence (Hawkins and Foote 1998).	

Element	Element Descriptor	General	Feather River Specific
Spawning and Egg Incubation (combined life stage water temperature index values			
Range for spawning and time required for incubation	Earliest and latest time of season or year in which spawning occurs and the time from fertilization to hatching. Note: Indicate at which temperature range. Incubation time is temperature-dependent.	In the Central Valley, steelhead spawning reportedly generally occurs from late-December to March, with embryo (i.e., eggs and alevins) incubation lasting roughly 2 to 3 months after deposition (McEwan 2001; Moyle 2002; Myrick and Cech 2001).	In the Feather River, steelhead spawning and embryo incubation reportedly extends from December through May, with peak spawning occurring in January and February (Busby et al. 1996; pers. com., B. Cavallo, 2004; Interagency Ecological Program Steelhead Project Work Team 1998; McEwan 2001; Moyle 2002).
Water temperature tolerance for spawning and egg incubation	Index water temperatures synthesized from examination of water temperature ranges reported in the literature. Indicate stressful or lethal levels.	**Index Values**	**Supporting Literature**
		52°F	Rainbow trout from Mattighofen (Austria) reportedly had the highest egg survival at 52.0°F compared to 45.0°F, 59.4°F, and 66.0°F (Humpesch 1985); Water temperatures from 48.0°F to 52.0°F are reported to be suitable for steelhead incubation and emergence in the American River and Clear Creek (NOAA 2000a; NOAA 2002b); The optimum water temperature range for steelhead spawning in the Central Valley reportedly is 46.0°F to 52.0°F (USFWS 1995); The optimum water temperature ranges for steelhead spawning and egg incubation were reported to be 46.0°F to 52.1°F for spawning and 48.0°F to 52.1°F for egg incubation (USBR 1997); The upper limit of the preferred water temperature range for steelhead spawning and egg incubation reportedly was 52.0°F (State Water Resources Control Board 2003).
		54°F	Big Qualicum River steelhead eggs reportedly had 96.6% survival to hatch at 53.6°F (Rombough 1988); The highest survival from fertilization to hatch

Element	Element Descriptor	General	Feather River Specific
			reportedly occurred at a water temperature of 53.6°F (Kamler and Kato 1983); Emergent fry were larger when North Santiam River (Oregon) winter steelhead eggs were incubated at 53.6°F than at 60.8°F (Redding and Schreck 1979); The upper optimal water temperature based on constant acclimation water temperatures necessary to achieve full protection of steelhead reportedly is between 51.8°F and 53.6°F (EPA 2001); Survival of rainbow trout eggs reportedly declined at water temperatures between 52.0 and 59.4°F (Humpesch 1985).
		57°F	From fertilization to 50% hatch, Big Qualicum River steelhead reportedly had 93% mortality at 60.8°F, 7.7% mortality at 57.2°F, and 1% mortality at 47.3°F and 39.2°F (Velsen 1987); From fertilization to 50% hatch, rainbow trout eggs from Ontario Provincial Normendale Hatchery reportedly had 56% survival when incubated at 59.0°F (Kwain 1975).

Element	Element Descriptor	General	Feather River Specific
Juvenile Rearing			
General rearing habitat and strategies	General description of freshwater environment and rearing behavior.	Regardless of life history strategy, for the first year or two of life rainbow trout and steelhead are found in cool, clear, fast-flowing permanent streams and rivers where riffles predominate over pools, there is ample cover from riparian vegetation or undercut banks, and invertebrate life is diverse and abundant (Moyle 2002). Following emergence, steelhead fry usually live in small schools in shallow waters along stream banks. As the steelhead grow, the schools break up and they establish individual feeding territories. Most steelhead live in riffles during their first year. Larger steelhead live in deeper, faster runs or pools. Their appearance and life are similar to that of non-anadromous resident rainbow trout. In comparison to Chinook salmon, which emigrate within a few months after emergence, steelhead rear to a relatively larger size. Consequently, juvenile steelhead are more dependent on larger and more abundant food resources than Chinook salmon and utilize deeper and faster runs and pools as they grow to larger sizes before emigration (USFWS 1995).	
Water temperature tolerance for juvenile rearing	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	The following water temperatures are reported for fry and juvenile rearing: ▪ chronic low stress: 60.1°F to 68.0°F (15.6°C to 20°C); ▪ medium stress: 68.1°F to 72.5°F (20.1°C to 22.5°C); and, ▪ high stress: greater than 72.5°F (>22.5°C) (USFWS 1995), 1995 LAR457 /id}. Mean critical thermal maxima under laboratory conditions for Nimbus hatchery strain juvenile steelhead reportedly ranged from 82°F to 85.3°F	Mean critical thermal maxima[1] for wild Feather River juvenile steelhead reportedly ranged from 87.1°F to 87.8°F (30.6°C to 31.0°C) in fasted and fed trial groups, respectively, under experimental conditions. Mean critical thermal maxima for hatchery-produced Feather River juvenile steelhead reportedly ranged from 84.9°F to 85.6°F (29.4°C to 29.8°C) across a range of ration levels under laboratory conditions. The difference between experimental critical thermal maxima for

[1] (Young and Cech Jr. 1996) describe the critical thermal maxima as "*the ecological lethal index because animals in nature may encounter such temperatures as acute fluctuations above their tolerance limits…*".

Element	Element Descriptor	General	Feather River Specific
		(27.8 °C to 29.6°C) across different temperature and ration treatments. Higher rearing/acclimation water temperatures [i.e., 59°F (15°C) and 66.2°F (19°C) vs. 51.8°F (11°C)] resulted in significantly higher critical thermal maxima. Ration did not result in critical thermal maxima effects, except within the 59°F (15°C) acclimation treatment (Cech and Myrick 1999). Rainbow trout are reportedly found where daytime water temperatures range from 32°F (0°C) in the winter to 80.6°F (27°C) in the summer. Water temperatures less than 39.2°F (<4°C) and greater than 73.4°F (>23°C) are lethal for unacclimated fish (Moyle 2002). Nielson et al. 1994 stated that wild steelhead populations in northern California avoided water temperatures ≥ 73.4°F (23°C) (EPA 2001). Central Valley steelhead reportedly successfully undergo the parr-smolt transformation process at water temperature ranges of 43.7°F to 52.3°F (6.5°C to 11.3°C) (Myrick and Cech 2001).	wild and hatchery produced steelhead is statistically significant, suggesting, according to Myrick and Cech (2000) that wild fish in the Feather River have a higher thermal tolerance than do hatchery-reared fish (Myrick and Cech 2000).
Water temperature preference for juvenile rearing	Range of suitable, preferred, or reported optimal water temperatures. Indicate whether literature, observational, or experimental derivation.	The reported optimum temperature range for fry and juvenile steelhead rearing is 55°F to 60°F (12.8°C to 15.5°C) (USFWS 1995) In laboratory trials with Nimbus Hatchery strain juvenile steelhead, preferred water temperatures ranged from 62.6°F to 68°F (17°C to 20°C), regardless of ration level or rearing/acclimation temperature (Cech and Myrick 1999). The reported preferred range for newly emerged steelhead fry is 45°F to 60°F (7.2°C to 15.5°C) (DWR and USBR 2000). The reported preferred water temperature range for fry and juvenile steelhead rearing is between 45°F to 60°F (7.2°C	Wild and hatchery-produced juvenile steelhead from the Feather River reportedly preferred water temperatures between 62.6°F to 68°F (17°C to 20°C) under laboratory conditions (Myrick and Cech 2001).

Element	Element Descriptor	General	Feather River Specific
		to 15.5°C) (Interagency Ecological Program Steelhead Project Work Team 1998). The preferred water temperature range for steelhead fry is reported to be between 55°F to 60.1°F (12.8°C to 15.6°C) (DFG 2000). The preferred water temperature range for the growth and development of Sacramento River steelhead fry is reported to be between 45°F to 65°F (7.2°C to 18.3°C) (NOAA 2000a). The preferred water temperature range for wild steelhead in the South Umpqua River, Oregon is reported to be between 59°F to 64°F (15°C to 17.8°C) (EPA 2001). The preferred water temperature range for juvenile steelhead rearing is reported to be between 45.1°F to 60.1°F (7.3°C to 15.6°C) (DFG 2000). The preferred water temperature range for the growth and development of Sacramento and American River juvenile steelhead is reported to be between 45°F to 65°F (7.2°C to 18.3°C) (NOAA 2000a). The maximum growth and survival of Central Valley juvenile steelhead reportedly occurs at water temperatures between 59°F to 66.2°F (15°C to 19°C) (Myrick and Cech 2001). The preferred water temperature range for juvenile steelhead rearing is reported to be between 62.6°F to 68°F (17°C to 20°C) (Myrick and Cech 2000).	
Water velocity ranges for rearing juveniles	Reported range of observed (minimum and maximum) water velocity utilization.	Steelhead fry utilize water velocities of 0.3 to 1.0 ft/sec (0.09 to 0.3 m/sec) (USFWS 1995).	Young-of-Year steelhead in the Feather River were observed from February through August. In February, all Young-of-

Element	Element Descriptor	General	Feather River Specific
		Steelhead juveniles utilize water velocities of 0.3 to 1.5 ft/sec (0.09 to 0.46 m/sec) (USFWS 1995). In laboratory trials with Nimbus Hatchery strain juvenile steelhead, critical swimming velocities ranged from 1.7 to 2.2 ft/sec (0.51 to 0.67 m/sec) across varied temperature and ration treatments (Cech and Myrick 1999).	Year steelhead observed were found at velocities from 0 to 0.50 ft/sec (0 to 0.15 m/sec); in April and June, Young-of-Year steelhead were observed in increasingly swifter waters, ranging from 0 to 0.50 ft/sec (0 to 0.15 m/sec) to greater than 3.0 ft/sec; in July, the greatest proportion of Young-of-Year steelhead were observed in waters greater than 3.0 ft/sec (0.91 m/sec); in August, the distribution of Young-of-Year steelhead approached normal (slightly skewed), with the greatest proportion of fish being found in water with velocities of 1.51 to 2.0 ft/sec (0.46 to 0.61 m/sec). Greater proportions of fish were found in water with velocities of 2.01 to 3.0 ft/sec (0.61 to 0.91 m/sec) than 0 to 1.5 ft/sec (0 to 0.46 m/sec) (DWR 2003).
Water velocities preferred by rearing juveniles	Reported range of most frequently observed water velocity utilization.	Reported optimal water velocities for steelhead fry (<2 inches or <50 mm in size) are 0.03 to 0.82 ft/sec (0.01 to 0.2 m/sec). Reported optimal water velocities for steelhead juveniles 2 to 3.9 inches (5.1 to 9.9 cm) in length are 0.33 to 0.98 ft/sec (0.1 to 0.3 m/sec) (Moyle 2002). The reported optimal water velocity for steelhead fry is 0.6 ft/sec (0.18 m/sec) (USFWS 1995). The reported optimal water velocity for steelhead juveniles is 0.9 ft/sec (0.27 m/sec) (USFWS 1995).	
Water depth range for juvenile rearing	Reported range of observed (minimum and maximum) water depth utilization.	Steelhead juveniles reportedly utilize water approximately 2 to 60 inches (5.1 to 152 cm) in depth (McEwan 2001).	From February through August, Young-of Year steelhead in the Feather River were observed at increasingly greater water depths; initially (i.e., in February) 100% of observed fish were found at depths between 0 and 9.4 inches (0 to 23.9 cm); in March, over 60% of Young-of Year steelhead remained at depths of 0 to 9.4 inches (0 to 23.9 cm), and approximately

Element	Element Descriptor	General	Feather River Specific
			30% of fish utilized depths between 9.8 inches (24.9 cm) and 19.3 inches (49 cm) [with a small proportion between 9.7 to 19.1 inches (24.6 to 48.5 cm)]; in April, the general distribution observed in March remained, with the addition of a small proportion of fish utilizing depths greater than 39.4 inches (100 cm); in May, more Young-of Year were observed in depths between 9.8 and 19.3 inches (24 to 49 cm), with smaller proportions observed from 0 to 9.4 inches (0 to 24 cm) (<40%); in June, the largest proportion of fish observed were observed between 9.8 and 19.3 inches (25 to 49 cm); in July, Young-of Year steelhead were observed primarily in the 0 to 9.4 inches (0 to 24 cm), 9.8 to 19.3 inches (25 to 49 cm), and 9.7 to 19.1 inches (50-74 cm) depth ranges, in proportions of slightly greater than 40%, slightly less than 40%, and approximately 30%, respectively [with few observations in the 29.5 to 38.10 inches (75 to 99 cm)] (DWR 2003).
Water depth preference for juvenile rearing	Reported range of most frequently observed water depth utilization.	Steelhead fry reportedly typically use water approximately 8 inches (20 cm) in depth (McEwan 2001). Juvenile steelhead reportedly typically use water approximately 15 inches (38 cm) in depth (McEwan 2001).	
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).	Steelhead fry will reportedly remain close to stream edges. Steelhead juveniles utilize rocks and other cover, and larger juvenile steelhead also utilize pockets behind rocks, runs or pools (Moyle 2002). Juvenile steelhead reportedly utilize relatively shallow depths and fast water velocities, which are less suitable to pikeminnows to avoid	Young-of Year steelhead in the Feather River were observed using small woody debris, large woody debris, overhead objects, aquatic vegetation, and undercut banks for cover. Large woody debris and undercut bank were used the least frequently among cover types. Young-of Year were observed using no apparent cover with a frequency of use

Element	Element Descriptor	General	Feather River Specific
		predation [i.e., in the Eel River, steelhead utilized depths of 27.6 to 15.4 inches (70 to 39 cm)], and water velocities of 0.46 to 1.4 ft/sec (0.14 to 0.43 m/sec)] (Moyle 2002).	approximately equal to that of small woody debris and aquatic vegetation (DWR 2003). From February through August, Young-of Year steelhead in the Feather River were observed at increasing distances from the channel edge, with the peak distance from edge occurring in July [from approximately 11.8 inches (30 cm) in February to approximately 70.9 inches (18 cm) in July] (DWR 2003).
Food base of juveniles	Indicate primary diet components. Also indicate the diet changes, if any, as growth occurs.	Rearing juveniles feed on a variety of aquatic and terrestrial insects and other small invertebrates (USFWS 1995). The gut content of juvenile steelhead seined from the lower American River was comprised primarily of chironomids, corixids, baetid mayflies, and hydropsychid caddisflies (Merz 1994). In the lower American River, where fluctuating flows from dam releases tend to limit the diversity of benthic organisms, steelhead feed largely on mayfly adults and larvae of chironomid midges (Moyle 2002). Anadromous steelhead leaving their home streams feed on estuarine invertebrates and marine krill (Moyle 2002).	
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.	Based on sampling of the lower American River, juvenile steelhead feed throughout the day, with peak feeding occurring at dawn (Merz 1994).	

Element	Element Descriptor	General	Feather River Specific
Predation of juveniles	Indicate which species prey on juveniles.	Avian predators of steelhead include kingfishers, mergansers, and herons. Large trout and pikeminnow also are predators of juvenile steelhead (Moyle 2002). Predators of steelhead include striped bass, pikeminnow, pinnipeds (adults and juveniles), and seabirds (S.P.Cramer & Associates 1995). It has been observed that steelhead fry can become prey of older steelhead (USFWS 1995).	
Timing range for juvenile rearing	Range of time of year (months) during which rearing occurs.	Central Valley steelhead rear year-round (McEwan 2001). Juveniles reside in Michigan streams for 1 to 3 years before smolting and emigrating to the Great Lakes (Newcomb and Coon 2001).	
Timing peak for juvenile rearing	Time of year (months) during which most rearing occurs.	Central Valley steelhead rear year-round (McEwan 2001).	
Juvenile Emigration			
Time spent in fresh water prior to emigrating	Duration (in years and/or months) from emergence to emigration to the ocean.	Juvenile steelhead can rear for nearly one year or longer before emigrating (USFWS 1995). Most naturally produced Central Valley steelhead rear for two years prior to emigrating (McEwan 2001). Juvenile steelhead will rear for 1 to 2 years.(USFWS 1995). Juvenile Central Valley steelhead will remain in freshwater for 1 to 3 years (DWR and USBR 2000). For ocean-maturing (winter-run) steelhead in the Sacramento River, 32% of juveniles emigrate after 1 year in freshwater, and 69% of juveniles emigrate after 2 years in freshwater (Busby et al. 1996).	

Element	Element Descriptor	General	Feather River Specific
Water temperature tolerances during emigration	Range of water temperatures allowing survival. Indicate stressful or lethal levels.	The following water temperatures are reported for juvenile steelhead emigration: ▪ chronic low stress: 52.4°F to 59.3°F (11.3°C to 15.2°C) ▪ medium stress: 59.4°F to 63.2°F (15.2°C to 17.3°C) ▪ high stress: >63.2°F (17.3°C) (USFWS 1995). Water temperatures ≤ 54.5°F (12.5°C) are reported to be considered suitable for emigrating juvenile steelhead (EPA 2001). When water temperatures were ≥ 55.4°F (13°C), the ATPase activity in juvenile steelhead was reportedly decreased and the migration of the fish was reduced (Zaugg and Wagner 1973). Central Valley steelhead reportedly show significant mortality at chronic water temperatures exceeding 77°F (25°C) (Myrick and Cech 2001).	
Water temperature preferences during emigration	Range of suitable, preferred or reported optimal water temperatures. Indicate whether literature, observational, or experimental derivation.	The reported optimal water temperature range for juvenile emigration is 44.4°F to 52.3°F (6.9°C to 11.3°C) (USFWS 1995). For northern populations of steelhead, water temperatures under 57°F (13.9°C) are reported as optimum for smoltification and emigration (DWR and USBR 2000; Interagency Ecological Program Steelhead Project Work Team 1998).	
Emigration timing range	Time of year juveniles commence emigration and duration of emigration	Central Valley winter-run steelhead emigration occurs from December through August (McEwan 2001).	
Emigration timing peak	Time of year most juveniles are emigrating.	Peak catch of yearling steelhead (both hatchery and naturally produced fish) in rotary screw traps in the Sacramento River near Knights Landing from September 1997 through October 1998 reportedly occurred from week 10 through 13 (i.e., throughout March) (Snider and Titus 2000).	

Element	Element Descriptor	General	Feather River Specific
		At pumping plants in the Delta, peak numbers of juvenile steelhead are reportedly observed in March and April (USFWS 1995). Peak emigration of Central Valley winter-run steelhead reportedly occurs from January through May (McEwan 2001). Steelhead reportedly emigrate during the months of April through June (Newcomb and Coon 2001).	
Size range of juveniles during emigration	Minimum and maximum sizes (inches or mm) of emigrating juveniles. Indicate average size.	Steelhead were captured moving downstream in Tye and Twiw creeks, southeastern Alaska with FL ranging from 3.5 to 7.5 inches (8.9 to 19 cm; mean FL for steelhead in Tye Creek was 5.1 inches (13.3 cm) and mean FL for steelhead in Twiw Creek was 5.2 inches (13.1 cm) (Bramblett et al. 2002). FL for females captured in the Dean River from July to September ranged from 29.3 to 7.5 inches (74.3 to 76.5 cm) and FL of males captured at the same time ranged from 30.1 to 31.7 inches (76.5 to 80.6 cm); mean FL for both groups was 29.6 inches (75.3 cm) (Hendry et al. 2002).	
Factors associated with emigration	Pulse flows, water temperature changes, turbidity levels, photoperiod, etc.	Steelhead in Michigan streams reportedly emigrate in water temperatures of 50°F to 59°F (10°C to 15°C); steelhead smolts migrate at night and during the spring with high flows from spring snowmelt (Newcomb and Coon 2001).	
Juvenile Rearing and Downstream Movement (combined life stage water temperature index values			
Fry and fingerling rearing and emigration timing range	Range of time of year (months) during which rearing occurs and time and duration of juvenile emigration.	After Central Valley steelhead emerge from the gravel, juveniles reportedly remain in freshwater for 1-3 years before smolting and migrating to saltwater (Myrick and Cech Jr. 2001). Shapovalov and Taft (1954) suggest that most Waddell Creek, CA steelhead rear in freshwater	

Element	Element Descriptor	General	Feather River Specific
		for two years.	
Water temperature tolerances during fry and fingerling rearing and emigration	Index water temperatures synthesized from examination of water temperature ranges reported in the literature. Indicate stressful or lethal levels.	**Index Values**	**Supporting Literature**
		65°F	The upper limit reportedly preferred for growth and development of Sacramento River and American River juvenile steelhead is 65°F (NOAA 2000a); Nimbus strain juvenile steelhead growth reportedly showed an increasing trend with water temperatures up to 66.2°F, irrespective of ration level or rearing temperature (Cech and Myrick 1999); The final preferred water temperature for rainbow trout fingerlings reportedly was between 66.2°F and 68°F (Cherry et al. 1977); Nimbus strain juvenile steelhead reportedly preferred water temperatures between 62.6°F and 68.0°F (Cech and Myrick 1999); Rainbow trout fingerlings reportedly preferred or selected water temperatures in the 62.6°F to 68.0°F range (McCauley and Pond 1971).
		68°F	Nimbus strain juvenile steelhead reportedly preferred water temperatures between 62.6°F and 68.0°F (Cech and Myrick 1999); The preferred water temperature for rainbow trout fingerlings reportedly was between 66.2 and 68°F (Cherry et al. 1977); The upper avoidance water temperature for juvenile rainbow trout reportedly was measured between 68°F and 71.6°F (Kaya et al. 1977 *in* McCullough 1999).
		72°F	Increased physiological stress, increased agonistic activity, and a decrease in forage activity in juvenile steelhead reportedly

Element	Element Descriptor	General	Feather River Specific
			occur after ambient stream water temperatures exceed 71.6°F (Nielsen et al. 1994); The upper avoidance water temperature for juvenile rainbow trout reportedly was measured between 68°F and 71.6°F (Kaya et al. 1977 *in* McCullough 1999); Estimates of upper thermal tolerance or avoidance limits for juvenile rainbow trout (at maximum ration) reportedly ranged from 71.6°F to 79.9°F (Ebersole et al. 2001 *in* EPA 2002).
		75°F	The maximum weekly average water temperature for survival of juvenile and adult rainbow trout reportedly is 75.2°F (EPA 2002); Rearing steelhead juveniles reportedly have an upper lethal limit of 75.0°F (NOAA 2001); Estimates of upper thermal tolerance or avoidance limits for juvenile rainbow trout (at maximum ration) reportedly ranged from 71.6°F to 79.9°F (Ebersole et al. 2001 *in* McCullough 1999).
Smolt Emigration			
Emigration timing range	Time of year juveniles commence emigration and duration of emigration	Steelhead smolts reportedly migrate out to sea at 1-3 years of age, at 10-25 cm FL (Moyle 2002).	In the Feather River, steelhead smolt emigration reportedly occurs from January through June (McEwan 2001; Newcomb and Coon 2001; Snider and Titus 2000; USFWS 1995).
Water temperature tolerances during emigration	Index water temperatures synthesized from examination of water temperature ranges reported in the literature. Indicate stressful or lethal levels.	**Index Values**	**Supporting Literature**
		52°F	Steelhead reportedly successfully smolt at water temperatures in the 43.7°F to 52.3°F range (Myrick and Cech 2001); Steelhead trout reportedly undergo the smolt transformation when reared in water temperatures below 52.3°F, but not at

Element	Element Descriptor	General	Feather River Specific
			higher water temperatures (Adams et al. 1975); The optimum water temperature range for successful smoltification in young steelhead reportedly is 44°F to 52.3°F (Rich 1987).
		55°F	ATPase activity reportedly was decreased and migration reduced for steelhead at water temperatures ≥55.4 (Zaugg and Wagner 1973); Water temperatures reportedly should be below 55.4°F at least 60 days prior to release of hatchery produced steelhead trout to prevent premature smolting and desmoltification (Wedemeyer et al. 1980); In winter steelhead, a water temperature of 54.1°F reportedly is nearly the upper limit for smolting (McCullough et al. 2001); Water temperatures less than or equal to 54.5°F are reportedly suitable for emigrating juvenile steelhead (EPA 2003).
Other Potential Factors			
DO	Levels of dissolved oxygen in water expressed in mg/l tolerated by fish.	In experimentally controlled conditions, fertilized steelhead eggs were subjected to a range of water velocities and dissolved oxygen levels and held at constant temperatures. Complete mortality of embryos occurred at dissolved oxygen concentrations of 1.6 mg/L, whereas 78-85% hatching success occurred at dissolved oxygen concentrations of 2.6 mg/L (the next highest treatment level). In summary, reductions in dissolved oxygen concentration, as well as decreases in water velocity reportedly each resulted in a longer developmental period to hatching, smaller embryos throughout development and at hatching, higher pre- and post-hatching mortalities, and an increased occurrence of structurally abnormal embryos (Silver et al. 1963). Survival of steelhead embryos reportedly	

Element	Element Descriptor	General	Feather River Specific
		increases with increasing levels of dissolved oxygen. (Chapman 1988). At low water temperatures, rainbow trout survive dissolved oxygen concentrations as low as 1.5 to 2.0 mg/L, but require a dissolved oxygen concentration close to saturation for growth (Moyle 2002).	
pH	Alkalinity/acidity of water (expressed in pH) that fish can tolerate.	Rainbow trout can live at pH values of 5.8 to 9.6, and the reported optimal range is 7.0 to 8.0 (Moyle 2002).	
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.	Steelhead tolerate a wide range of turbidities from clear low flow periods to turbid water runoff conditions (Moyle 2002).	
Factors contributing to mortality	Indicate causes of fish mortality (e.g. fishing/angling mortality, drastic habitat alterations, unfavorable climatic changes, etc).	Stressors affecting steelhead on the west coast include logging, agriculture, urbanization, disease, predation, water diversions, dams and other structures, gravel mining, dredging and sediment disposal, and contaminants. Water development and management activities have reportedly been identified as the primary stressor to Central Valley steelhead (McEwan 2001). Although hatcheries have maintained the steelhead fishery in Sacramento River, habitat protection and restoration measures for wild stocks were reportedly largely ignored (Moyle 2002). Hatchery strains of rainbow trout are reportedly typically of mixed origins because of intense selection for desirable traits, such as rapid growth under crowded conditions, resistance to disease, and high fecundity (Moyle 2002).	
General passage considerations (upstream and	Indicate issues associated with fish passage (e.g. burst speed, max speed, handling	Mortality of steelhead seen in the estuary or ocean may be related to earlier experience (result of cumulative stresses) as observed with	

Element	Element Descriptor	General	Feather River Specific
downstream)	stress, survival rates, stressors, body type, etc).	steelhead in the Snake River system, Wyoming (Budy et al. 2002). Steelhead that passed through turbines within the Snake River system, Wyoming were exposed to pressure changes and mechanical injuries (Budy et al. 2002). Steelhead passing through the bypass within the Snake River system, Wyoming experienced an increase in turbulence (Budy et al. 2002). There are reportedly several problems associated with the passage of steelhead through dams by way of collection, bypass, and turbines within the Snake River system, Wyoming. These include: • Delay of smolts in forebay; • Concentration of smolts in forebay and tailrace at bypass outflow; • Increase of predation rates near dam where smolts congregate; • Increased exposure to pressure changes; and • Mechanical injuries (Budy et al. 2002). Advantages associated with spillways for steelhead passage include: • Less delay than other methods; • Avoid some of mechanical injury; • Predators more dispersed in the tailwater of the spillway; and • Flow determined the proportion of fish that would be passed through spillway (Budy et al. 2002). Steelhead reportedly expend more energy and time getting through the non-free flowing areas within the Snake River system, Wyoming than they would expend traversing the free flowing areas (Budy et al. 2002). The magnitude of stress in steelhead at capture	

Element	Element Descriptor	General	Feather River Specific
		sites is very difficult to measure, but reportedly can lead to • Delayed mortality; • Metabolic disturbances which can lead to lower survival rates; • Increased vulnerability to predators because of hydrosystem induced stress; and • Avoidance of salt water; and • Lowered disease resistance (Budy et al. 2002). Truck or barge transport shortens travel time and may result in premature saltwater entry when steelhead are reportedly not physiologically ready for entry (Budy et al. 2002). Low-flow conditions increased stress of steelhead migrating through the hydrosystem within the Snake River, Wyoming [i.e., increased delays and increased travel times] (Budy et al. 2002). Direct mortality may be lowest for steelhead bypassed as opposed to being passed through turbines or over spillways within the Snake River system, Wyoming but delayed mortality reportedly occurs in bypassed steelhead (Budy et al. 2002). Recent PIT tag data are direct evidence that delayed mortality of both in-river steelhead and transported steelhead (smolts) is related to the hydropower system within the Snake River, Wyoming (Budy et al. 2002). The decreases in survival rates of steelhead were in the smolt to adult lifestage rather than spawner to adult (Budy et al. 2002).	

Element	Element Descriptor	General	Feather River Specific
		During the years 1958 to 1968, 6 dams were completed on the Columbia River system. These low head dams provided passage for steelhead but reportedly delayed migrations and caused up migrating adult mortalities (Raymond 1988). During the years 1969 to 1984, there was a major increase in steelhead smolt mortalities within the Columbia River basin; • Mortalities due to direct passage through turbines, delays in passage through reservoirs, and supersaturation of atmospheric gasses; and • Storage reservoirs cause reductions in flows that delay smolt migrations. More time traveling downstream means prolonged exposure to predation and disease, reportedly creating increased mortalities (Raymond 1988). Response of steelhead smolts to mass transportation from the Snake River, Wyoming has been reported as “excellent” (Raymond 1988). Delayed mortality due to disease also has been reportedly seen in steelhead the Columbia-Snake River system (Monk et al. 1989). Wydemeyer (1972) showed that in coho and steelhead fingerlings held in water with 3 ppt salt concentrations the stress of handling (as measured by blood chemistry) was alleviated (Monk et al. 1989). During the years 1971 to 1975, mortality studies on the Columbia-Snake River system reportedly showed that 15-20% of Chinook salmon died within 48 hours after release from the truck transport but steelhead incurred less than 1%	

Element	Element Descriptor	General	Feather River Specific
		mortality (Monk et al. 1989). Stressed steelhead groups hauled in salt water and held in freshwater had a significantly lower survival rate than fish hauled in saltwater (Monk et al. 1989). Responses of fish from Smith Falls Trout Hatchery, British Columbia to tank truck transportation include: • In 8 out of 9 cases there was a significant increases in the lactic acid above the average condition of recovered fish; and • In 6 out of 9 cases the blood lactic acid levels were higher (Black and Barrett 1957). Studies of fish transported from Smith Falls, British Columbia found that increased lactic acid is reportedly associated with death in the steelhead trout (Black and Barrett 1957). Minimal handling of fish transported from Smith Falls, British Columbia reportedly caused a significant increase in muscular activity both for cutthroat trout and steelhead (Black and Barrett 1957). Handling and live transport from Smith Falls, British Columbia for two hours reportedly caused a very significant degree of muscular activity in steelhead (Black and Barrett 1957). Surface bypasses are reportedly thought to be less stressful to steelhead smolts than are powerhouse bypass systems that use intake screens (Johnson et al. 2001). Fish distribution patterns were reportedly greatly altered by strobe light treatments before and during daytime fill events on the Snake River	

Element	Element Descriptor	General	Feather River Specific
		(Johnson et al. 2001). Strobe lights were reportedly shown to effectively clear the immediate area in front of culvert entrances of fish on the Snake River (Johnson et al. 2001). The lateral line function reportedly can be temporarily disabled by exposure to increased intensity sound (seen in steelhead in lab study) (Popper and Carlson 1998). Gas bubble disease reportedly affects the lateral line system (Heber & Schiewe, 1976) to the point of total unresponsiveness with progressive formation of bubbles beneath the skin (Popper and Carlson 1998). Gas saturated water below dams reportedly adversely affects smolts (Popper and Carlson 1998). Steelhead responded to the onset of sound when the stimulus was a pure tone from 10 to 280 Hz. The maximum behavioral response (changes in swimming patterns of large groups of fish) reportedly occurred when the sounds were from 35 to 170 Hz (Popper and Carlson 1998). The fish never moved more than 60 cm from the sound source (underwater loudspeaker), which occurred at frequencies from 40 to 120 Hz (Popper and Carlson 1998). Higher proportions of radio-tagged steelhead reportedly entered a surface bypass and collector when a behavioral guidance structure (a steel wall 330 m long and 17 to 24 m deep) was installed compared to when it was not at the Lower Granite Dam on the Snake River,	

Element	Element Descriptor	General	Feather River Specific
		Washington (American Fisheries Society 2001). Passage efficiency for spawning Chinook salmon and wild steelhead was slightly higher with a behavioral guidance structure (a steel wall 330 m long and 17 to 24 m deep) was in [place compared to when it was not at the Lower Granite Dam on the Snake River, Washington (American Fisheries Society 2001). Results indicated that survival of transported steelhead was greater than the survival of steelhead left to migrate through the dams and bypass facilities in the Snake River system (Ward et al. 1997). Concentrations of cortisol in steelhead smolts was reportedly significantly increased during passage through any of three flumes during daytime and nighttime tests on the Columbia River system, Washington (1987) (Congleton et al. 1988). Slight darkening of a corrugated metal flume and receiving tank during daytime tests conducted on dam bypass facilities in 1987 reportedly effectively reduced the stress response in steelhead smolts to passage on the Columbia River system (Congleton et al. 1988). Traps were reportedly successful in capturing and safely holding a large number of steelhead smolts (i.e., up to 2500 smolts per night) for passage below a dam at the Little Manistee River weir, a tributary to Lake Michigan (Seelbach et al. 1985). Several thousand adult steelhead were reportedly passed safely both upstream and downstream per year at Little Manistee River	

Element	Element Descriptor	General	Feather River Specific
		weir, a tributary to Lake Michigan (Seelbach et al. 1985). Damage can reportedly occur to gills, eyes and internal organs when fish are passed over spillways and can potentially occur when the impact velocity of fish on the water surface in the downstream pool exceeds 52.5 ft/sec (16m/sec) within the Columbia River basin (Larinier 2000). The water column reportedly reaches its critical velocity for fish after a drop of 42.7 feet (13 meters). At drops greater than 42.7 feet (13 meters) injuries may become more significant and mortality increases rapidly in proportion to the drop (100% mortality for 164 to 197 feet [50 to 60 meters]) as observed within the Columbia River basin (Larinier 2000). Extended-length screens and higher levels of spill earlier in the migration season reportedly decreased the percentage of juvenile steelhead passed through turbines at each dam, thereby reducing dam-related mortalities on the lower Snake and Columbia rivers (Muir et al. 2001). Handling and anesthesia reportedly may have affected survival for steelhead migrants during a passage study in the lower Snake and Columbia rivers (i.e. handled and anesthetized fish may have been more vulnerable to predators) (Muir et al. 2001). In several studies, steelhead transported below dams as juveniles in the Snake River reportedly returned as adults at significantly higher rates than did those that migrated in river (Ebel et al. 1973, Slatick et al. 1975, Ebel 1980, Park 1985, Mathews 1992 *in* NOAA 2000c).	

Element	Element Descriptor	General	Feather River Specific
		Straying rates of transported Snake River steelhead have been reported as follows: • Between 1 and 3%, • In studies conducted between 1975 and 1980, of marked fish, 0.2% of steelhead adults were identified as strays; Ebel (1980) and Park (1985) agreed that straying had a minimal impact on overall adult returns (NOAA 2000c). There is no direct evidence to show that increased straying of steelhead into the Deschutes River is related to the juvenile fish transportation program (NOAA 2000b). Direct Transportation Mortality has been reported as follows: • 0.1 to 8.9% depending on facility, species, and life stage overall for collection facilities (Council on Environmental Quality 1997). • Collection and transportation, (COE) estimates that average seasonal direct mortality for collection and transportation combined reportedly is less than 2% (Council on Environmental Quality 1997). • Transport mortality potentially caused by stress, disease and injury (Council on Environmental Quality 1997). • Release studies conducted from 1992 to 1996 showed no evidence of large-scale predation on smolts immediately following release from the barges (NOAA 2000c). Recovery from stress has been reported as follows: • Elevated plasma cortisol levels associated with stress induced by handling and marking procedures was reportedly seen to decrease significantly during 3 hours of truck transportation (Matthews et al. 1977);	

Element	Element Descriptor	General	Feather River Specific
		• A 1993 study showed that previously elevated stress indicators decreased during the course of barge transport (Schreck et al. 1994); and • Recent studies reported that elevated blood plasma cortisol levels in barged steelhead largely returned to normal during the trip downriver except during peak migration when levels remained elevated throughout the collection and transportation process (NOAA 2000c). During 1994 and 1995, studies at John Daly Dam on the Columbia River demonstrated that collection and loading were also stressful to steelhead smolts. Recovery reportedly varied widely over the course of migration season (NOAA 2000c). Salt water was not reported to add any benefit to the overall survival of steelhead juveniles transported on the Columbia and Snake rivers (Park et al. 1980). Research reportedly suggests that there are more returning adult steelhead with truck and or barge transport of juveniles downstream on the Columbia and Snake rivers (Matthews 1992). Current studies reportedly suggest that homing is not affected by downstream transportation of steelhead juveniles on the Columbia and Snake rivers (Matthews 1992). Ruggles and Ryan (1964) reportedly found louvers to be successful in guiding juvenile steelhead (CH2M Hill 1980). The Brownlee Skimmer Net, located in Brownlee Reservoir on the Snake River, reportedly proved only partially successful because many	

Element	Element Descriptor	General	Feather River Specific
		fingerlings passed under or through the net and left the reservoir via turbine or spillway (Sims 1970 *in* CH2M Hill 1980). Bell (1973) is quoted by DWR (2003) as reporting sustained swimming speeds for steelhead in the Columbia River to be in the range of 0 to 4.6 ft/sec. Steelhead prolonged swimming speeds in the Columbia River are reported to be in the range of 4.6 to 13.7 ft/sec. Bell also reports burst swimming speeds for steelhead trout in the Columbia River to be between 13.7 and 26.5 ft/sec (Mills et al. 2003). Adult anadromous-sized steelhead, with a burst swimming speed of 26.5 ft/sec, fresh of saltwater or still a long distance from their spawning grounds and that have not yet had their spawning colors develop, have been reported to jump 10.9 feet [HL = (26.5 ft/sec(sin 90°))^2/2*32.2 ft/sec)] (Mills et al. 2003). The most conservative estimate of the height of Salmon Falls, Feather River is 15 feet. The maximum height of the fish's leap for anadromous-sized steelhead for this location was reported to be 6.1 feet. The analysis suggests that Salmon Falls is an elevation barrier for anadromous-sized steelhead under the high flow conditions observed in March 2003 (Mills et al. 2003). The measured height of Miocene Dam, North Fork Feather River under low flow conditions was 10.1 feet. The maximum height of the fish's leap for anadromous-sized steelhead for this location was reported to be 6.1 feet. The analysis suggests that Miocene Dam is an elevation barrier for anadromous-sized steelhead under the low flow conditions observed in October 2002	

Element	Element Descriptor	General	Feather River Specific
		(Mills et al. 2003). The measured height of Miocene Dam, North Fork Feather River under high flow conditions was 7.9 feet. The maximum height of the fish's leap for anadromous-sized steelhead for this location was reported to be 6.1 ft. The analysis suggests that Miocene Dam is an elevation barrier for anadromous-sized steelhead under the high flow conditions observed in March 2003 (Mills et al. 2003). The most conservative measured height of Big Bend Dam, North Fork Feather River under low flow conditions was 30 feet. The maximum height of the fish's leap for anadromous-sized steelhead for this location was reported to be 6.1 feet. The analysis suggests that Big Bend Dam is an elevation barrier for anadromous-sized steelhead under the low flow conditions observed in October 2002 (Mills et al. 2003). The measured height of Curtain Falls, North Fork Feather River under low flow conditions was 25 feet. The maximum height of the fish's leap for anadromous-sized steelhead for this location was reported to be 6.1 feet. The analysis suggests that Curtain Falls is an elevation barrier for anadromous-sized steelhead under the low flow conditions observed in October 2002 (Mills et al. 2003). The most conservative estimated height of Ponderosa Dam, South Fork Feather River under low flow conditions was 35 feet. The maximum height of the fish's leap for anadromous-sized steelhead for this location was reported to be 6.1 feet. The analysis suggests that Ponderosa Dam is an elevation barrier for anadromous-sized steelhead under the low flow conditions observed	

Element	Element Descriptor	General	Feather River Specific
		in October 2002 (Mills et al. 2003). The measured heights of Middle Concow Creek Falls and Upper Concow Creek Falls, Concow Creek under low flow conditions were 8 feet and 13 feet, respectively. The maximum height of the fish's leap for anadromous-sized steelhead for this location was reported to be 6.1 feet. The analysis suggests that both Middle Concow Creek Falls and Upper Concow Creek Falls are elevation barriers for anadromous-sized steelhead under the low flow conditions observed in July 2003 (Mills et al. 2003). The estimated height of each of the three potential barriers (Berry Creek Falls #1, Berry Creek Old Dam, and Berry Creek Falls #2) on Berry Creek, a tributary of the North Fork Feather River, was 27 feet, 5.8 feet, and 12 feet. The maximum height of the fish's leap for anadromous-sized steelhead for this location was reported to be 6.1 feet. The analysis suggests that Berry Creek Falls #1 and Berry Creek Falls #2 are elevation barriers for anadromous-sized steelhead under the low flow conditions observed in October 2002 (Mills et al. 2003). The estimated range of Berry Creek Old Dam was 8.5 feet. The maximum height of the fish's leap for anadromous-sized steelhead for this location was reported to be 4.84 feet (Mills et al. 2003). The measured height of lower French Creek Falls, French Creek, which is a large tributary of the North Fork Feather River, under low flow conditions was 10 feet. The maximum height of the fish's leap for anadromous-sized steelhead for this location was reported to be 6.1 ft. The	

Element	Element Descriptor	General	Feather River Specific
		analysis suggests that lower French Creek Falls is an elevation barrier for anadromous-sized steelhead under the low flow conditions observed in October 2002 (Mills et al. 2003). The measured height of lower French Creek Falls, French Creek, which is a large tributary of the North Fork Feather River, under high flow conditions was 7 feet. The maximum height of the fish's leap for anadromous-sized steelhead for this location was reported to be 6.1 ft. The analysis suggests that lower French Creek Falls is an elevation barrier for anadromous-sized steelhead under the high flow conditions observed in March 2003 (Mills et al. 2003). The measured height of Chino Creek Falls #1 and Chino Creek Falls #2, Chino Creek, which is a tributary of the North Fork Feather River, was 20 feet and 14.2 feet, respectively. The maximum height of the fish's leap for anadromous-sized steelhead for this location was reported to be 6.1 ft. The analysis suggests that Chino Creek Falls #1 and Chino Creek Falls #2 are both elevation barriers for anadromous-sized steelhead under the low flow conditions observed in October 2002 (Mills et al. 2003). The measured height of Stony Creek Falls, Stony Creek, which is a tributary of the North Fork Feather River, was 20 feet. The maximum height of the fish's leap for anadromous-sized steelhead for this location was reported to be 6.1 ft. The analysis suggests that Stony Creek Falls is an elevation barrier for anadromous-sized steelhead under the low flow conditions observed in October 2002 (Mills et al. 2003). The measured height of Sucker Run Creek Boulder Falls, Sucker Run Creek, which is a	

Element	Element Descriptor	General	Feather River Specific
		tributary of the South Fork Feather River, was 4.1 feet. The maximum height of the fish's leap for anadromous-sized steelhead for this location was reported to be 6.1 ft (Mills et al. 2003). The estimated range of Sucker Run Creek Boulder Falls was 7.7 feet. The maximum height of the fish's leap for anadromous-sized steelhead for this location was reported to be 5.5 feet (Mills et al. 2003). The measured heights of Fall River Falls and Feather Falls, Fall River, which is a tributary of the North Fork Feather River were 20 feet and 640 feet, respectively. The maximum height of the fish's leap for anadromous-sized steelhead for this location was reported to be 6.1 feet. The analysis suggests that Fall River Falls and Feather Falls are elevation barriers for anadromous-sized steelhead under the low flow conditions observed in July 2002 (Mills et al. 2003).	

References

Adams, B. L., W. S. Zaugg, and L. R. McLain. 1975. Inhibition of Salt Water Survival and Na-K-ATPase Elevation in Steelhead Trout (*Salmo gairdneri*) by Moderate Water Temperatures. Transactions of the American Fisheries Society 104:766-769.

American Fisheries Society. 2001. Fisheries, vol. 26.

Black, E. C. and I. Barrett. 1957. Increase in Levels of Lactic Acid in the Blood of Cutthroat and Steelhead Trout Following Handling and Live Transportation. The Canadian Fish Culturist 20:13-24.

Bramblett, R. G., M. D. Bryant, B. E. Wright, and R. G. White. 2002. Seasonal Use of Small Tributary and Main-Stem Habitats by Juvenile Steelhead, Coho Salmon, and Dolly Varden in a Southeastern Alaska Drainage Basin. Transactions of the American Fisheries Society 131:498-506.

Budy, P. E., G. P. Thiede, N. Bouwes, C. E. Petrosky, and H. Schaller. 2002. Evidence Linking Delayed Mortality of Snake River Salmon to Their Earlier Hydrosystem Experience. North American Journal of Fisheries Management 22:35-51.

Busby, P. J., T. C. Wainwright, G. J. Bryant, L. J. Lierheimer, R. S. Waples, F. W. Waknitz, and I. V. Lagomarsino. 1996. Status Review of West Coast Steelhead From Washington, Idaho, Oregon, and California. Report No. NMFS-NWFSC-27. NOAA Tech. Memo. U.S. Dep. Commer.

Cavallo, B., Environmental Scientist, DWR, Sacramento, CA. verbal communication with B. Ellrott, Fisheries Biologist, SWRI, Sacramento, CA. Establishment of Instream Flow and Water Temperature Targets for the Feather River. February 4, 2004.

Cech Jr., J. J. and C. A. Myrick. 1999. Steelhead and Chinook Salmon Bioenergetics: Temperature, Ration, and Genetic Effects. Technical Completion Report- Project No. UCAL-WRC-W-885. University of California Water Resources Center.

CH2M Hill. 1980. Survival of Downstream Migrant Coho Salmon and Steelhead Trout Through Bulb Turbines.

Chandler, G. L. and T. C. Bjornn. 1988. Abundance, Growth, and Interactions of Juvenile Steelhead Relative to Time of Emergence. Transactions of the American Fisheries Society 117:432-443.

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

Chapman, D. W., D. E. Weitkamp, T. L. Welsh, M. B. Dell, and T. H. Schadt. 1986. Effects of River Flow on the Distribution of Chinook Salmon Redds. Transactions of the American Fisheries Society 115:537-547.

Cherry, D. S., K. L. Dickson, J. Jr. Cairns, and J. R. Stauffer. 1977. Preferred, Avoided, and Lethal Temperatures of Fish During Rising Temperature Conditions. Journal of the Fisheries Research Board of Canada 34:239-246.

Congleton, J. L., E. J. Wagner, and R. R. Ringe. 1988. Evaluation of Fishway Designs for Downstream Passage of Spring Chinook Salmon and Steelhead Trout Smolts, 1987. Final Report.

Council on Environmental Quality. 1997. Considering Cumulative Effects Under the National Environmental Policy Act.

DFG. 2000. Lower American River Pilot Salmon and Steelhead Spawning Habitat Improvement Project. Quarterly Status Report July 1999-March 2000. U.S. Fish and Wildlife Service.

DFG. 2002. State and Federally Listed Endangered and Threatened Animals of California. California Natural Diversity Database. DFG, Habitat Conservation Division, Wildlife and Habitat Data Analysis Branch.

DWR. 2003. Redd Dewatering and Juvenile Steelhead and Chinook Salmon Stranding in the Lower Feather River , 2002-2003: Interim Report SP-F10, Task 3C. Sacramento, CA: DWR, Division of Environmental Services.

DWR and USBR. 2000. Biological Assessment- Effects of the Central Valley Project and State Water Project on Steelhead and Spring-Run Chinook Salmon.

EPA. 2001. Salmonid Behavior and Water Temperature - Issue Paper 1. Report No. EPA-910-D-01-001. EPA.

EPA. 2002. National Recommended Water Quality Criteria: 2002. Report No. EPA-822-R-02-047.

EPA. 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. EPA 910-B-03-002. Seattle, WA: Region 10 Office of Water.

Fry, D. H. 1973. Anadromous Fishes of California. Sacramento: California Department of Fish and Game.

Hawkins, D. K. and C. J. Foote. 1998. Early Survival and Development of Coastal Cutthroat Trout (*Oncorhynchus clarki clarki*), Steelhead (*Oncorhynchus mykiss*), and Reciprocal Hybrids. Canadian Journal of Fisheries and Aquatic Science 55:2097-2104.

Hendry, M. A., J. K. Wenburg, K. W. Myers, and A. P. Hendry. 2002. Genetic and Phenotypic Variation Through the Migratory Season Provides Evidence for Multiple Populations of Wild Steelhead in the Dean River, British Columbia. Transactions of the American Fisheries Society 131:418-434.

Humpesch, U. H. 1985. Inter- and Intra-Specific Variation in Hatching Success and Embryonic Development of Five Species of Salmonids and *Thymallus thymallus*. Archiwum Hydrobiologia 104:129-144.

Interagency Ecological Program Steelhead Project Work Team. nd. Monitoring, Assessment, and Research on Central Valley Steelhead: Status of Knowledge, Review of Existing Programs, and Assessment of Needs.

Johnson, R. L., M. A. Simmons, C. S. Simmons, and S. L. Blanton. 2001. A New Multibeam Sonar Technique for Evaluating Fine-Scale Fish Behavior Near Hydroelectric Dam Guidance Structures. American Fisheries Society Symposium 26:161-170.

Kamler, E. and T. Kato. 1983. Efficiency of Yolk Utilization by Salmo Gairdneri in Relation to Incubation Temperature and Egg Size. Polskie Archiwum Hydrobiologii 30:271-306.

Kwain, W. 1975. Effects of Temperature on Development and Survival of Rainbow Trout, *Salmo Gairdneri*, in Acid Waters. Journal of the Fisheries Research Board of Canada 32:493-497.

Larinier, M. 2000. Dams and Fish Migration. World Commission on Dams.

Leitritz, E. and R. C. Lewis. 1980. Trout and Salmon Culture (Hatchery Methods). California Fish Bulletin Number 164. University of California.

Matthews, G. M. 1992. Potential of Short-Haul Barging As a Bypass Release Strategy. Seattle, WA: NOAA.

Matthews, G. M., G. A. Swan, and J. R. Smith. 1977. Improved Bypass and Collection System for Protection of Juvenile Salmon and Steelhead Trout at Lower Granite Dam. Marine Fisheries Review 39:10-14.

McCauley, R. W. and W. L. Pond. 1971. Temperature Selection of Rainbow Trout (*Salmo Gairdneri*) Fingerlings in Vertical and Horizontal Gradients. Journal of the Fisheries Research Board of Canada 28:1801-1804.

McCullough, D. A. 1999. A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, With Special Reference to Chinook Salmon. Report No. EPA 910-R-99-010. Seattle, WA: EPA, Region 10.

McCullough, D. A., S. Spalding, D. Sturdevant, and M. Hicks. 2001. Summary of Technical Literature Examining the Physiological Effects of Temperature on Salmonids - Issue Paper 5. Report No. EPA-910-D-01-005. United States Environmental Protection Agency.

McEwan, D. 2001. Central Valley Steelhead *in* Contributions to the Biology of Central Valley Salmonids. Brown, R. L. (ed.), Sacramento, CA: California Department of Fish and Game, pp 1-43.

McEwan, D. and T. A. Jackson. 1996. Steelhead Restoration and Management Plan for California. California Department of Fish and Game.

Merz, J. E. 1994. A Dietary Analysis of Juvenile Sacramento Squawfish (*Ptychocheilus grandis*), Chinook Salmon (*Oncorhynchus tshawytscha*), and Steelhead Trout (*O. mykiss*) in the Lower American River, Sacramento County, California. California State University, Sacramento.

Mills, T., T. Duster, A. Niggemyer, and A. Pitts. 2003. Assessment of Potential Fish Passage Impediments Above Lake Oroville's High Water Mark.

Monk, B., D. Weaver, C. Thompson, and F. Ossiander. 1989. Effects of Flow and Weir Design on the Passage Behavior of American Shad and Salmonids in an Experimental Fish Ladder. North American Journal of Fisheries Management 9:60-67.

Moyle, P. B.2002. Inland Fishes of California. Berkeley: University of California Press.

Muir, W. D., S. G. Smith, J. G. Williams, and B. P. Sandford. 2001. Survival of Juvenile Salmonids Passing Through Bypass Systems, Turbines, and Spillways With and Without Flow Deflectors at Snake River Dams. North American Journal of Fisheries Management 21:135-146.

Myrick, C. A. and J. J. Cech Jr. 2001. Temperature Effects on Chinook Salmon and Steelhead: A Review Focusing on California's Central Valley Populations. Bay-Delta Modeling Forum Technical Publication 01-1.

Myrick, C. A. and J. J. Cech. 2000. Swimming Performance of Four California Stream Fishes: Temperature Effects. Environmental Biology of Fishes 58:289-295.

Nakamoto, R. J. 1994. Characteristics of Pools Used by Adult Summer Steelhead Oversummering in the New River, California. Transactions of the American Fisheries Society 123:757-765.

Newcomb, T. J. and T. G. Coon. 2001. Evaluation of Three Methods for Estimating Numbers of Steelhead Smolts Emigrating From Great Lakes Tributaries. North American Journal of Fisheries Management 21:548-560.

Nielsen, J. L., T. E. Lisle, and V. Ozaki. 1994. Thermally Stratified Pools and Their Use by Steelhead in Northern California Streams. Transactions of the American Fisheries Society 123:613-626.

NOAA. 1998. Final Rule: Notice of Determination. Endangered and Threatened Species: Threatened Status for Two ESUs of Steelhead in Washington, Oregon, and California. Federal Register, 63(53):13347-13371. March 19, 1998.

NOAA. 2000a. Biological Opinion for the Proposed Operation of the Federal Central Valley Project and the State Water Project for December 1, 1999 Through March 31, 2000. NOAA Fisheries.

NOAA. 2000b. Predation on Salmonids Relative to the Federal Columbia River Power System. White Paper. Seattle, Washington: Northwest Fisheries Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration.

NOAA. 2000c. Summary of Research Related to Transportation of Juvenile Anadromous Salmonids Around Snake and Columbia River Dams. 1-35.

NOAA. 2001. The Effects of Summer Dams on Salmon and Steelhead in California Coastal Watersheds and Recommendations for Mitigating Their Impacts. Santa Rosa, CA: National Marine Fisheries Service, Southwest Region.

NOAA 2002a. nd. Consent decree withdrawing critical habitat designations for 19 ESUs of salmon and steelhead. Available at http://www.nwr.noaa.gov/1press/CHdecree.html. Accessed on March 12, 2004.

NOAA. 2002b. Biological Opinion on Interim Operations of the Central Valley Project and State Water Project Between April 1, 2002 and March 31, 2004. Long Beach: National Marine Fisheries Service, Southwest Region.

Orcutt, D. R., B. R. Pulliam, and A. Arp. 1968. Characteristics of Steelhead Trout Redds in Idaho Streams. Transactions of the American Fisheries Society 97:42-45.

Pacific States Marine Fisheries Commission. nd. Anadromous Fish Life History Profiles. Available at http://www.psmfc.org/habitat/edu_anad_table.html. Accessed on January 16, 2003.

Park, D. L., T. E. Ruehle, J. R. Harmon, and B. H. Monk. 1980. Transport Research on the Columbia and Snake Rivers - Annual Report of Research 1980. Seattle, WA: U.S. Army Corps of Engineers and NOAA.

Placer County Water Agency and USBR. 2002. American River Pump Station Project FEIS/EIR.

Popper, A. N. and T. J. Carlson. 1998. Application of Sound and Other Stimuli to Control Fish Behavior. Transactions of the American Fisheries Society 127:673-707.

Raymond, H. L. 1988. Effects of Hydroelectric Development and Fisheries Enhancement on Spring and Summer Chinook Salmon and Steelhead in the Columbia River Basin. North American Journal of Fisheries Management 8:1-24.

Redding, J. M. and C. B. Schreck. 1979. Possible Adaptive Significance of Certain Enzyme Polymorphisms in Steelhead Trout (*Salmo gairdneri*). Journal of the Fisheries Research Board of Canada 36:544-551.

Rich, A. A. 1987. Water Temperatures Which Optimize Growth and Survival of the Anadromous Fishery Resources of the Lower American River.

Robards, M. D. and T. P. Quinn. 2002. The Migratory Timing of Adult Summer-Run Steelhead in the Columbia River Over Six Decades of Environmental Change. Transactions of the American Fisheries Society 131:523-536.

Rombough, P. J. 1988. Growth, Aerobic Metabolism, and Dissolved Oxygen Requirements of Embryos and Alevins of Steelhead, *Salmo gairdneri*. Canadian Journal of Zoology 66:651-660.

S.P.Cramer & Associates. 1995. The Status of Steelhead Populations in California in Regards to the Endangered Species Act. Report Submitted to the National Marine Fisheries Service on Behalf of the Association of California Water Agencies. Gresham, OP: S.P. Cramer & Associates, Inc.

Schreck, C. B., J. C. Snelling, R. D. Ewing, C. S. Bradford, L. E. Davis, and C. H. Slater. 1994. Migratory Behavior of Adult Spring Chinook Salmon in the Willamette River and Its Tributaries. Project No. 88-160-3, Contract No. DE-AI79-88BP92818. Portland: U.S. Department of Energy, Bonneville Power Administration.

Seelbach, P. W., R. N. Lockwood, and G. R. Alexander. 1985. A Modified Incline Screen Trap for Catching Salmonid Smolts in Large Rivers. North American Journal of Fisheries Management 5:494-498.

Shapovalov, L. and A. C. Taft. 1954. The Life Histories of the Steelhead Rainbow Trout (*Salmo gairdneri gairdneri*) and Silver Salmon (*Oncorhynchus kisutch*) With Special Reference to Waddell Creek, California, and Recommendations Regarding Their Management. Fish Bulletin No. 98. California Department of Fish and Game.

Silver, S. S., C. E. Warren , and P. Doudoroff. 1963. Dissolved Oxygen Requirements of Developing Steelhead Trout and Chinook Salmon Embryos at Different Water Velocities. Transactions of the American Fisheries Society 92:327-343.

Smith, C. E., W. P. Dwyer, and R. G. Piper. 1983. Effect of Water Temperature on Egg Quality of Cutthroat Trout. The Progressive Fish-Culturist 45:176-178.

Snider, B. and R. G. Titus. 2000. Lower American River Emigration Survey October 1996-September 1997. Stream Evaluation Program Technical Report No. 00-2. California Department of Fish and Game.

State Water Resources Control Board. 2003. Revised Water Right Decision 1644 in the Matter of Fishery Resources and Water Right Issues of the Lower Yuba River.

USBR. 1997. Central Valley Improvement Act, Draft Programmatic Environmental Impact Statement: Technical Appendix, Volume III. Sacramento, CA: U.S. Bureau of Reclamation.

USBR. 2003. Summary of USBR Chinook Salmon Temperature Mortality Models for Use With CALSIM II- Unpublished Work.

USFWS. 1995. Working Paper on Restoration Needs: Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California. Vol 2. Stockton, CA: U.S. Fish and Wildlife Service.

Velsen, F. P. 1987. Temperature and Incubation in Pacific Salmon and Rainbow Trout: Compilation of Data on Median Hatching Time, Mortality and Embryotic Staging. Canadian Data Report of Fisheries and Aquatic Sciences 626. Nanaimo, BC: Department of Fisheries and Oceans, Fisheries Research Branch.

Wang, J. C. S. 1986. Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: A Guide to the Early Life Histories. IEP Technical Report No. 9. California Department of Water Resources, California Department of Fish and Game, U.S. Bureau of Reclamation, and U.S. Fish and Wildlife Service.

Ward, D. L., R. R. Boyce, F. R. Young, and F. E. Olney. 1997. A Review and Assessment of Transportation Studies for Juvenile Chinook Salmon in the Snake River. North American Journal of Fisheries Management 17:652-662.

Wedemeyer, G. A., R. L. Saunders, and W. C. Clarke. 1980. Environmental Factors Affecting Smoltification and Early Marine Survival of Anadromous Salmonids. Marine Fisheries Review 42:1-14.

Young, P. S. and J. J. Cech Jr. 1996. Environmental Tolerances and Requirements of Splittail. Transactions of the American Fisheries Society 125:664-678.

Zaugg, W. S. and H. H. Wagner. 1973. Gill ATPase Activity Related to Parr-Smolt Transformation and Migration in Steelhead Trout (*Salmo Gairdneri*): Influence of Photoperiod and Temperature. Comparative Biochemistry and Physiology 45B:955-965.