Chapter 16 Essential Fish Habitat Assessment

Essential Fish Habitat Background

The Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) mandates Federal action agencies which fund, permit, or carry out activities that may adversely impact the essential fish habitat (EFH) of Federally managed fish species to consult with the NMFS regarding the potential adverse effects of their actions on EFH (Section 305 (b)(2). Section 600.920(a)(1) of the EFH final regulations state that consultations are required of Federal action agencies for renewals, reviews, or substantial revisions of actions if the renewal, review, or revision may adversely affect EFH. The EFH regulations require that Federal action agencies obligated to consult on EFH also provide NMFS with a written assessment of the effects of their action on EFH (50 CFR Section 600.920). The statute also requires Federal action agencies receiving NMFS EFH Conservation Recommendations to provide a detailed written response to NMFS within 30 days upon receipt detailing how they intend to avoid, mitigate or offset the impact of the activity on EFH (Section 305(b)(4)(B).

The objective of this EFH assessment is to describe potential adverse effects to designated EFH for Federally-managed fisheries species within the proposed action area. It also describes conservation measures proposed to avoid, minimize, or otherwise offset potential adverse effects to designated EFH resulting from the proposed action.

The northern anchovy and starry flounder are managed as “monitored species” by the Coastal Pelagic Species Fishery Management Plan and the Pacific Coast Groundfish Fishery Management Plan of the Pacific Fishery Management Council (PFMC), respectively, and are subject to Essential Fish Habitat consultation as a result (PFMC 1998a, 1998c).

The fall/late fall-run Chinook salmon *Oncorhynchus tschawytscha* is a species of concern and information can be found in the salmon Chapters 5 and 6 of this document for EFH.

Effects on Central Valley spring-run Chinook salmon, Sacramento River winter-run Chinook salmon, Southern Oregon/Northern California Coast coho salmon, Central Valley steelhead, and Central California Coast steelhead habitat are described in this biological assessment in Chapters 11 and 13 and are summarized in Chapter 15.

Identification of Essential Fish Habitat

Essential fish habitat is defined as those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. For the purpose of interpreting the definition of EFH, “waters” include aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include areas historically used by fish where appropriate; “substrate” includes sediment, hard bottom, structures underlying the waters, and associated biological communities; “necessary” means habitat required to support a sustainable fishery and a healthy ecosystem; and “spawning, breeding, feeding, or growth to maturity” covers a species full life cycle. The following important components of EFH must be adequate for spawning, rearing, and migration:

- Substrate composition
- Water quality
- Water quantity, depth, and velocity
- Channel gradient and stability
- Food
- Cover and habitat complexity
- Space
- Access and passage
- Habitat connectivity

The Coastal Pelagic Species Fishery Management Plan has designated EFH for all coastal pelagic species, including the central subpopulation of the northern anchovy (PFMC 1998a). Essential fish habitat is defined to be all marine and estuarine waters along the Pacific coast from Washington to California. The specific limits of this area are defined by temperature-based thermoclines and isotherms, which vary seasonally and annually (PFMC 1998a). The level of EFH information is 1 (Presence/absence distribution data are available) for this species (PFMC 1998a).

Reclamation and DWR's proposed operation is described in Chapter 2 of the BA for the CVP and SWP. The Bay/Delta provides habitat for northern anchovy *Engraulis mordax* and starry flounder *Platichthys stellatus*, which are covered under the EFH provisions of Magnuson-Stevens Act, but are not listed under the ESA.

Description of the Federally-managed fisheries species

Northern Anchovy

Description and Life History

Northern anchovies are small, short-lived, fish typically found in schools near the water surface. They are short-lived, rarely exceeding 4 years of age and 7 inches (17.78 cm) in length, although individuals 7 years old and 9 inches (22.86 cm) long have been recorded (Messersmith 1969). Some anchovies reach sexual maturity at the end of their first year of life when 3.5 to 3.9 inches (90 to 100 mm) SL; about 50 percent are mature at 5.1 inches (130 mm) SL when between 2 and 3 years old; all are mature when 5.9 inches (150 mm) SL or 4 years old (Clark and Phillips, 1952). MacGregor (1968) reports that female anchovies, 3.8 to 5.4 inches (97- 138 mm) SL contained 4,023 to 21,297 eggs in an advanced stage of development. This equals 574 per gram of fish or 520 million eggs per short ton of female biomass. He was unable to determine the number of times a female spawns in a season. However, Baxter (1966) reported that although little has been published on the fecundity of the northern anchovy, each large female spawns an estimated 20 to 30 thousand eggs annually and spawns two or three times each year. There is always a reservoir of maturing eggs in the ovary of an adult female in spawning condition. The fraction of one-year-olds that is sexually mature in a given year depends on water temperature and has been observed to range from 47 to 100 percent. They spawn during every month of the year, but spawning increases during late winter and early spring and peaks during February to April. Richardson (1981) reports that peak spawning occurs from January through April when southward current flow is minimal, water temperatures are reaching minimal levels for the year, upwelling is minimal, and day length is at minimum duration. Spawning has been observed over a temperature range of 54 ^{o} to 71 ^{o} F. Individual females spawn batches of eggs throughout the spawning season at intervals as short as seven to 10 days. This species is a broadcast spawner and females can produce up to 30,000 eggs a year in batches of about 6,000. Most spawning takes place in channels or within 60 miles of the coast in the upper mixed layers at night, in water temperatures of 54º F to 59º F. The San Francisco Bay is thought to provide favorable reproductive habitat for the anchovy because abundant food exists for both adults and larvae and coastal upwelling keeps eggs and larvae in productive areas. Spawning in the bay occurs at higher temperatures and lower salinities than spawning in coastal areas (McCrae 1994, Bergen and Jacobson 2001). In a single year study by McGowen (1986), either eggs or larvae were caught by net in San Francisco Bay every month. Both were most abundant when water temperature was high. Mean egg abundance did not differ among stations but larvae were more abundant within the San Francisco Bay at high and low salinity than near the ocean entrance to the Bay. Larvae longer than 15 mm were collected over the shoals in spring and autumn but were in the channel during winter. Zooplankton and microzooplankton were abundant relative to mean California Current densities. Adult spawning biomass in the Bay was 767 tons in July 1978, based on egg abundance and fecundity parameters of oceanic animals. San Francisco Bay was a good spawning area for northern anchovy because food for adults and larvae was abundant and because advective losses of larvae would have been lower in the Bay than in coastal waters at the same latitude.

Northern anchovy eggs are oval, pelagic, and approximately 1.5 by 0.75 millimeters (mm) in size. Eggs are found near the water surface and require two to four days to hatch, depending on water temperatures. Larvae are also found near the water surface (CDFG 2001). Larvae range in size from 2.5 to 25 mm in length and begin schooling at 11 to 12 mm in length. Juveniles range in size from 25 to 140 mm in length. Some fish mature at less than one year of age (71 to 100 mm) and all are nature at two to three years. Maximum age is seven years, but most live for four years. Maximum size is about 230 mm, although most are not over 158 mm in length (McCrae 1994, Bergen and Jacobson 2001). Ahlstrom (1959) reports that approximately 93 percent of the larvae are taken in water between 14.0 ^{o} and 17.4 ^{o} C (57.2 ^{o} and 67.3 ^{o} F) while most eggs are taken between 13.0 ^{o} and 17.5 ^{o} C (35.4 ^{o} and 63.5 ^{o} F). Fish-of-the-year apparently tolerate somewhat higher water temperatures than do adults.

Anchovies feed diurnally either by filter feeding or biting, depending on the size of the food (Berkeley Elibrary 2002). Juvenile and adult northern anchovies are considered secondary and higher consumers, selectively eating larger zooplankton, fish eggs, and fish larvae. Baxter (1966) noted that they have been observed to be predatory on small fish at times, even their own kind. He also noted l+-inch fish in the stomachs of 5+-inch anchovies. First-feeding larvae eat phytoplankton and dinoflagellates, while larger larvae pick up copepods and other zooplankton. Female anchovies need to eat approximately 4 to 5 percent of their wet weight per day for growth and reproduction (Goals Project 2000).

All life stages of the northern anchovy are important prey for virtually every predatory fish, bird, and mammal in the California current (Baxter 1967), including California halibut, Chinook and Coho salmon, rockfishes, yellowtail, tunas, sharks, squid, harbor seal, northern fur seal, sea lions, common murre, brown pelican, sooty shearwater, and cormorants. Baxter (1966) reported that anchovies constituted 12.8 percent by volume of the diet of California yellowtail (*SerioZa dorsalis*) (Craig, 1960) and 29.1 percent by volume of the diet of Chinook salmon (*Oncorhynchus tshawytscha*) off San Francisco (Merkel, 1957). Qualitative studies have shown anchovies to be an important constituent in the diets of all of the large predatory game fish off California. Baxter (1966) noted that the Pacific bonito (*Xarda chiliensis*) populations have historically correlated well with Northern anchovy numbers. The breeding success of California brown pelicans and elegant tern production is correlated with anchovy abundance (Bergen and Jacobson 2001; Schaffner 1986). Competitors with the anchovy include sardines and other schooling planktivores, such as jacksmelt and topsmelt. These species are also potential predators on young anchovy life stages (Goals Project 2000).

Distribution

Northern anchovies are pelagic schooling fishes generally found in coastal waters with surface temperatures between 14.5^{o} and 20.0^{o} C (58.1^{o} and 68.O^{o} F) but appear to prefer water temperatures between 14.5 and 18.5ºC (Hart 1973). Anchovies occur from the Queen Charlotte Islands, British Columbia to Cape San Lucas, Baja California. California Cooperative Oceanic Fisheries Investigations (CalCOFI) surveys show they are most abundant from San Francisco to Magdalena Bay. North of San Francisco, occasional surveys by the Department of Fish and Game have not found anchovies in abundance (Messersmith et al. 1969). The northern anchovy is one of the most abundant and productive fishes in the San Francisco Bay area (Berkeley Elibrary 2002). The northern anchovy occurs from Suisun Bay to South San Francisco Bay and occasionally in the lower Delta. This species is most abundant downstream of the Carquinez Strait and outside the Bay in the California Current (Herbold et al. 1992, Goals Project 2000).

The east-west geographic boundary of EFH for the northern anchovy is defined to be all marine and estuarine waters from the shoreline along the coasts of California, Oregon, and Washington offshore to the limits of the exclusive economic zone and above the thermocline where sea surface temperatures range between 10^{o} C to 26^{o} C (50^{o} F to 78.8^{o} F). The southern extent of EFH for the anchovy is the United States-Mexico maritime boundary. The northern boundary of the anchovy's EFH is the position of the 10^{o} C (50^{o} F) isotherm which varies both seasonally and annually (PFMC 1998b). McHugh (1951) concluded that the anchovy population is divided into three subpopulations which do not intermingle completely: (i) British Columbia to northern (California (Monterey Ray), (ii) off southern California and northern Baja California, and (iii) off central and southern Baja California. His conclusions were based on an analysis of meristic data (dorsal, anal, and pectoral fin rays, vertebrae and gill rakers). Hubbs (1925) (as reported in Baxter 1966) described a separate subspecies (*E. nz. nanzis*) which inhabits San Francisco Bay and tolerates much-reduced salinities. In both mean and modal number of vertebrae the bay subspecies has two fewer than the ocean subspecies. It is a much smaller fish, the largest found by Hubbs measured 99 mm TL. Its head averages longer, the body deeper and more compressed. The early development is also apparently more accelerated and transformation from postlarval to juvenile stages occurs at a much smaller size. Similar brackish-water forms also are known for the European anchovy (*E. encrasicholus*) and Australian anchovy (*E. australis*) (Blackburn, 1950). However, no further work has been detected in the literature. Miller (1956), working with age and size compositions of commercial and live-bait catches from central and southern California, aerial surveys, and sea surveys, suggested the possible existence of "local" stocks and the complete separation of central and southern California populations. However, not enough information has been collected to support or refute this (Messersmith 1969).

There is a great deal of regional variation in age composition (number of fish in each age group) and size at age with older fish and larger fish found at relatively offshore and northerly locations. In warm years, relatively old and large fish are found farther north than during cooler years. These patterns are probably due to northern and offshore migration of large fish, regional differences in growth rate, and water temperatures. The adults and juveniles of the northern anchovy are pelagic and form tightly packed schools that range from the water surface to 164 fathoms deep (McCrae 1994). This species is found from seawater to mesohaline (moderately brackish water with salinity range of 5 to 18 ppt) and occasionally found in oligohaline (brackish water with low salinity range of 0.5 to 5 ppt) areas. Adults are found in estuaries, near-shore areas, and out to 300 miles offshore, although most are found within 100 miles of shore (Airame 2000). Juveniles are abundant in shallow near-shore areas and estuaries.

The northern anchovy does not migrate extensively but does have inshore-offshore, along-shore, and daily movements (McCrae 1994). Some exchange of anchovies between major fishing areas does occur. Tagging studies between 1966 and 1968 (Messersmith et al. 1969) indicated that fish from as far away as San Diego and San Francisco do contribute to the Monterey Bay fishery and that fish from Monterey Bay reach southern California. However, to what extent it is unclear.

Habitat requirements

River

The Northern Anchovy is common in surveys of the lower tidal portions of Sacramento and San Joaquin rivers (Herrgesell 1994). However, because of their salinity requirements, northern anchovy have not been recorded above brackish water within these systems.

Delta

Between 1979 and 1999, northern anchovy made up less than 1% of the total fish captured by otter trawl and beach seine in Suisun Marsh (Matern et al. 2002). However, they were the 4th – most common fish larvae species in the Suisun Bay in a 1991 survey and adults are also common in San Pablo Bay (Herrgesell 1994).

Bay

Although northern anchovy are found in the San Francisco Bay area throughout the year, they tend to peak there from April to October (Goals Project 2000). Larvae numbers are typically found in high density in mid and upper level trawl surveys; so much so, that in a 1992 survey, samples for other species was difficult (Herrgesell 1994). However, by April, larval anchovy numbers appear to diminish. The spring influx to the bay areas may result from higher temperatures and increasing plankton production in the bay and coastal upwelling; the autumn exodus may be linked to cooler temperatures in the bay. Larvae and juveniles that were spawned in late summer tend to overwinter in the bay. In the summer and fall months, anchovy larvae follow the salt wedge into warm, productive shallows of Suisun Bay and the lower Delta (Berkeley Elibrary 2002). Schooling juveniles are found in sea- and freshwater in the

Sacramento-San Joaquin estuary, especially in July and August. During the summer, adults and juveniles have daily movements from 60 to 100 fathoms deep in the day to surface waters at night (Bergen and Jacobson 2001).

The primary fresh water inputs to the San Francisco Estuary are derived from regional precipitation (quantity and form {ie rain or snow]) and to a greater extent, the Sacramento and San Joaquin Rivers (Kimmerer 2002). River inflow is largely regulated by upstream reservoir releases. A significant fraction of this inflow is exported out of the Delta by the CVP and the SWP affecting variation in through-estuary outflow, creating lower winter and higher summer outflow than what occurred historically. This can have a strong influence on the mixing zone (X2), where fresh and salt water collide and overall Estuary salinity (Uncles and Peterson 1996). This mixing zone is a highly productive environment (Kimmerer 2002).

Movement of the mixing zone is complex and dependent upon a number of factors, including tidal cycles (Cloern et al. 1989) and fresh water inflow. Wind wave action can also be important for mixing. Over the course of a year, X2 can range from San Pablo Bay during high flow periods, to well into the Delta during the summer drought. The position of X2 is monitored and maintained by releasing water from upstream reservoirs and operation of manmade barriers (ie Suisun Marsh gates) in anticipation of export demand. This is mandated by in the Vernalis Salinity Standard, which was legally established to maintain habitat quality in the Estuary for wildlife and to prevent salinity from encroaching upstream to the export pumps (Trott 2006). Gravitational circulation causes stratified high salinity water at depth to flow landward while low salinity water on top flows seaward (Monismith 1996). The effect of gravitational circulation may be most pronounced during periods of high fresh water flow, providing a negative feedback for maintaining the salt field and the distribution of pelagic organisms in the Estuary.

Mixing is important at the landward edge of gravitational circulation, often around X2, where the water column becomes less stratified (Burau 1998). A fixed mixing zone occurs at the east end of the Carquinez Strait, where the deep channel becomes dramatically shallower as it enters Suisun Bay (Schoellhamer 2001). Mixing is critical in maintaining salinity such that extremely large inputs of fresh water are required to move X2 a short distance to the west. Mixing also assists pelagic organisms in maintaining position in the Estuary (Kimmerer 2004) and slowing the advection of primary and secondary production out of the system. These relationships appear to have a significant influence on fish species within the Estuary (Feyrer et al. 2007).

Furthermore, phytoplankton, zooplankton, and larval and adult fish can become entrained in the export pumps, causing a potentially significant but unknown impact on the abundance of these organisms. This interaction may have a significant influence on food sources and predators of northern anchovy and starry flounder within the Bay.

Population Trends

Estimates of northern anchovy biomass in the central subpopulation averaged 359,000 tons from 1963 through 1972, increased rapidly to over 1.7 million tons in 1974 and then declined to 359,000 tons in 1978 (CDFG 2001). Since 1978, biomass levels have tended to decline slowly, falling to an average of 289,000 tons from 1986 through 1994 (Jacobson et al. 1994). Total anchovy harvests and exploitation rates since 1983 have been below theoretical levels for maximum sustained yield. Although stock biomass estimates are unavailable for recent years, it is believed that anchovy production is being determined mostly by natural influences, such as ocean temperature (CDFG 2001). Surveys of the South San Francisco Bay (MSI 2002) showed significant decreases in Northern anchovies between 1973 and 2003. According to NOAA (), recent biomass estimates for the central subpopulation (from San Francisco to Baja, California) indicate that biomass averaged 326,000 metric tons until 1970, increased rapidly to 1.6 million metric tons in 1974, and then declined to 521,000 metric tons in 1978. During the early 1990s, biomass declined to about 150,000 metric tons and then increased to 388,000 metric tons in 1995. No new stock assessment has been made, as this species in currently managed based on landings.

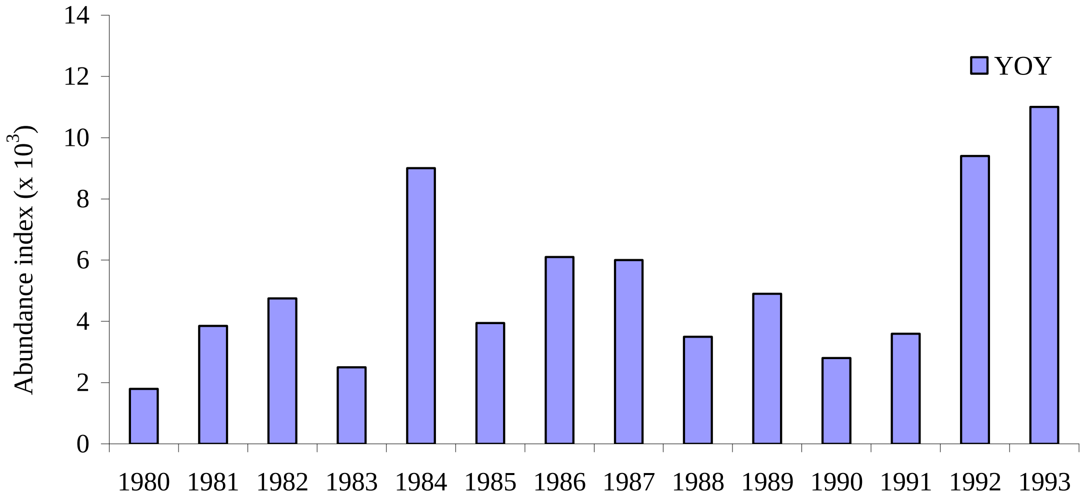


Figure 16-1 The annual abundance indices for northern anchovies are generated from the San Francisco Bay Monitoring Program midwater trawl data.

Data source: California Department of Fish and Game/ Bay Delta Region web page.

(http://www.delta.dfg.ca.gov/baydelta/monitoring/naab.asp)

According to Swanson (2007), although northern anchovy are always found in all sub-regions of the estuary, their abundance differs markedly. For the past 27 years, northern anchovy have been most abundant in Central Bay, least abundant in Suisun Bay, and present at intermediate abundance levels in San Pablo and South Bays (Figure 16-2).

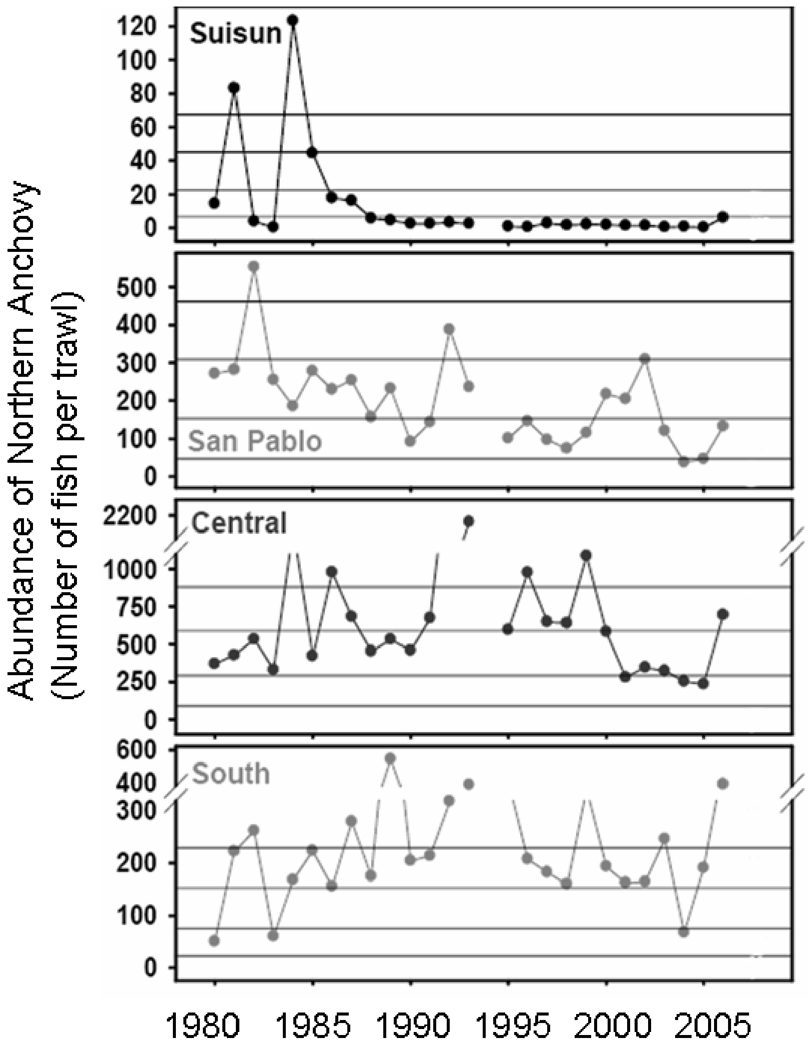


Figure 16-2 Abundance of Northern Anchovy within four sections of the San Francisco Bay, 1980 through 2005. Data Source: CDFG 2005.

Baxter (1966) stated that the California anchovy fishery has been in reality two distinct fisheries, the commercial fishery and that for live bait and both are quite modest compared to anchovy fisheries in other parts of the world. Historically, most of the catch was "reduced" (or processed) into oil and fish meal and sold as a protein supplement for use in poultry feed (Conrad 1991). About 3,000 - 6,000 metric tons (mt) per year are harvested live for use as bait in various sport fisheries, while another 1,000 - 3,000 mt per year are harvested for other commercial products, such as pet food. During its peak years in the mid-1970s the reduction fishery accounted for about 90 percent of the total U. S. harvest. In the 1980s landings for reduction declined below 6,000 mt annually and were exceeded by nonreduction landings for most of the decade. Both have been dropped steadily since the 1970’s (CDFG 2001).

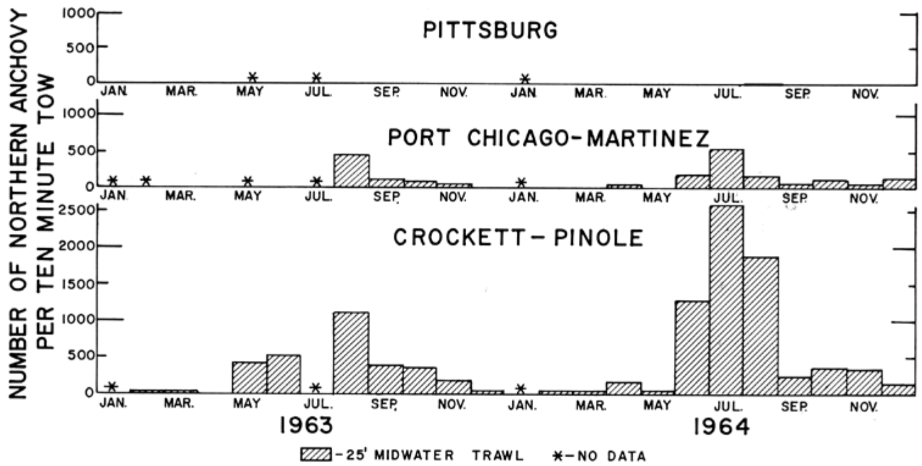


FIGURE 5. Monthly trawl catch of northern anchovy, *Engraulis mordax.*

Figure 16-3 California Department of Fish and Game (1966) Ecological studies of the Sacramento-San Joaquin estuary; Part 1,: Zooplankton, zoobenthos, and fishes of San Pablo and Suisun Bays, zooplankton and zoobenthos of the Delta

Starry Flounder

Description and Life History

The starry flounder, a flatfish also known as rough jacket, belongs to the family Pleuronectidae. According to Moyle (2002), they are characterized by having both eyes on the upper side of the head, a white "belly" with a single pectoral fin in the middle, pelvic fins on the dorsoventral ridge behind the operculum, and dorsal and anal fins that extend around the body on each side. Although they are the only flatfish likely to be found in freshwater, they can be distinguished from other flounders that might occur in brackish water by the distinctive, alternating white to orange and black bands on the dorsal and anal fins, as well as by roughness of their skin, caused by the star-shaped plates (modified scales). Although they belong to the right-eyed flounder family, the eyes may be either side of the head.

Most spawning occurs in shallow waters near the mouths of rivers and estuaries during the winter. In central California, December and January are the peak months of spawning. The number of eggs produced by each female depends on size but a 27-inch fish may produce about 11 million eggs.

Females grow faster and reach larger sizes than males. In central California, most males are sexually mature at two years averaging 14.5 inches; most females at three years and 16 inches. The maximum size reported is 36 inches.

The starry flounder is covered by the West Coast Groundfish Fishery Management Plan (PFMC 1998c). Starry flounder range from the Sea of Japan, north to the Bering Sea and the Arctic coast of Alaska, and southward down the coast of North America to southern California (Haugen and Thomas 2001). Starry flounder can be found in Suisun Bay and the lower portion of the San Joaquin River in the Delta (Figure 16-4). The distribution of the starry flounder tends to shift with growth. Young juveniles are commonly found in fresh or brackish water of Suisun Bay, Suisun Marsh, and the Delta, older juveniles range from brackish to marine water of Suisun and

San Pablo Bays, and adults tend to live in shallow marine waters within and outside the San Francisco Bay before returning to estuaries to spawn (Goals Project 2000).

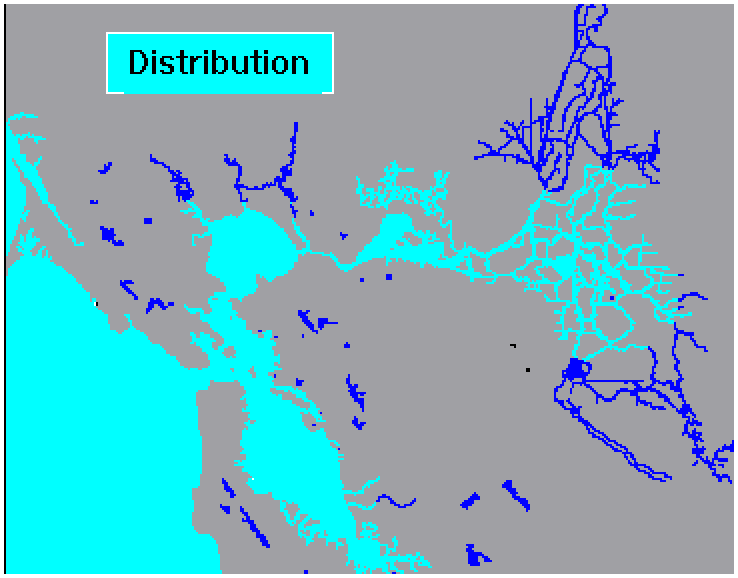


Figure 16-4 San Francisco Bay starry flounder distribution (Source: California Department of Fish and Game/ Bay Delta Region web page (http://www.delta.dfg.ca.gov/baydelta/monitoring/stfl.asp)

Starry flounder is an important member of the inner continental shelf and shallow sublittoral communities, and is one of the most common flatfish in the San Francisco Bay and Delta (Haugen and Thomas 2001). Older juveniles and adults are found from 120 km up coastal rivers to the outer continental shelf at 375 m, but most adults are found within 150 m. Spawning occurs in estuaries or sheltered inshore bays in water less than 45 m deep (Goals Project 2000). Juveniles prefer sandy and muddy substrates and adults prefer sandy and coarse substrates. Eggs are found in polyhaline (brackish water with moderate salinity range from 18 to 30 ppt) to euhaline (brackish water with high salinity range from 30 to 40 ppt) waters; juveniles are found in mesohaline (brackish water with moderate salinity range from 5 to 18 ppt) to fresh waters; adults and larvae are found in euhaline to fresh waters. All life stages can survive and grow at temperatures below 0º C to 12.5º C (32º F to 54.5º F) (Orcutt 1950).

Starry flounder is not considered to be a migratory species. Adults move inshore in winter or early spring to spawn and offshore and deeper in the summer and fall, but these coastal movements are generally less than 5 km. While some starry flounder have shown movements of greater than 200 km, but this is not considered typical. Adults and juveniles are known to swim great distances up major coastal rivers (greater than 120 km) but this is not a migratory trend. Larvae may be transported great distances by oceanic currents (CDFG 2001).

Starry flounder are oviparous; eggs are fertilized externally. Spawning occurs annually in a short time frame in winter and spring, with the exact timing depending on location. In central California, starry flounder spawn from November to February, peaking in December and January (Orcutt 1950). The number of eggs produced by females depends on fish size; a 56 cm fish can produce 11,000,000 eggs (CDFG 2001). Fertilized eggs are spherical and between 0.89 and 1.01 mm in diameter (Orcutt 1950). Eggs hatch in 2.8 days at 12.5º C (54.5º F), 4.6 days at 10.0ºC

(50º F), and 14.7 days at 2.0° C to 5.4º C (35.6º F to 41.7º F). Eggs are pelagic and occur at or near the surface over water 20 to 70 m deep (CDFG 2001).

Eggs and larvae of the starry flounder are epipelagic, while juveniles and adults are demersal. Larvae are approximately 2 mm long at hatching and they start settling to the bottom after two months at approximately 7 mm in length. Metamorphosis to the benthic juvenile form occurs at 10 to 12 mm and sexually immature juveniles range in size from 10 mm to 45 cm, depending on sex (Orcutt 1950). Transforming larvae and juveniles depend on ocean currents to keep them in rearing areas near estuarine areas and the lower reaches of major coastal rivers (Goals Project 2000). Starry flounder tend to rear for up to two years in estuarine areas before moving to shallow coastal marine waters. Adults occur in estuaries or their freshwater sources year-round in Puget Sound. Females begin maturing at 24 cm and three years, but some may not mature until 45 cm and four to six years. Males begin maturing at two years and 22 cm, but some may not reach maturity until four years and 36 cm (Orcutt 1950). Maximum age is reported as 21 years and maximum length is 915 mm.

Starry flounder change their diet as they develop from pelagic to demersal stages (Orcutt 1950). Larvae tend to be planktivorous and eat copepods, amphipods, eggs and nauplii as well as barnacle larvae and diatoms. Juveniles and adults are primary to secondary carnivores on larger benthic invertebrates. Newly metamorphosed juveniles feed on copepods, amphipods, annelid worms, and the siphon tubes of clams. Larger fish with jaws and teeth feed on a wider variety of items, including clams, crabs, polychaete worms, sand dollars, brittle stars, and other more mobile foods (Orcutt 1950). Historically, in San Francisco Bay, small starry flounder fed mainly on opossum shrimp until the invasion of the overbite clam (*Potamocorbula amurensis*) caused a major reduction in shrimp abundance, forcing them to switch to a more diverse diet (Ganssle 1966, Herbold 1987, Feyrer 1999). Moyle (2002) states that in freshwater, starry flounder shift to feeding on insect larvae buried in soft bottoms, such as tipulid larvae (Porter 1964) and annelid worms (Martin 1995) and this may put the flounder under some osmotic stress, because digestion rates are 2-3 times faster in salt water than in fresh (Porter 1964). Starry flounder do not feed during spawning or coldwater periods.

Starry flounder larvae and juveniles are eaten by larger fish, and wading and diving seabirds (e.g., herons and cormorants). Adults are eaten by pinnipeds, larger fishes, sharks and marine mammals.

The starry flounder probably competes with other soft-bottom benthic fishes of estuaries and shallow nearshore bays. Individuals with characteristics intermediate between starry flounder and English sole are evidence of possible hybridization between those species (Haugen and Thomas 2001).

The Pacific Coast Groundfish Fishery Management Plan (PFMC 1998c) has designated EFH for 83 species of groundfish, which taken together include all waters from the high water line, and the upriver extent of saltwater intrusion in river mouths along the coast from Washington to California. Composite habitats most important for the starry flounder are estuarine (for all life stages), non-rocky shelf (for juveniles and adults), and neritic habitats (for eggs and larvae), as defined by the fishery management plan (PFMC 1998d). The level of EFH information is 1 (Presence/absence distribution data are available) for all life stages of this species. When Level 1 information is available, EFH for a species' life stage is its general distribution, the geographic area of known habitat associations containing most (e.g., about 95 percent) of the individuals (PFMC 1998d). The National Marine Fisheries Service is proposing to amend the fishery plan to identify and describe essential fish habitat for each managed groundfish species (PFMC 1998c).

Distribution

The starry flounder is known to occur in coastal waters of the Pacific and Arctic oceans and connecting seas, and rivers within 33 degrees to 73 degrees N. latitude and from 105 degrees W. to 127 degrees E. longitude (Orcutt 1950). Thus it is one of the most widely distributed flounders. In the eastern Pacific the southern limit of its range is at the mouth of the Santa Ynez River at Surf, Santa Barbara County, California. The species becomes more numerous in northern California and is found along the entire Pacific coast of North America from the Santa Ynez River to the Alaskan Peninsula. It occurs along the Aleutian Island chain westward to the Commander Islands and the Kamchatka Peninsula and then extends southward along the east coast of Kamchatka, and Kurile Islands, and the main islands of Japan to Tokyo Bay.

It also occurs in the peripheral seas. It is known from the Sea of Japan south to Obama, Japan and Gensan, Korea; and from the entire Gulf of Tartary. Hubbs and Kuronuma (1942) have mapped it as occurring along all of the shores of Okhotsk Sea although they give no definite locality records and I have been unable to find any elsewhere. Starry flounder have been found along the southern and eastern limits of the Bering Sea and along the northern coast of Alaska and Canada eastward as far as Coronation Gulf. Whether it occurs along the northwestern shores of the Bering Sea is uncertain and there appear to be no records along the arctic coast of Asia.

Habitat requirements

Although considered a euryhaline fish, Gunter (1942) reported that the starry flounder had been taken 75 miles upstream in the Columbia River. According to Orcutt (1950), a US Fish and Wildlife Service study of salmon and striped bass was conducted with fyke nets fished just below the surface of the water one-half mile below the Antioch Bridge in the San Joaquin River and six miles downstream from Rio Vista in the Sacramento River. Although the collecting nets were not designed or set for the capture of bottom fishes, they took, in addition to the salmon and striped bass, 80 starry flounder in the San Joaquin River. At Antioch the salinity varied from about 0.06 to 9.0 parts per thousand during the period from April through September, in which the flounder were caught; a variation from fresh water to brackish water having a salinity about one-quarter that of the ocean. At Rio Vista the salinity varied from 0.02 to 0.5 parts per thousand and the Sacramento River water could be considered nothing but fresh during the entire period of the experiment. Nevertheless 193 starry flounder were caught at the latter station.

River

In streams, they generally prefer tidal, low-gradient areas that have sandy or muddy bottoms. Most found in fresh water are young-of-the-year. During dry years abundances may be lower but young are more likely to be found farther upstream and to be entrained by the pumps in the south Delta (Moyle 2002). The smallest fish are generally found farthest upstream (Ganssle 1966), and they seek areas with higher salinity as they grow larger (Baxter et al. 1999). Thus, in April-June most young-of-the-year are living in salinities of less than 2ppt, but by July and August they have shifted to salinities of 10-15 ppt (Baxter et al. 1999). Temperatures may also influence distribution because they are usually found at 10-20oC (Baxter et al. 1999). Starry flounders

<20cm TL encountered in freshwater seem to be mostly migrants from salt water, rather than fish that have reared there (Moyle 2002).

Delta

Between 1979 and 1999, starry flounder made up 1% of the total fish captured by otter trawl and beach seine in Suisun Marsh (Matern et al. 2002). Meng et al. (1994) considered starry flounder a seasonal fish species within the marsh.

Bay

In the San Francisco Estuary some smaller flounders may have resulted from spawning in the estuary, but most are apparently carried into San Francisco Bay from nearshore ocean waters by strong tidal currents along the bottom (Baxter et al. 1999). These currents are strongest during years of high outflow from the rivers, and, as a consequence, juvenile starry flounder tend to be most abundant in the estuary during wet years (Jassby et al. 1995, Gunter 1942 as reported in Moyle 2002). Higher abundances may be related to the greater extent of low-salinity rearing areas and the greater abundance of food organisms preferred by small flounders (Herbold et al. 1992). Ralston (2005) showed that the summertime abundance of young-of-the-year(YOY) starry flounder in San Francisco Bay is closely related to discharge into the bay the previous winter, and that the relatively long discharge record can be used to hind-cast starry flounder recruitment.

Population Trends

The starry flounder was a common species in commercial and recreational fisheries of California prior to the 1980s, but has declined dramatically in the 1990s and this trend is mirrored in the CDFG otter trawl data (Figure 16-5). This flounder is generally not targeted by commercial fishers, except in Puget Sound, but is mostly taken as by-catch by bottom trawl, gill nets, and trammel nets. Recreational catch occurs by angling from piers, boats, and shore in estuarine and rocky areas including rocky structures adjacent to Alcatraz Island (PFMC 1998d). Commercial catch trends suggest that populations of this flounder are at extremely low levels, reduced from more than 1 million pounds of annual landings in the 1970s to an average of 62,225 pounds of annual landings in the 1990s (Haugen and Thomas 2001). However, Moyle (2002) suggests that it is unclear whether this decline is related to changing estuary conditions or to changes in fishing regulations that reduce catch (Leet et al. 1992). SWP/CVP fish salvage facilities in the Sacramento-San Joaquin Delta recorded average monthly salvage records for the starry flounder for the period from 1981 to 2002 as 187 fish per month at CVP and 77 at SWP (Foss 2003).

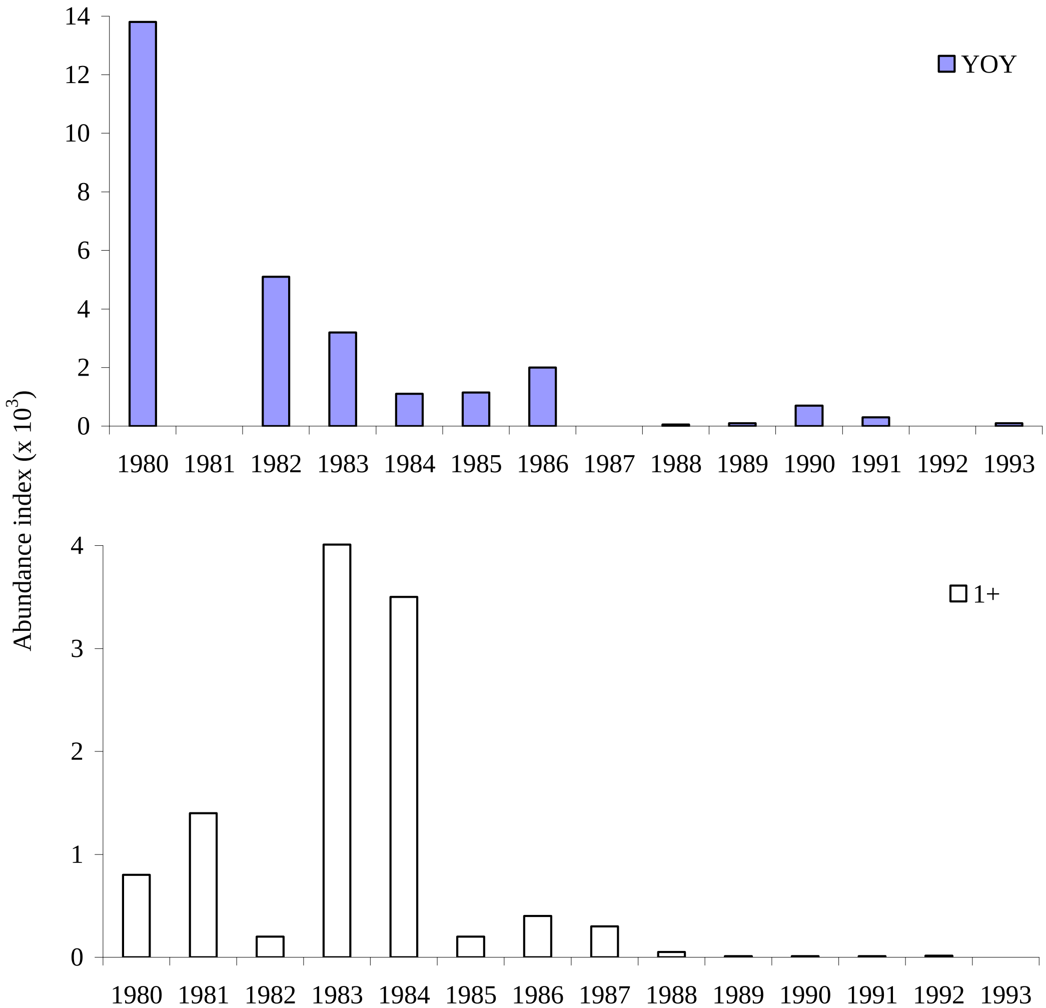


Figure 16-5 Abundance estimates of starrry flounder young-of-the-year (YOY) and age 1+, captured by otter trawl. Data source: California Department of Fish and Game/ Bay Delta Region web page. (http://www.delta.dfg.ca.gov/baydelta/monitoring/stflab.asp)

Potential Effects of Proposed Project

The primary fresh water inputs to the San Francisco Estuary are derived from regional precipitation (quantity and form [ie rain or snow]) and to a greater extent, the Sacramento and San Joaquin Rivers (Kimmerer 2002). River inflow is largely regulated by upstream reservoir releases. A fraction of this inflow is exported out of the Delta by the CVP and the SWP affecting variation in through-estuary outflow, creating lower winter and higher summer outflow than what occurred historically. This can have a strong influence on the mixing zone (X2), where fresh and salt water collide and the overall salinity of the Estuary (Uncles and Peterson 1996). This mixing zone is a highly productive environment (Kimmerer 2002).

Movement of the mixing zone is complex and dependent upon a number of factors, including tidal cycles (Cloern et al. 1989) and fresh water inflow. Wind wave action can also be important for mixing. Over the course of a year, X2 can range from San Pablo Bay during high flow periods, to well into the Delta during the summer drought. The position of X2 is monitored and maintained by releasing water from upstream reservoirs and operation of manmade barriers (ie Suisun Marsh gates) in anticipation of export demand. This is mandated in the Vernalis Salinity Standard, which was legally established to maintain habitat quality in the Estuary for wildlife and to prevent salinity from encroaching upstream to the export pumps. Gravitational circulation causes stratified high salinity water at depth to flow landward while low salinity water on top flows seaward (Monismith 1996). The effect of gravitational circulation may be most pronounced during periods of high fresh water flow, providing a negative feedback for maintaining the salt field and the distribution of pelagic organisms in the Estuary.

Mixing is important at the landward edge of gravitational circulation, often around X2, where the water column becomes less stratified (Burau 1998). A fixed mixing zone occurs at the east end of the Carquinez Strait, where the deep channel becomes dramatically shallower as it enters Suisun Bay (Schoellhamer 2001). Mixing is critical in maintaining salinity such that extremely large inputs of fresh water are required to move X2 a short distance to the west. Mixing also assists pelagic organisms in maintaining position in the Estuary (Kimmerer 2004) and slowing the advection of primary and secondary production out of the system. These relationships appear to have a significant influence on fish species within the Estuary (Feyrer et al. 2007).

Furthermore, phytoplankton, zooplankton, and larval and adult fish can become entrained in the export pumps, causing a potentially significant but unknown impact on the abundance of these organisms. Reduced outflow may have effects on salinity and sediment composition within the Estuary, controlling the size and species composition within this area (Siegfried et al. 1980). Rivers are also one of the largest sources of phosphorous and nitrogen to the ocean environment, having a significant effect on oceanic production (Tyrrell 1999). Potential impacts of river modification include effects on migration patterns, spawning habitat, species diversity, water quality and distribution and production of lower trophic levels in the marine environment (Drinkwater and Frank 1994). Therefore, these interactions may have an influence on prey as well as predators of northern anchovy and starry flounder within the Estuary and potentially along the adjacent coast.

Northern Anchovy

The northern anchovy is primarily a marine and estuarine species. The CVP and SWP operations may have some effects on marine and estuary conditions and it is possible that some adverse effects from the proposed project on northern anchovy EFH may occur within the marine and estuary environment. There are no records of northern anchovy salvage at the CVP or SWP fish salvage facilities and therefore no adverse effects are expected within the river environment.

Starry Flounder

The withdrawal of seawater can create unnatural conditions to the EFH of starry flounder. Various life stages can be affected by water intake operations such as entrapment through water withdrawal and impingement on intake screens. Starry flounder salvage occurs at the CVP and SWP export facilities (Table 16-1). Most salvage occurs in May, June, and July. The salvaged flounder are young of year fish with the largest fish 3 to 4 inches long (Lloyd Hess, pers comm.). High approach velocities along with intake structures can create unnatural conditions to the EFH of starry flounder. These structures may withdraw most larval and post-larval organisms, and some proportion of more advanced life stages. Periods of low light (e.g., turbid waters, nocturnal periods) may also entrap adult and subadults. Freshwater withdrawal also reduces the volume and perhaps timing of freshwater reaching estuarine environments, thereby potentially altering circulation patterns, salinity, and the upstream migration of saltwater.

Starry flounder is primarily a marine and estuarine species. CVP and SWP operations do not significantly affect marine conditions, although they can affect estuarine conditions and some take occurs at the pumping plants. The proposed CVP OCAP can affect EFH of the starry flounder in the Delta by changing flow and water quality. Starry flounder is a widespread species not directly targeted by commercial fisheries. Effects to starry flounder habitat are minor relative to flounder habitat as a whole and no commercial fisheries will be affected by localized effects on the habitat or population.

Table 16-1 Starry flounder salvage at the SWP and CVP export facilities, 1981 – 2002.

Starry Flounder Salvage at the SWP and CVP Delta Fish Salvage Facilities, 1981 - 2002

				1 = SWP, 2 = CVP		
Sum of SALVAGE			Sum of SA	FACILITY		
MONTH	Total		MONTH	1	2	Grand Total
1	24		1		24	24
2	181		2		181	181
3	33		3	33		33
4	325		4	294	31	325
5	1733		5	795	938	1733
6	7188		6	6174	1014	7188
7	2242		7	1849	393	2242
8	295		8	154	141	295
9	51		9	27	24	51
10	76		10		76	76
11	6		11	6		6
12	12		12		12	12
Grand Total	12166		Grand Tot	9332	2834	12166

Sum of SALVAGE	MONTH												
YEAR	1	2	3	4	5	6	7	8	9	10	11	12	Grand Total
1981				169	405			48	19				641
1983						60							60
1984						294							294
1985					154	2429	78						2661
1986				31	46	66	615						758
1987				64				168					232
1988		128			49	2707	829						3713
1989					3								3
1990						267	143						410
1991		53			63	43	119			28			306
1992			25	6	29					36		12	108
1994				1	18	24	24						67
1995						12							12
1996						126	170	15	8				319
1997				45	816	854	42	36		12			1805
1998	24				102	80	30		24				260
1999					12	94	96	4			6		212
2000			8	9	24	72	24	24					161
2001							24						24
2002					12	60	48						120
Grand Total	24	181	33	325	1733	7188	2242	295	51	76	6	12	12166

Essential Fish Habitat Conservation Measures

The Coastal Pelagic Species Fishery Management Plan (PFMC 1998a) requires a permit to commercially harvest coastal pelagic finfish species, such as the northern anchovy, south of Point Arena, California. The fishery management plan includes the northern anchovy as a “monitored species” because of low fishery demand and high stock size and thus does not impose harvest limits based on biomass estimates. There is no limit on live bait catch for this species.

The Pacific Coast Groundfish Fishery Management Plan (PFMC 1998c) outlines measures to reduce negative impacts on essential fish habitat. These measures include fishing gear restrictions, seasonal and area closures, harvest limits, among others. There are currently no harvest limits specific to the starry flounder. Conservation measures include recommending that all intake structures be designed to minimize entrainment or impingement of fish, and mitigation should be provided for the net loss of habitat from placement of the intake structure and delivery pipeline.

Conclusion for Northern Anchovy and Starry Flounder

Upon review of the effects of Reclamation’s proposed CVP OCAP, the proposed project may affect EFH of the northern anchovy and the starry flounder.

Essential Fish Habitat for Chinook Salmon

Distribution and Status

Note: The following information is background data on fall and late fall-run Chinook salmon *Oncorhynchus tshawytscha*. The effects for these runs are included in chapters 10 and 11 and summarized at the end of this chapter.

On September 16, 1999, NMFS determined that listing was not warranted for this ESU (NMFS 1999). However, sufficient concerns remained to justify adding them to the candidate species list (qualify as species of concern) (NMFS 2004). The ESU includes all naturally spawned populations of fall-run Chinook salmon in the Sacramento and San Joaquin River basins and their tributaries, east of Carquinez Strait, California. Major river basins containing spawning and rearing habitat for this ESU comprise approximately 13,760 square miles in California.

Effects on Central Valley spring-run Chinook salmon, Sacramento River winter-run Chinook salmon, Southern Oregon/Northern California Coast coho salmon, Central Valley steelhead, and Central California Coast steelhead habitat are described in the biological assessment in Chapters 11 and 13 and are summarized in Chapter 15.

Chinook salmon are the largest of the Pacific salmon and are highly prized by commercial, sport, and subsistence fishers. Chinook salmon can be found in the ocean along the west coast of North America from south of Monterey, California, to Alaska, but the southern extent of spawning is in the San Joaquin and Kings rivers (Moyle 2002). The fisheries of healthy Pacific coast Chinook salmon stocks are managed by the Council under the Pacific Salmon Fishery Management Plan. Approximately, 80 percent of the California catch comes from the Central Valley as opposed to the Klammath River system although as much as 90% may be of hatchery origin (Barnett-Johnson et al. 2007). These stocks include fall and late-fall run Chinook salmon from the Klammath and Central Valley systems. In 2003, preliminary estimates of California coastal community and state personal income impacts of the troll and recreational salmon fishery collectively for the Fort Bragg, and San Francisco/Monterey port areas was $27.0 million and $10.7 million, respectively. Jeffres and Merz (2000) found that salmon sport anglers spent $352 K on a 90 mi section of the Central Delta. Extrapolated to the 1100 miles available to salmon in the Central Valley (Yoshiyama et al. 1996), Chinook salmon sport harvest may be worth another $6.7 million. Historically, fall run Chinook salmon used rivers and their 21 tributaries in the Central Valley from the Kings River in the south to the Pit and McCloud rivers in the north

(Schick et al. 2005). Late fall-run Chinook salmon probably used the Sacramento River and tributaries above Shasta Dam (Moyle et al. 1995). The late fall-run was identified as separate from the fall-run in the Sacramento River after the Red Bluff Diversion Dam was constructed in 1966 and fish counts could be more accurately made at the fish ladder there.

Description and Life History

Spawning adult Chinook are the largest of the Pacific salmon, typically, 75-80 cm standard length (9-10 kg), with lengths in excess 140 cm (45 kg)(Moyle 2002). Parr have 6-12 parr marks, each equal to or wider than the spaces between and most extending below the lateral line (Moyle 2002). The parr adipose fin is pigmented on the upper edge but clear at its center and base. Adults are identified from the only other common Pacific salmon in coastal California waters, the coho *O. kisutch* by the Chinook salmon's black gums on the lower jaw. Because of their large populations and body sizes, Pacific salmon are a major food source for terrestrial and aquatic organisms associated with spawning streams, from bears (*Ursus* spp) to bacteria (Willson et al. 1998; Cederholm et al. 1999; Hilderbrand et al. 1999). Pacific salmon spend most of their life cycles as top predators in the nutrient-rich North Pacific Ocean, where they incorporate carbon, nitrogen, phosphorus, and other micronutrients into their body tissues. These tissues provide an important nutrient and energy subsidy to oligotrophic streams where the salmon spawn and eventually die (Willson and Halupka 1995; Wipfli et al. 1998). Chinook salmon may provide a significant nutrient subsidy to local agricultural interests within the Central Valley where populations still exist (Merz and Moyle 2006). Because of their relatively low abundance in coastal and oceanic waters, Chinook salmon in the marine environment are typically only an incidental food item in the diet of other fishes, marine mammals, and coastal sea birds.

Healy (1991) divided Chinook salmon into two life-history strategies, stream and ocean. Stream-type Chinook salmon have adults that run up streams before they reach full maturity, in spring or summer, and juveniles that spend a long time (usually >1 year) in fresh water (Table 16-2). Ocean-type Chinook salmon have adults that spawn soon after entering fresh water, in summer and fall, and juveniles that spend a relatively short time (3-12 months) rearing in fresh water (Moyle 2002).

Table 16-2 Fall-run and Late Fall-run Life History Traits (Data sources: Moyle et. al. 1995; Moyle 2002).

Trait	Fall-run	Late Fall-run
Spawning migration	June-December	October-April
Spawning period	Late September-December	Early January-April
Juvenile period	March-December	April-June
Juvenile stream residence	1-7 months	7-13 months
Typical ge at spawning	4-5 years	3-4 years
Holding before spawning	Days-weeks	1-3 months

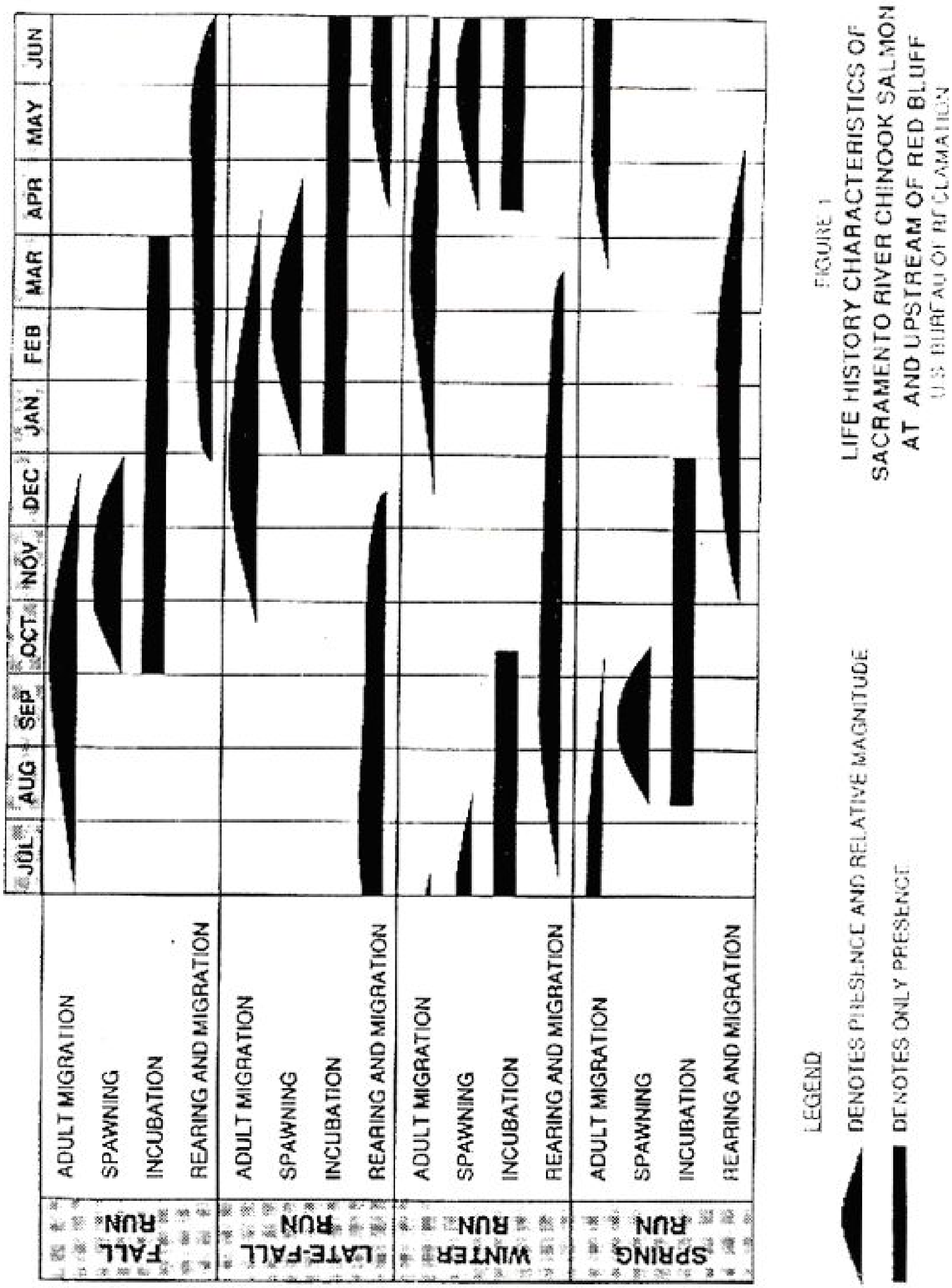


Figure 16-6 Life cycle timing for Sacramento River Chinook salmon. Adapted from Vogel and Marine (1991).

According to Moyle (2002), the fall-run are an unambiguous ocean-type Chinook salmon adapted for spawning in lowland reaches of big rivers and their tributaries. They move up from the ocean in late summer and early fall (Figure 16-6) in mature condition and typically spawn within a few days or weeks of arriving on the spawning grounds. Juveniles typically emerge from the gravel in winter and spring and move downstream within a few months, to rear in mainstem rivers or estuaries before heading to the ocean (Kjelson et al. 1982).

Late-fall-run Chinook salmon are mostly a stream-type salmon found in the Sacramento River today (Moyle 2002). They are the largest and most fecund salmon in California because they historically came in as 4- and 5-year-old fish (Moyle et al. 1995; Fisher 1994). Adults typically hold in the river for 1-3 months before spawning. Juveniles enter the ocean after 7-13 months rearing in fresh water, at 150-170 mm FL, considerably larger and older than fall-run Chinook salmon (Moyle 2002).

Ocean Distribution

Since 1981, Pacific salmon *Oncorhynchus* spp. tagged with coded-wire tags (CWTs) have been recovered in commercial fisheries and research programs in the North Pacific Ocean, Gulf of Alaska, and Bering Sea-Aleutian Islands (Celewycz et al. 2007). The known range of North American Chinook salmon, as shown by tagging experiments, extends across almost the entire Bering Sea, north to 60°03’N and west to 172°12’E. In the North Pacific, the known ocean range of North American Chinook salmon extends north from about 40°N (in the coastal waters just off California) and west to the waters just south of Adak Island in the central Aleutians (176°34’W, 51°29’N)(Celewycz et al. 2007).

Fall-run Chinook salmon normally spend 2-4 years in the ocean although Feather River salmon normally have a 4 to 5 year ocean residency (Moyle 2002). Available data suggest that while in the ocean, fall-run Chinook salmon remain primarily in the coastal waters off California (NMFS 1997).

Along the California coast, adult Chinook salmon are key predators responding in their distribution and abundance to availability of food resources (Adams 2001). Chinook salmon found in the Gulf of the Farallone are predominantly 3-year-old fish preparing to enter the Bay-Delta ecosystem and various tributaries of the Sacramento-San Joaquin River system where they will spawn, and eventually die. They typically move into the Gulf in February and March, and are generally found off the Golden Gate from Bolinas Point in the north to Point San Pedro in the south. Their diets consist of Pacific herring (recently emigrated from November to February spawning in San Francisco Bay) and anchovies. The herring are particularly vulnerable to Chinook predation as they are weakened from spawning. Chinook may move offshore again in April to June to feed on euphausiid shrimp *Thysanoessa spinifera* (krill), crab larvae, and juvenile rockfish; and, the return to the nearshore in July to forage exclusively on anchovy. The distribution of adult Chinook salmon and their stomach contents strongly relates to the availability and composition of food resources, such as anchovy, and the availability of those food resources is related to climatic and ocean conditions.

Anchovies begin to gather in nearshore waters in February and March before their migration into the Bay in April and April represents the transition time in Chinook salmon nearshore and offshore feeding habits. Euphausiids are taken as prey from surface and subsurface swarms that occur over a wide area of the Gulf during April and May (Adams 2001). It is the carotenoid pigment in crustaceans, like euphausiids, that gives the salmon flesh its pink color. Dungeness crab *Cancer magister* megalopa larvae dominate the diets of Chinook salmon for a short time period, during their last pelagic phase in early April. More than 7,000 megalopa have been found in a single Chinook salmon stomach. In May and June, Chinook salmon move further offshore and start feeding on euphausiids and juvenile rockfish. In years when juvenile rockfish are abundant, they are the preferred prey and dominate the Chinook salmon diet, whereas in low-abundance years, Chinook salmon feed mainly on euphausiids. Later in the summer the Gulf water warms due to the absence of upwelling, and anchovies simultaneously move out of the Bay and into the Gulf. This is coupled with a seasonal disappearance of juvenile rockfish, causing the salmon to return to the nearshore and capitalize on the feeding opportunity presented by the anchovies. Diet information has confirmed the salmon's dependence on aggregations of prey, and the prevalence of opportunistic feeding (Adams 2001). This natural concentration of Chinook salmon makes them susseptable to increased angling take (citation). However, the dependence on these traditional prey complexes may be disrupted during strong El Niños or other changes to ocean conditions. When prey aggregations fail to occur, the condition (length-to-weight relationship) may decrease similar to what was recorded during California's commercial salmon catch in El Niños years.

Inland Habitat Requirements and Special Considerations

Specific information on habitat requirements of Chinook salmon in the inland waterways of the California Central Valley is provided in Chapters 5 and 6.

Adult migration

Specific cues triggering adult fall-run Chinook salmon to return to their spawning grounds from the Pacific Ocean are not well understood. Returning fall-run Chinook salmon average 35.4 inches (90 cm) in length (Moyle 2002). Chinook adults metamorphose from the silvery ocean form into the characteristic dark maroon to olive brown spawning colors. During the upward migration, adults stop feeding as their digestive tract degrades, causing them to live increasingly on body fat reserves. Spawning Chinook salmon are sexually dimorphic, with males darker and typically larger than females. Head and adipose fin to body length is typically greater in males (Merz and Merz 2004). Often the male's back humps and jaw hooks, creating a kype; teeth become more prominent and sharp. As this occurs, both sexes lose their ability to heal injuries and fight disease (Allen and Hassler 1986). The ability for Chinook to find their way back to their home stream in order to spawn is mainly related to the long-term olfaction memory of the salmon, but is also aided by their vision (Healey, 1991) and may be stimulated by higher streamflow and changes in water turbidity, temperature and oxygen content (Allen and Hassler 1986). Migratory routes must be free of barriers that can impede or prevent movement upstream and downstream. Numerous issues, such as predation and water quality can affect the ability of adults to reach spawning areas and complete successful spawning (Goniea et al. 2006; Beamsdorfer 2000; Hillemeier 1999). These are further affected by anthropogenic effects such water diversion; channel modification and water quality controls (Stein xxxx; Hallock et al. 1970). Male salmon often reach the spawning grounds before females to set up territories. Although some feeding has been documented at river mouth entry, in general, Chinook salmon do not eat during their migration to spawning areas or during holding before spawning (Moyle et al. 1995).

Spawning

In general, spawning Chinook salmon require gravel and cobble areas, primarily at the head of riffles, with adequate hyporheic flow to ensure embryo survival (Table 16-3). Chinook salmon select gravel for spawning with a median diameter between 7 and 300 mm (Platts et al. 1979, Reiser and Bjornn 1979, Kondolf 1988). Within this range, the particle sizes used for redd formation can vary with the size of the fish (Burner 1951, Kondolf and Wolman 1993). Kondolf and Wolman (1993) determined that the relation between fish length and gravel size can be described by an envelope curve. In general, fish can spawn in gravels with a median diameter up to about 10% of their body length (Kondolf and Wolman 1993).

Table 16-3 Criteria defining suitable fall-run Chinook salmon spawning habitat (sources: Platts et al. 1979; Reiser and Bjornn 1979; Kondolf 1988; Hanrahan et al. 2004).

Variable	Values
Depth	0.30-9.50 m
Velocity	0.25-2.25 m•s^{-1}
Substrate	7-305 mm
Channel-bed slope	0.0 - 5.0%

Although optimal spawning habitat as defined by habitat suitability models is generally found in riffles, proximity of habitat to structural cover (pools, large woody debris, boulder clusters and overhanging vegetation) and hydrodynamic shear zones provide equally important refuge from predation and resting zones for energy conservation (Wheaton et al. 2004; Merz 2001).

Chinook adults tolerate water temperatures between 51 and 67ºF (10.6 and 19.4ºC) with temperatures between 42°F and 58°F considered most suitable for spawning (Bell 1986). Further discussion of water quality issues are provided in Chapters 5 and 6. CV fall-run Chinook salmon typically spawn within a few days or weeks of arriving at their spawning grounds (Moyle 2002). Spawning takes place between September and early January.

The female Chinook salmon usually chooses a nesting site in gravel deposits at the lower lip of a pool just above a riffle (Burner 1951; Briggs 1953). During spawning, the female makes a redd (an area containing several individual nests) by turning on her side and repeatedly flexing her body and tail to force gravel and fine sediment into the water column; these sediments are deposited a short distance downstream. The completed nest forms an oval depression with a mound of gravel located immediately downstream.

Fecundity varies greatly among Chinook salmon of different populations. For example, fecundity of fall-run Chinook salmon averages 3,634 eggs per female in the Klamath River but 7,295 eggs in Sacramento River fish (Allen and Hassler 1986). Difference in female size alone cannot account for the variation in fecundity (Healey and Heard 1984).

Embryo development

Optimum substrate for embryos is a gravel/cobble mixture with a mean diameter of 0.5 to 4 inches and a composition including less than 5 percent fines (particles less than 0.3 inch in diameter) (Platts et al. 1979; Reiser and Bjornn 1979 both as cited in DFG 1998). The incubation life stage for fall-run Chinook salmon generally extends from about September through March. The intragravel residence period of incubating eggs and alevins (yolk-sac fry) and egg incubation survival rates and times are highly dependent on water temperature and dissolved oxygen (Merz et al. 2006). Optimal water temperatures for incubation range between 48°F and 58°F (8.9°C to 14.4°C). Incubation temperatures of 62°F to 64°F appear to be the physiological limit for embryo development resulting in 80 to 100 percent mortality prior to emergence (USFWS 1999). Suitable water temperatures for incubation range between 48°F and 58°F. In general, fall-run Chinook salmon fry emerge during December through March (Yoshiyama et al. 1998).

Fry and Juvenile Rearing and Emigration

In the California Central Valley, juvenile Chinook salmon have been reported to emigrate from approximately mid-November through July, with peak emigration occurring from January through March (Painter 1977; DWR 2003). The vast majority of the fall-run Chinook salmon emigrate as fry (Seesholtz et al. 2004), suggesting that rearing habitat is limiting or that conditions later in the season are less suitable. For the most part, fall-run Chinook salmon juveniles rear in tidal freshwater habitats of the Delta. Primary locations where these fish rear are unknown; however, in wetter years it appears that many young salmon rear for weeks to months in the Yolo Bypass floodplain immediately downstream of the Feather River before migrating to the estuary (Sommer et al. 2001). Juvenile fall-run salmon may rear for up to several months within the Delta before entering the ocean (Kjelson et al. 1982; Yoshiyama et al. 1998). Banks et al. (1971) and Rich (1987) report that preferred/optimal water temperatures for juvenile fall-run Chinook salmon rearing are from 54°F to 60°F.

Juvenile Chinook salmon diets often vary by habitat type. Chironomid midges are typically cited as an important prey for juvenile Chinook salmon upstream of the Delta (Sasaki 1966; Merz and Vanicek 1996; Moore 1997; Sommer et al. 2001), whereas crustaceans may be more important in the western Delta (Sasaki 1966; Kjelson et al. 1982). Upstream reservoirs can provide a significant food source to lower rivers, such as zooplankton. Prey size and ingestion rates are also significantly affected by juvenile salmon size and water temperature within the stream (Merz 2002a; Merz 2002b).

Typically, juvenile Chinook salmon do not move into brackish water until they have undergone smoltification, after which they move quickly to the ocean (Reclamation 2004). Scale analysis indicates that fall-run Chinook salmon smolts enter the ocean at an average fork length (FL) of about 85 mm (DFG unpublished data).

Population Trends

Central Valley Chinook salmon constitute the majority of salmon produced in California and at times have accounted for 70 percent or more of the statewide commercial harvest (Yoshiyama et al. 2001). Central Valley populations are monitored in a number of ways. Adult Chinook production is estimated using tributary escapement counts and adding this number to the estimated ocean harvest. Tributary counts come from carcass counts, fish ladder counts, aerial redd surveys, hatchery returns and in-river harvest. The total escapement (in-river plus hatchery) of fall-run Chinook in the Central Valley from 1952-2001 is shown in Figure 16-7.

Figure 16-8 shows Chinook salmon in-river escapement estimates by watershed from 2001-2007. The watershed specific component of the ocean harvest of fall-run Chinook salmon is calculated by multiplying the total ocean harvest by the watershed-specific proportion of the total in-river run size. Tagging programs have not been sufficiently implemented Central Valley wide to provide more exact commercial harvest estimates by watershed. During 1999, ocean harvest accounted for 41 percent (335,700) of the total Central Valley Chinook production of 822,352 (all runs combined). The total production includes both natural in-river and hatchery production estimates.

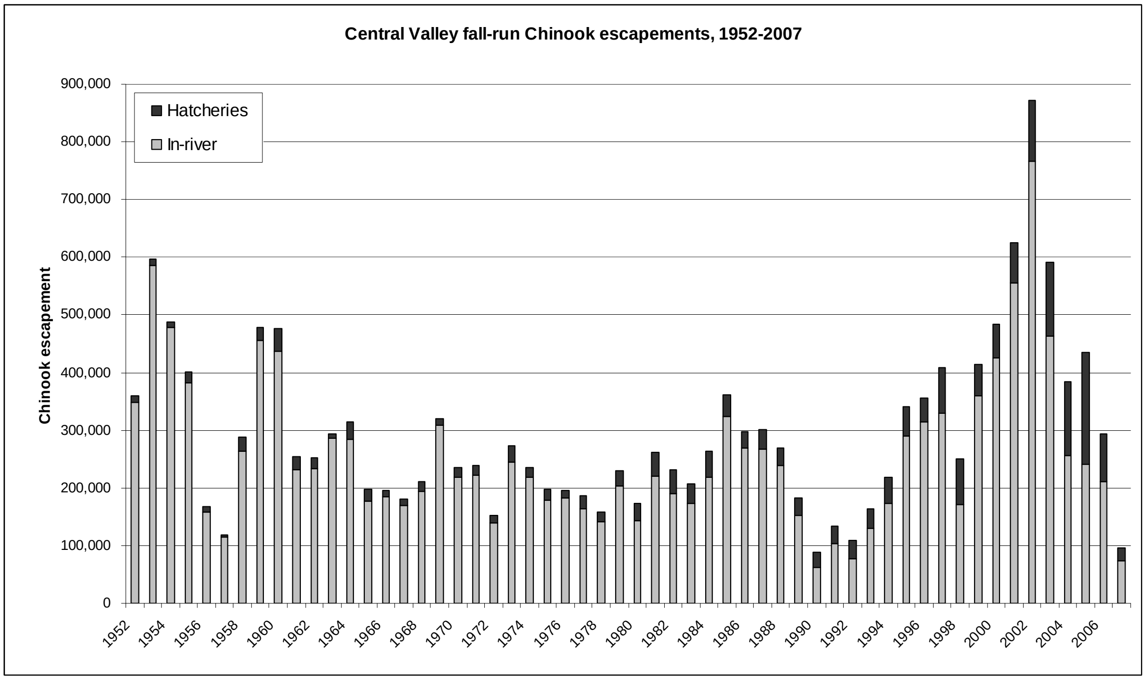


Figure 16-7 Central Valley fall-run Chinook salmon escapements, 1952-2007. Source: DFG data.

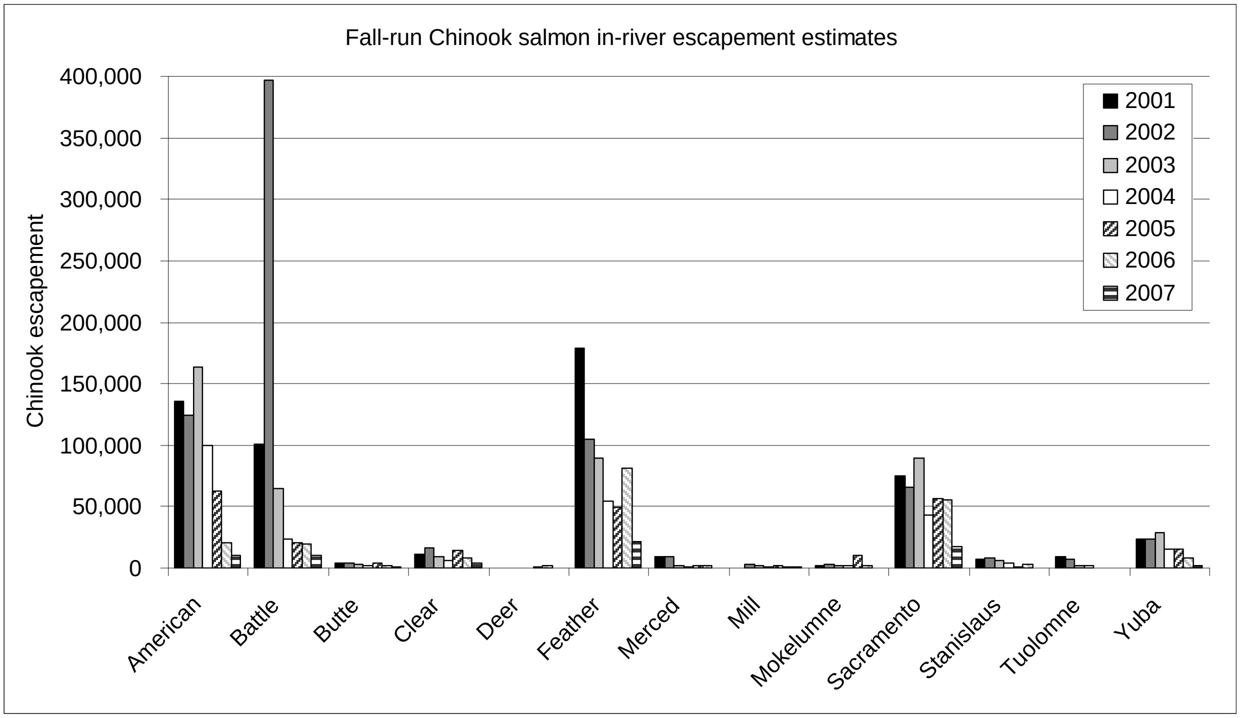


Figure 16-8 Fall-run Chinook salmon in-river escapement estimates in the California Central Valley, 2001-2007. Source: Interior (2008).

The Comprehensive Assessment and Monitoring Program (CAMP) annual report (Interior 2001) summarizes results of monitoring anadromous fisheries production in the Central Valley relative to the CVPIA doubling goal. The CVPIA set the baseline anadromous fisheries production level as the average attained during 1967-91. Progress toward production targets is assessed using a modification of the Pacific Salmon Commission's (1996) rebuilding assessment methods when a minimum of five years of monitoring data is available. Indicator races or species are classified into three categories: (1) those at or above their production target; (2) those meeting their rebuilding schedule; and (3) those not rebuilding. Results based on past escapement estimates need to be qualified due to the vagaries of the estimation methods used over the years (DFG 2003).

Battle Creek, Clear Creek, and Mokelumne River populations of fall-run Chinook salmon and Butte Creek spring-run salmon are classified as meeting restoration goals. Fall-run salmon from the Yuba watershed are classified as Rebuilding. All other races and watershed-specific runs of Chinook salmon are classified as Not Rebuilding, except for American River fall-run salmon classified as Indeterminate. Table 16-4 shows the 1995-99 mean Chinook salmon production expressed as a percent of the goal, which is the mean of the 1967-91 production.

Many variables affect yearly salmon production including ocean conditions and water supplies, which have recently been at good levels for California salmon runs. The 2000, 2001, and 2002 Chinook salmon runs were outstanding in many Central Valley watersheds.

Table 16-4 Status of CAMP-monitored Central Valley stocks of Chinook salmon races using Pacific Salmon Commission methodology.

Watershed	*Race*	*1995-99 mean Chinook production as percent of goal*	*Watershed status through 1999 Chinook run*
American	Fall-run	77 percent	Indeterminate, declines halted
Battle	Fall-run	235 percent	Above goal
Butte	Spring-run	551 percent	Above goal
Clear	Fall-run	218 percent	Above goal
Deer	Spring-run	44 percent	Not Rebuilding
Feather	Fall-run	63 percent	Not Rebuilding
Merced	Fall-run	49 percent	Not Rebuilding
Mill	Spring-run	22 percent	Not Rebuilding
Mokelumne	Fall-run	169 percent	Above goal
Sacramento	Fall-run	48 percent	Not Rebuilding
	Spring-run	2 percent	Not Rebuilding
	Winter-run	5 percent	Not Rebuilding
Stanislaus	Fall-run	17 percent	Not Rebuilding
Tuolumne	Fall-run	30 percent	Not Rebuilding
Yuba	Fall-run	91 percent	Rebuilding, declines halted
Total (all CAMP streams)	Fall-run	66 percent	Not Rebuilding
	Spring-run	22 percent	Not Rebuilding
	Winter-run	5 percent	Not Rebuilding

Trinity River

The Trinity River, a tributary to the Klamath River, is approximately 130 miles (209 km) long with a 2,853 sq mi (7,389 km²) watershed. Its headwaters are located in northeastern Trinity County, in the Shasta-Trinity National Forest along the east side of the Scott Mountains (Trinity Alps). It flows along the west side of the Trinity Mountains into Clair Engle Reservoir (20 miles (32 km) long) formed by the Trinity Dam, then immediately into the smaller Lewiston Reservoir. From the reservoir it flows past Weaverville and along the southern side of the Trinity Alps. The New River enters the Trinity from the north at Burnt Ranch and the South Fork Trinity River from the south along the Humboldt-Trinity county line. From the confluence with the South Fork it flows through the Hoopa Valley Indian Reservation and joins the Klamath from the south in northern Humboldt County at Weitchpec, approximately 20 miles (32 km) from the Pacific coast. The Trinity Alps watershed generates an average annual water runoff of approximately 1,250,000 acre-feet at Lewiston. Lewiston Dam acts as a storage and diversion facility, sending water through the Clear Creek Tunnel to Judge Francis Carr Powerhouse and Whiskeytown Lake. Since completion of the Trinity and Lewiston Dams in 1963, as much as 90 percent of that water runoff has been diverted from the Trinity River Basin to the San Luis Reservoir.

Trinity River Chinook salmon populations are composed of two races, spring-run and fall-run (Leidy and Leidy 1984). The fall-run Chinook salmon migration begins in August and continues into December (CDFG 1992; CDFG 1994; CDFG 1996). Fall-run Chinook salmon begin spawning in mid-October, activity peaks in November, and continues through December. The first spawning activity usually occurs just downstream from Lewiston Dam. As the spawning season progresses into November, spawning extends downstream as far as the Hoopa Valley (USFWS 1991; HTV 1996).

Emergence of fall-run Chinook salmon fry begins in December and continues into mid-April (Leidy and Leidy 1984). Juvenile Chinook salmon typically leave the Basin (outmigrate) after a few months of growth in the Trinity River. Outmigration from the upper river, as indicated by monitoring near Junction City, begins in March and peaks in early May, ending by late May or early June. Outmigration from the lower Trinity River, as indicated by monitoring near Willow Creek, peaks in May and June, and continues through the fall.

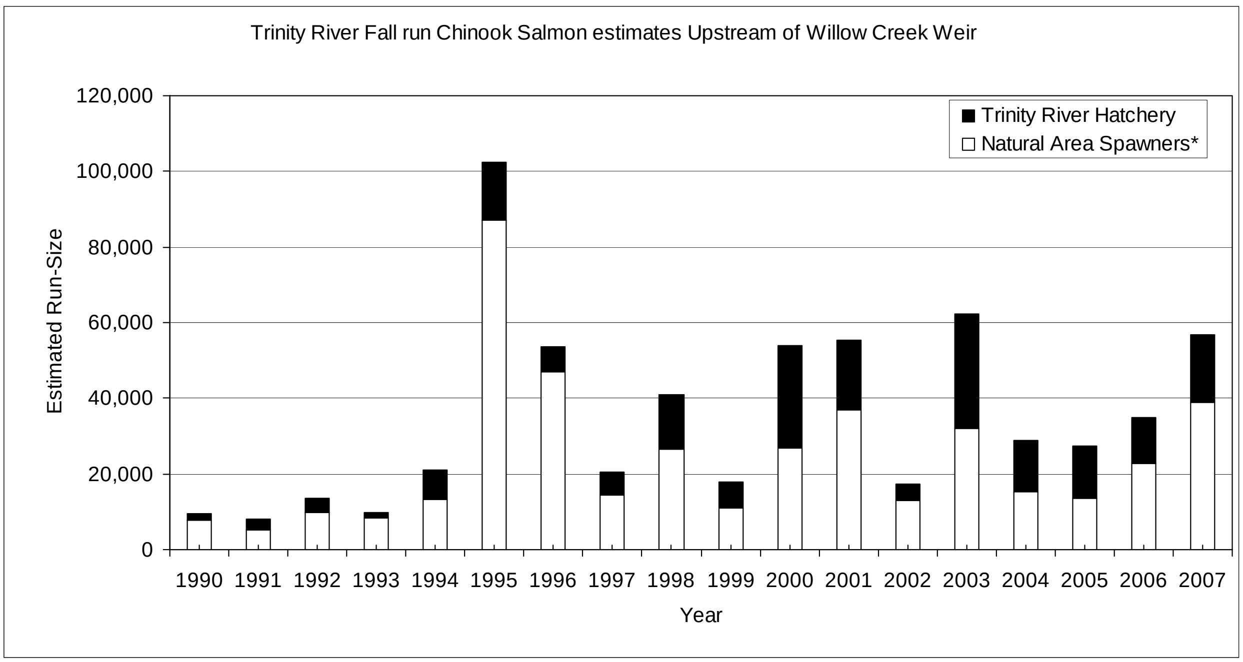
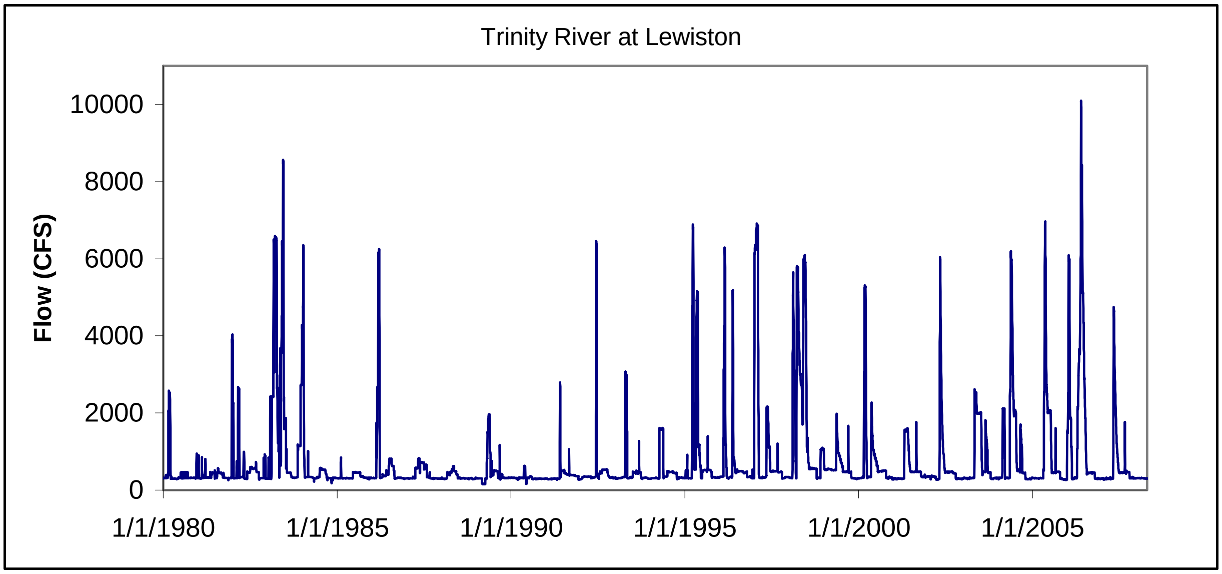


Figure 16-9 Fall-run Chinook salmon run-size for the Trinity River upstream of Willow Creek Weir from 1977 through 2006. *Natural area spawners includes both wild and hatchery fish that spawn in areas outside Trinity River Hatchery.

Hatchery History and Operations

Pre-spawn mortality has been as high as 43.7% for fall-run females (CDFG 1992).

Hydrology



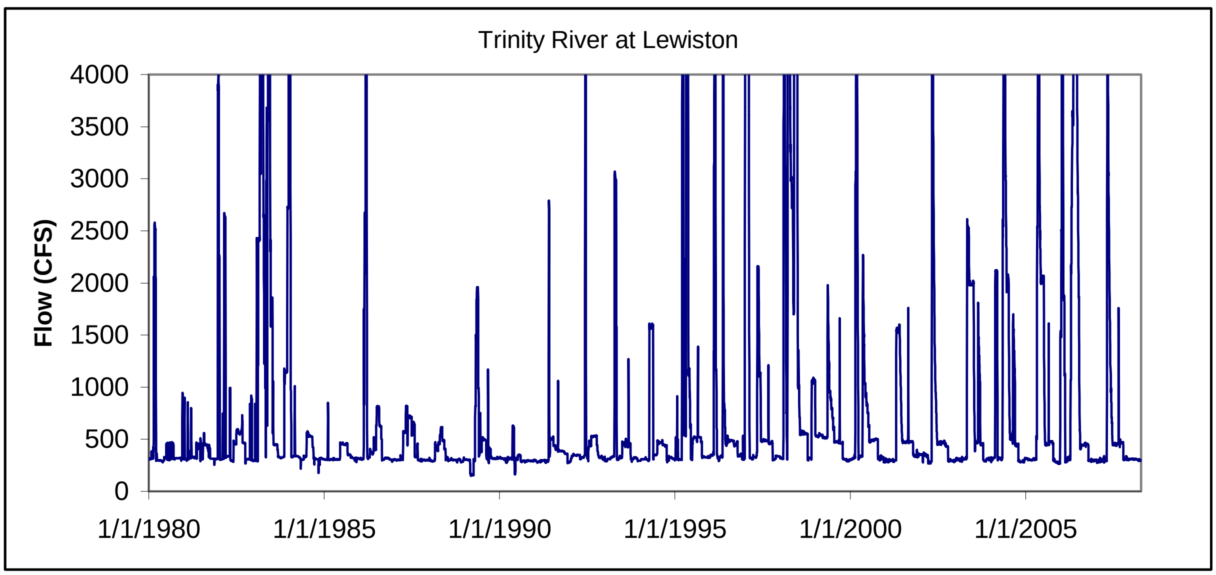


Figure 16-10 Trinity River flows as at the town of Lewiston, 1980-2008. The top chart shows the entire hydrograph. The bottom chart shows a close-up of the 0 to 4000 cfs range.

Clear Creek

Clear Creek originates on the eastern side of the Trinity Alps and flows south to its confluence with the Sacramento River. The Clear Creek watershed is approximately 35 miles long, ranges from five to 12 miles wide, and covers a total area of approximately 249 square miles, or 159,437 acres. Maximum elevation in the watershed is 6,209 feet at the top of Shasta Bally. Clear Creek channel morphology varies from steep confined bedrock reaches above Clear Creek Road bridge to wide meandering alluvial reaches from the bridge to its confluence with the

Sacramento River. Fish passage through ladders on Saeltzer Dam (constructed in 1903), six miles upstream of the Sacramento River confluence, was poor so the dam was removed in 2000. Upstream of Saeltzer Dam at river mile 9.9 and 12 are two series of natural falls which could be barriers to upstream migrants (DFG 1984b).

Fall and late fall-run Chinook salmon use the creek during the fall, winter and spring, when water temperatures are cooler. Therefore, fall and late fall-run Chinook were not as severely impacted by the loss of habitat upstream. In 1995, an unusually large run of 9,298 fall-run Chinook salmon spawned in Clear Creek (Figure 16-11). Increased minimum flow releases are thought to be one factor responsible for the increased number of spawners during that year (Figure 16-12). Late fall-run Chinook spawn in January through April. High seasonal flows and turbid water hinder the ability to conduct escapement surveys during that time of year. Fry and juvenile Chinook rear from January through May. Some late fall-run Chinook juveniles may remain in stream through June, depending on flow and water temperature conditions that occur during the season.

Pulse flows have been proposed for Clear Creek to provide an attraction flow to spring-run Chinook in the mainstem Sacramento River. A release of 1,200 cfs for one day (plus ramping) was proposed in 2000 but was not implemented due to concerns over attracting winter-run into Clear Creek. Because there has been no significant spring-run in Clear Creek in the recent past, pulse flows may aid re-establishment of spring-run in Clear Creek by attracting some fish that would otherwise remain in the Sacramento River.

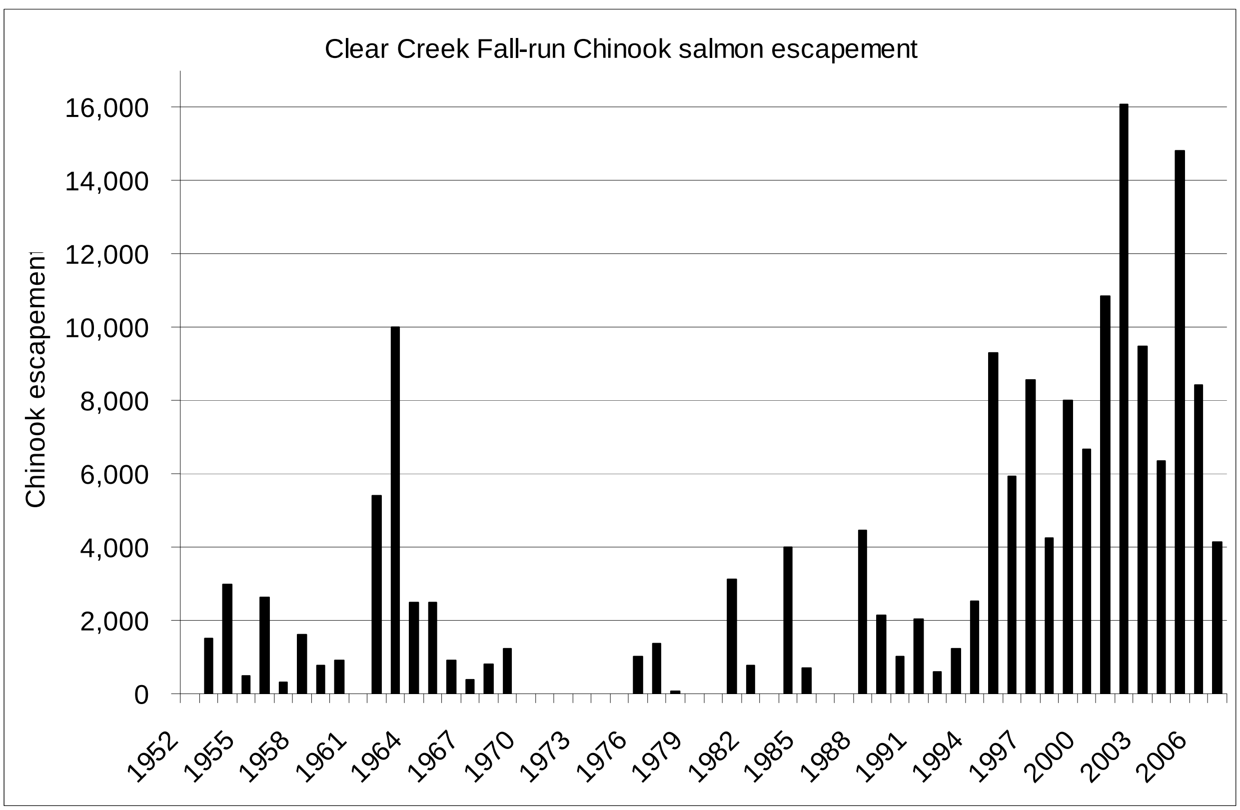


Figure 16-11 Clear Creek fall-run Chinook salmon escapement, 1951-2000. Source: DFG data.

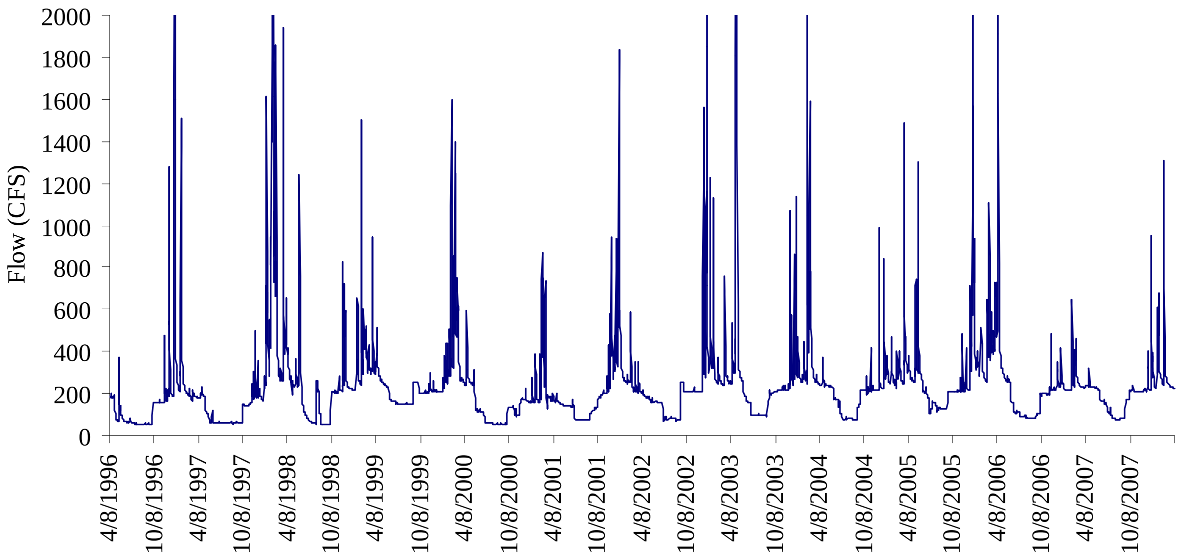


Figure 16-12 Average daily flow in Clear Creek, 1996-2007.

Sacramento River

The Sacramento River drains a watershed area of 21,250 square miles. Keswick Dam at river mile 302 serves as the upstream limit to anadromous habitat. The river is constrained by levees along much of the lower reaches. Stressors identified in the Sacramento River include high water temperatures, a modified hydrograph, simplified instream habitat, diversion dams, predation, and harvest. Water temperature and flow fluctuation are the main short-term factors affected by operation of the water projects.

Escapement of fall-run in the Sacramento River exceeded 100,000 fish every year except one between 1959 and 1970. Escapement has not exceeded 100,000 since 1970. The primary spawning area used by Chinook salmon is in the area from the city of Red Bluff upstream to Keswick Dam. Spawning densities for each of the four runs are generally highest in this reach. This reach is where operations of the Shasta/Keswick and Trinity Divisions of the CVP have the most significant effects on salmon spawning and rearing habitat in the mainstream Sacramento River. Rapid flow fluctuations can dewater edge and backwater habitat and strand fry and juvenile salmon. Redds can also be dewatered as a result of flow fluctuations. Approximately 15 to 30 percent of the total number of fall and late fall-run Chinook spawn downstream of Red Bluff when water quality is good (Vogel and Marine 1991).

Run timing for all Chinook salmon runs and life stages in the Sacramento River is depicted in Figure 16-6. All life stages are present in the river essentially at all times through the year. Abundance of adult Chinook peaks in the fall during the fall-run spawning migrations and then tapers off as fish considered late fall-run spawn. Winter-run enter the river as the late fall-run fish are spawning, starting in January. The winter-run then spawn with the peak in spawning activity in June. Spring-run enter the river soon after the winter run, starting in March and April.

They then hold out until spawning in August and September, during the lowest water flows of the year while temperatures are still relatively high.

Fall-run are entering the river as spring-run are spawning. Fall-run Chinook salmon escapement is shown in Figure 16-13 , the hydrograph since 1993 is in Figure 16-14 .

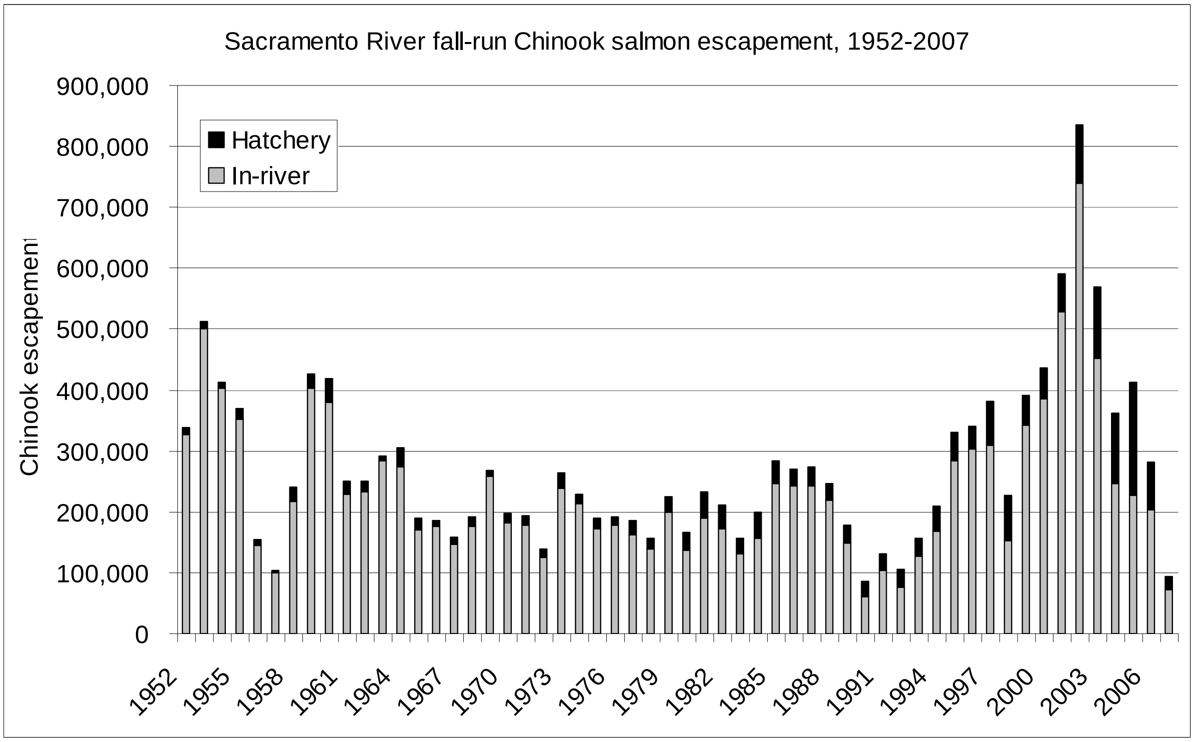


Figure 16-13 Fall-run Chinook salmon escapement in the Sacramento River, 1952-2007.

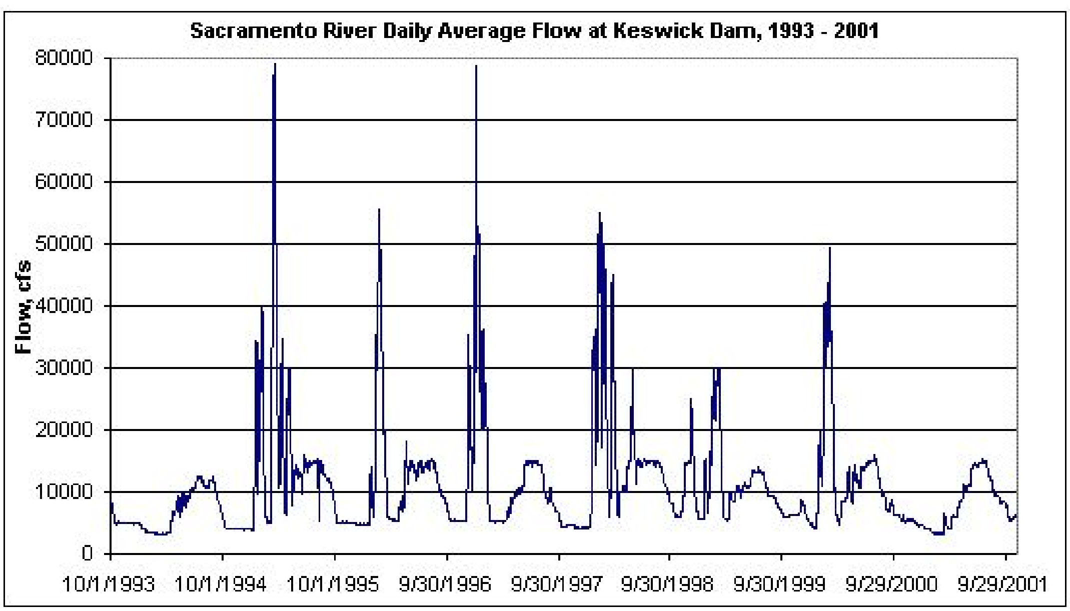


Figure 16-14 Sacramento River daily average flow at Keswick Dam from 1993-2001.

Sacramento River water temperature is controlled primarily by using releases from Shasta Lake through the TCD and also by diversions from Trinity River. The TCD was installed in 1997. Prior to 1997 low level releases were made by opening the lower river outlets, which bypasses power. The TCD enabled power bypasses to be greatly reduced while maintaining desired water temperatures in downstream fish habitat and provides seasonal flexibility to maximize use of cold water volume.

Flows in the Sacramento River generally peak during winter and spring storm events. Sustained moderately high releases (greater than 10,000 cfs) occur during the major irrigation season of June through September. These flows help to meet water temperature criteria for winter-run Chinook spawning and incubation. They also maintain suitable habitat for spring-run and early returning fall-run fish.

American River

The American River drains a roughly triangular watershed covering 1,895 square miles that is widest at the crest of the Sierra Nevada, and narrows almost to the width of the river at its confluence with the Sacramento River at the City of Sacramento. Elevations range from 10,400 feet at the headwaters to about 200 feet at Folsom Dam. Folsom Dam, completed in 1956, provides flood control, hydropower generation and water supply storage. The reservoir is kept partly empty during the winter so that temporary storage is available to regulate the runoff from major storms, preventing flooding in the downstream urban area. Nimbus Dam is seven miles downstream from Folsom Dam. It serves as the limit to upstream migration for anadromous fish. Available anadromous habitat in the American River watershed has been reduced from 161 miles to 23 miles.

Adult Chinook salmon begin to enter the American River in August. Upstream migration peaks in October. Spawning generally commences close to November 1 and peaks in late November. Early spawning success is low if water temperature in early November is above 60° F . American River Chinook salmon escapement has averaged 41,895 since 1952 and ranged from 6,437 to 110,903 (Figure 16-15). Peaks in escapement over 60,000 fish occurred in 1973, 1974, 1981, 1985, 1995, 1996, 1998, and 2000. Low escapements, less than 20,000, fish occurred in 1955, 1956, 1957, 1990, and 1992.

Juvenile Chinook emigration from the American River generally begins in December, peaks in February and March and tails off into June. Nearly all (>99 percent) of the emigrating Chinook salmon from the American River moving past the smolt traps at Watt Avenue are pre-smolts. This suggests that the smolting process is not completed in the lower American River but will continue downstream, likely in the Delta and estuary (Snider and Titus 2000). The 2001 outmigration past Watt Avenue was estimated to be 25 million fish, the largest measured from the American River since rotary screw trapping began (Bill Snider, personal communication, 2001).

The main stressors identified in the American River include an altered flow regime, high water temperatures, hatchery operations and reduced habitat complexity and diversity. The operation of Folsom and Nimbus Dams for water delivery and flood control can affect all of the stressors directly or indirectly.

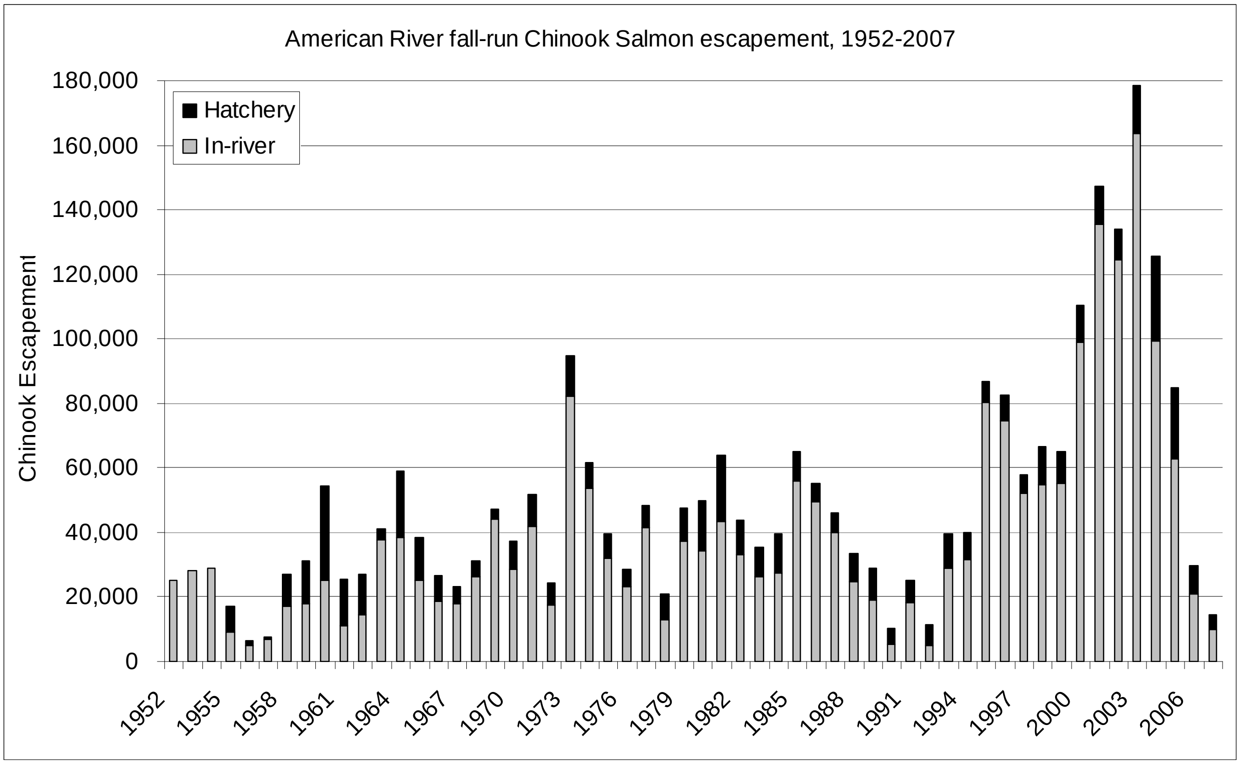


Figure 16-15 American River Chinook salmon escapement estimates, 1952-2007.

Dam operations store water runoff during winter and spring to be released for instream flows, water delivery, and water quality during late spring, summer and fall. Historical high flows in the river have been dampened for flood control and water storage. Moderate flows of around 1,500 to 2,500 cfs have been extended throughout much of the year to provide appropriate instream flows for fish, water quality in the Delta and water for pumping in the Delta. The long-term effect of the lack of high flows is the simplification of instream habitat. High channel forming flows maintain high quality spawning habitat and riparian floodplain conditions. High flows mobilize spawning sized gravels from streambanks and incorporate them into the active channel. Low flows that typically occurred in late summer and fall do not occur because of the dampening effect of the dam operations. High flows are not as high as occurred under natural conditions but the duration of high flows is longer because flood control operations spread them out over time. The longer duration of moderately high flows may be sufficient enough to wash quality spawning gravel out of riffles and deposit it in deeper water where it is unavailable for spawning but not high enough to mobilize new gravel supplies from the extensive gravel bars, banks, and floodplain. Ayres Associates (2001) used detailed topography of the river to model sediment mobilization at various flows in the American River. They found that at 115,000 cfs (the highest flow modeled) particles up to 70 mm median diameter would be moved in the high density spawning areas around Sailor Bar and Sunrise Avenue. Preferred spawning gravel size is 50-125 mm (2-5 inches) in diameter.

Flow fluctuations (below flood release flows) occur as a result of Delta water quality conditions requiring increased releases to maintain water quality for the desired pumping rates. Flow fluctuations can cause stranding of fish and dewatering of redds when the flows are reduced.

Based on cross sections measured in 1998 by the FWS, flow changes of 100 cfs generally change the water depth by about 1 inch in a flow range of 1,000 to 3,000 cfs and by about 0.5 inch in a flow range from about 3,000 to 11,000 cfs. These depth changes vary throughout the river depending on the channel configuration at a location. Decreases in water depth of about 6 inches following spawning can begin to dry up the shallowest redds and will change water velocity over and through the redds.

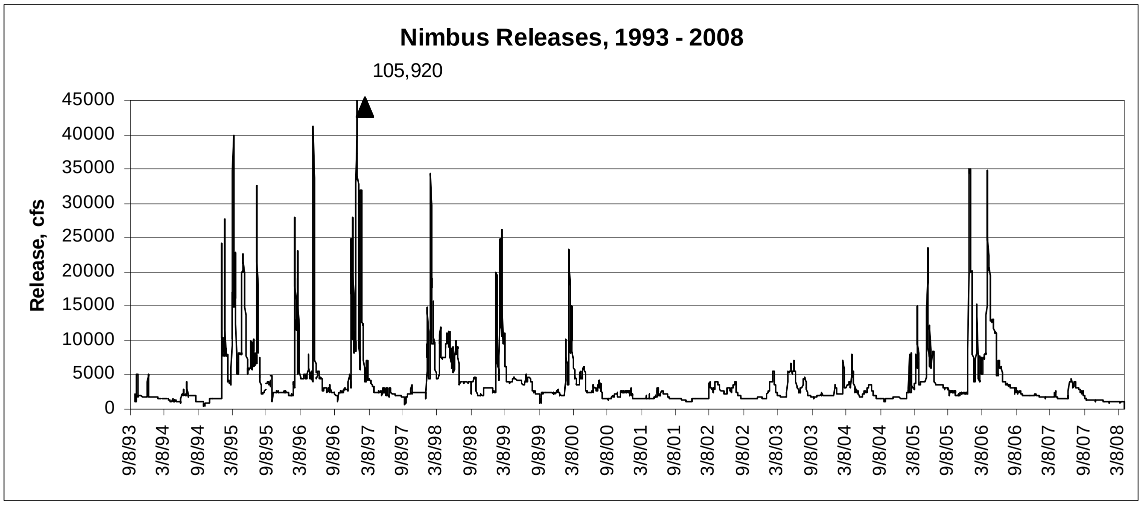
Snider (2001) is evaluating the effects of flow fluctuations on salmon stranding in the American River. Aerial photos and ground truthing were used to measure areas isolated during flow changes. The greatest area isolated occurs at flows around 11,000 cfs (183 acres) and 8,000 cfs (85 acres). Smaller areas of isolation occur around 4,000 cfs (3.6 acres), 3,000 cfs (14.5 acres), 2,000 cfs (13.3 acres), and 1,000 cfs (12.7 acres). Although off-channel areas are important salmon habitat, when salmonids become isolated in off-channel areas for extended periods mortality occurs.

The period of concern for flow fluctuations causing stranding of redds and juvenile Chinook in the American River extends from the initiation of spawning at about the beginning of November until juveniles have emigrated from the river, generally by the end of June. Figure 4–22 shows American River flows from 1993-2001.

FWS (1997) measured 21 cross sections of the American River in high density Chinook spawning areas. They estimated the flows at which the greatest usable spawning area would be available based on water velocity, water depth, and substrate size. Most cross sections showed the greatest usable spawning area available to be in a flow range between 1,600 and 2,400 cfs. Table 16-5shows the average of the weighted usable spawning area from the 21 cross sections expressed as 1,000 square feet of spawning area per 1,000 feet of stream. Weighted usable spawning area peaked at a flow of 1,800 cfs.

In order to maximize survival from egg to fry, flows need to be maintained near or above the level at which spawning occurred. Chinook spawning occurs at water depths greater than about 6 inches. Drops in flow greater than about 500 cfs from the preferred spawning flows following spawning need to be carefully considered. A 500 cfs drop will lower water level in most areas by about 5 inches. Some mortality could occur when water flow over redds drops as flow drops but mortality is greatest when redds begin to become dewatered. Because most Chinook do not spend much time rearing in the American River, spawning habitat may be a limiting factor to Chinook production. Most spawning occurs upstream of the Goethe Park side channels, where river channel gradients are generally higher and riffles more frequent.

Folsom Dam storage capacity is small relative to the annual runoff from the watershed. Because of this, the amount of cold water that can be stored during the winter for release during the summer and fall is limited. Chinook typically begin to show up in the American River in August. Spawning usually initiates about November 1 or when water temperatures fall below a daily average of 60° F . A temperature of 56° F or below is best for survival of incubating eggs. In dry years, such as 2001, water temperature does not reach 60° F until mid-November. A dense school of Chinook holds below the hatchery diversion weir from October until spawning commences. The hatchery opens the fish ladder when water temperature reaches 60° F , typically late October to mid-November. If spawning is delayed past mid-November, the typical peak in spawning, then significant mortality of eggs or pre-spawning mortality may occur. Fish holding in high densities are particularly vulnerable to the effects of high water temperatures, which when coupled with low streamflow can deplete dissolved oxygen and increase disease.



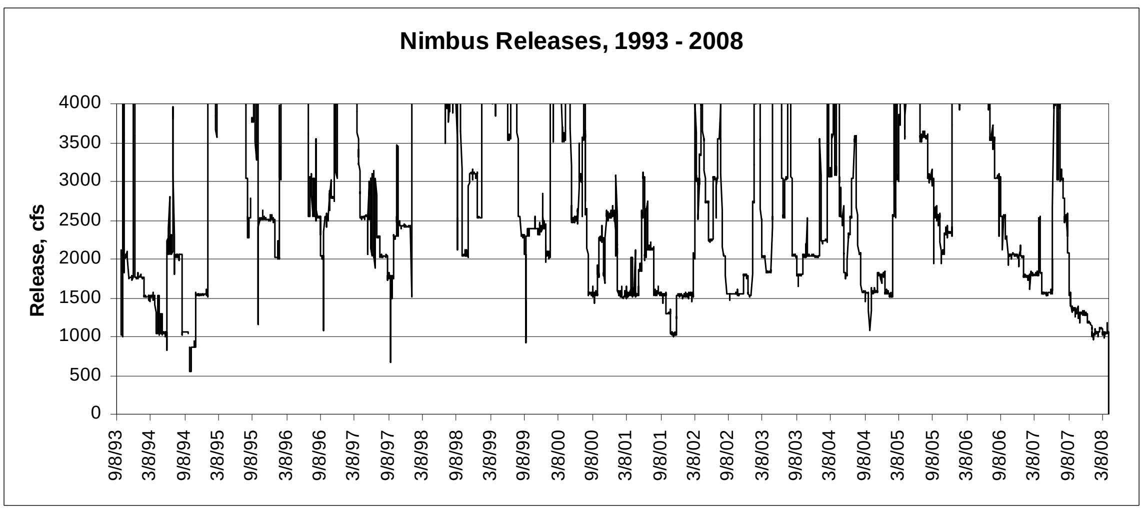


Figure 16-16 American River flows as released from Nimbus Dam, 1993-2008. The top chart shows the entire hydrograph. The bottom chart shows a close-up of the 0 to 4000 cfs range.

Table 16-5 Average weighted usable spawning area in the American River (expressed as 1,000 square feet of spawning area per 1,000 feet of stream) from 21 cross sections measured in 1996. Summarized from FWS 1997.

Flow (cfs)	*Average Weighted Usable Area, 1996*
1000	62
1200	71
1400	78
1600	82
1800	84

Flow (cfs)	*Average Weighted Usable Area, 1996*
2000	83
2200	81
2400	78
2600	74
2800	69
3000	65
3200	60
3400	56
3600	52
3800	48
4000	45
4200	42
4400	38
4600	36
4800	33
5000	31
5200	28
5400	26
5600	25
5800	23
6000	21

American River water temperatures are typically suitable for egg incubation once water temperature cools to 56° F . Before cooling to 56° F , temperature-related mortality of spawned Chinook eggs may occur. Generally temperatures reach 56° F by early December. Cool water temperatures are then sustained through winter egg incubation and juvenile rearing and emigration through the spring.

Efforts are underway by various groups coordinated by the Water Forum to improve American River water temperatures for salmonids. A funding proposal has been submitted for temperature curtains in Lake Natoma. Temperature curtains may lower water temperatures in the river by 3° F during summer and fall. Mechanization and reconfiguration of the temperature shutters on Folsom Dam has also been proposed. The temperature shutter work is expected to improve flexibility in operation of the shutters to spread out cold water availability for a longer period of the year. Construction is underway on Folsom Dam water supply intake to reduce depletions from the coldwater pool. El Dorado Irrigation District is also pursuing a new water intake which would be constructed so that water would not be taken from the cold water pool. Efforts are underway to raise Folsom Dam to provide better flood protection to downstream urban areas. If the dam is raised then the increased storage capacity may alleviate the water temperature concerns in many years.

Reclamation funds operation of Nimbus Salmon and Steelhead Hatchery as mitigation for the habitat blocked by construction of Nimbus and Folsom Dams. An average of 9,370 adults, 22 percent of the average in-river escapement, have been taken at the hatchery each year since 1955.

The hatchery production goal is for 4,000,000 fall Chinook salmon smolts each year. The smolts are released into San Pablo Bay to increase survival over in-river releases. A recent review of hatchery practices in California (DFG and NMFS 2001) recommended discontinuing releases downstream of the American River. They recommended instead to consider releasing Chinook smolts at the hatchery during periods when flow releases can be obtained to maximize smolt survival through the Delta. No consistent coded wire tagging program has been in place so the proportion of the returning salmon that are of hatchery origin v. in-river spawned is unknown. A portion of the release group was coded wire tagged in 2001. This should allow estimates of contribution to commercial and sports fisheries to be made. The proportion of hatchery production contributing to in-river spawning should be able to be determined by comparing the proportion of adipose clipped fish in the carcass mark-recapture survey escapement estimate to the proportion of the release group tagged. Coded wire tagging is recommended to continue to determine contribution to commercial and sports fisheries and survival to spawning.

Stanislaus River

The Stanislaus River is the northern most major tributary to the San Joaquin River. Average monthly unimpaired flows at New Melones Dam are approximately 96,000 af. These flows are reduced to approximately 57,000 af at Ripon, near the confluence with the San Joaquin River, due to flow diversion and regulation at Goodwin Dam.

Goodwin Dam is about 15 miles below New Melones. It serves as the limit to upstream migration for anadromous fish. Anadromous habitat has been reduced from 113 miles to 46 miles. There are approximately forty small, unscreened pump diversions (for agricultural purposes) along the river. New Melones Reservoir is operated to store water during the winter and spring and release it during the summer (San Joaquin River Group Authority 1999).

Adult Chinook salmon begin to return to the Stanislaus River in August with the peak in returns occurring in October. Spawning activity peaks in November and continues into January. Adult Chinook have occasionally been observed in the Stanislaus as early as May. Stanislaus River Chinook escapements have averaged 5,556 and ranged from 0 to 35,000 between 1947 and 2000 (Figure 16-17). Peaks in escapement of over 10,000 fish occurred in the late 1940s, early 50s, late 60s and early 70s, and mid 80s.

The downstream migration of Chinook salmon fry and smolts in the Stanislaus River generally begins in December with newly emergent fry and continues into June. A majority emigrate as fry in January through March. A smaller proportion rear for about one to four months in the river before emigrating. While out-migration of smolts does not appear to be triggered by high flows (Demko et al. 2000), peaks in movement of fry are often correlated with high flow events. When high flow events do not occur, a greater proportion of fry establish rearing territories in the river and remain there longer. Figure 16-18 shows recent Chinook outmigration estimates and prior fall spawning escapement estimates. Higher escapements appeared to result in higher juvenile outmigration until 2001 when outmigration was low. This may be due to the lack of freshets during the outmigration period in 2001 resulting in more fish remaining in the river longer, decreasing in-river survival.

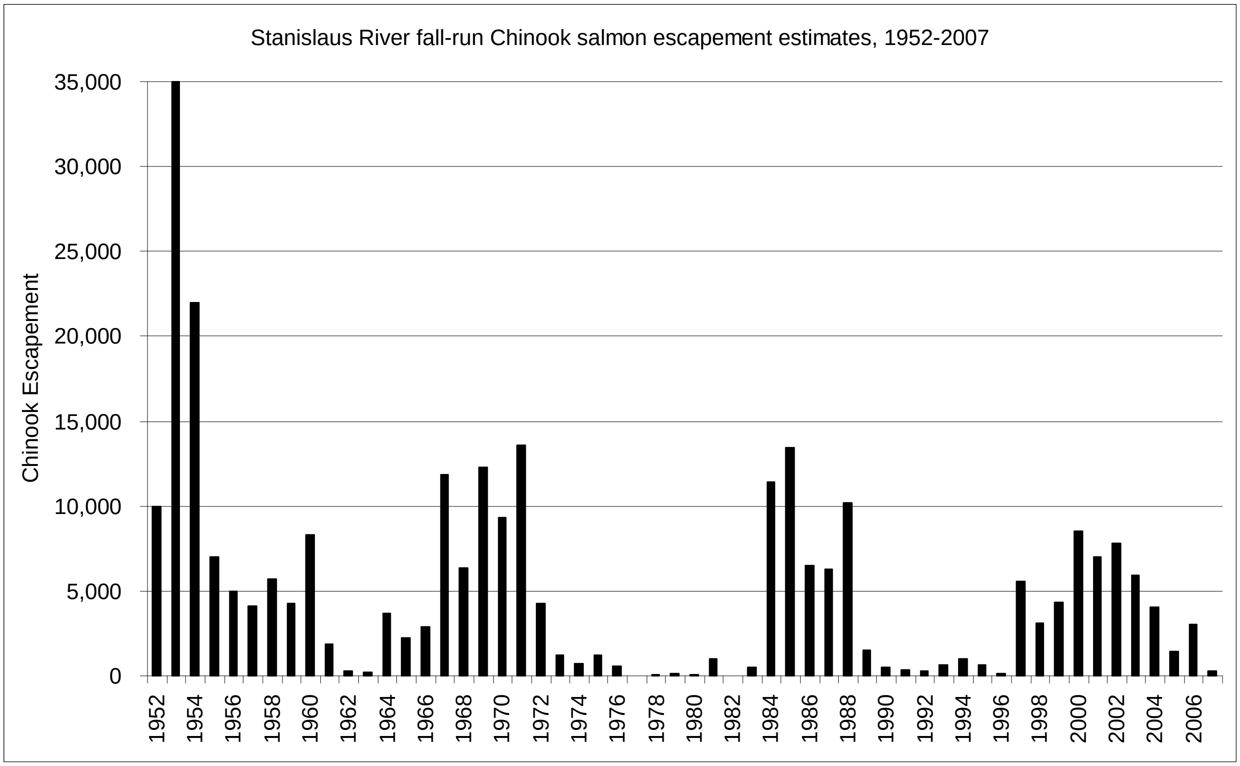


Figure 16-17 Chinook salmon escapement in the Stanislaus River, 1952-2007.

The main Chinook salmon stressors identified in the Stanislaus River include an altered hydrograph lacking peak flows, water temperatures during summer and fall, predation by striped bass and pikeminnows, and a shortage of spawning gravel. Operation of New Melones and Goodwin Dam for water delivery and flood control can affect all of these stressors, directly or indirectly.

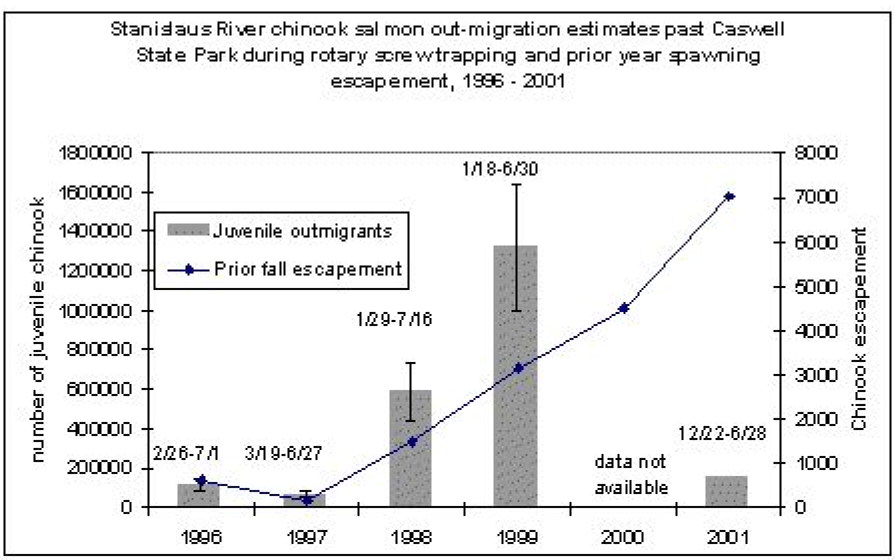
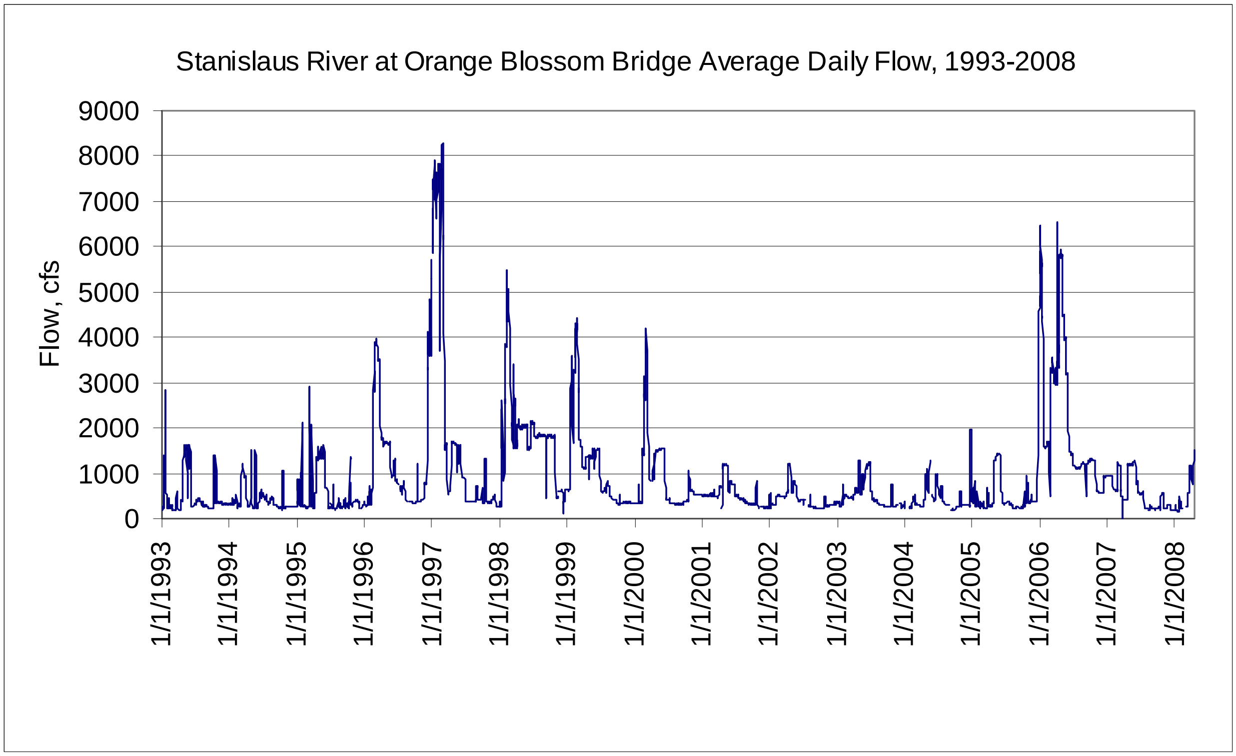


Figure 16-18 Stanislaus River Chinook salmon out-migration estimates past Caswell State Park during rotary screw trapping and prior year spawning escapement, 1996-2001.

Error bars are 95 percent confidence intervals. Dates of trapping are shown above the bars. 1996-97 trapping captured only the latter part of the run. 1996-99 data is from Demko et al. (2000). 2001 estimate calculated from data provided by S.P. Cramer & Associates.

Dam operations store water during winter and spring for releases to irrigators during late spring, summer, and fall. Historical high flows in the river have been dampened for flood control and water storage (Figure 16-19) The 20-year flood flow has been decreased by eight times compared to the historic flow. Moderate flows of around 300-600 cfs have been extended out through much of the year to provide better water quality in the Stanislaus for fish and in the Delta for pumping operations. The long-term effect of the lack of high flows is the simplification of instream habitat. High channel forming flows maintain high quality spawning habitat and riparian floodplain conditions. With reduced flows, riparian vegetation along the banks has become more stable. When high flows do occur they are unable to reshape the channel as occurred historically when high flood flows were more frequent events. High flows mobilize spawning sized gravels from streambanks and incorporate them into the active channel. In the absence of high flows, spawning habitat quality has decreased. In addition, the dams have eliminated recruitment of spawning gravel from upstream sources. Based on an aerial photo analysis 161,400 square feet (30 percent) of spawning gravel was lost between 1961 and 1972 and 150,600 square feet was lost between 1972 and 1994. Spawning gravel additions have occurred regularly in an attempt to maintain good spawning habitat.



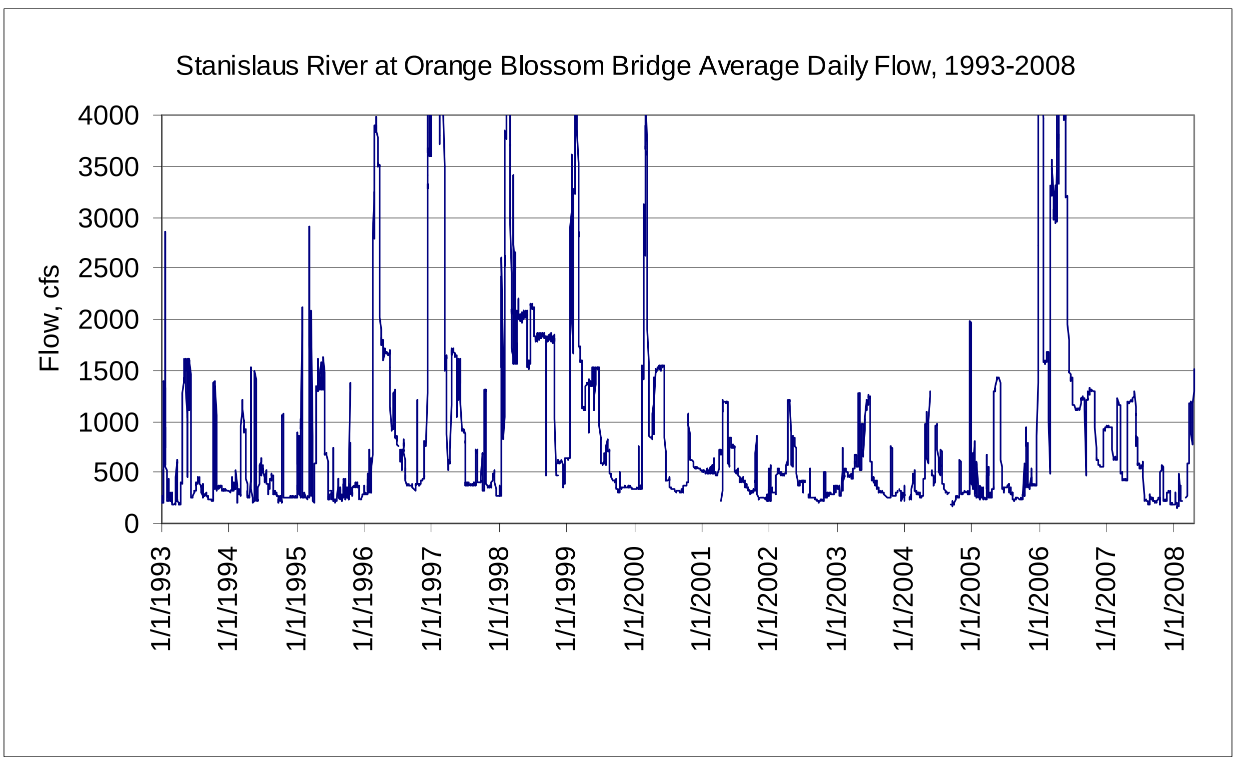


Figure 16-19 Stanislaus River flow at Orange Blossom Bridge, 1993-2008. The top chart shows the entire hydrograph. The bottom chart shows a close-up of the 0 to 4000 cfs range.

Access to upstream habitat, where water temperatures are cooler, has been blocked by the dams. Therefore, cool water temperatures are critical in the available anadromous habitat. The summer time release of water stored in upstream reservoirs provides late summer flows higher than those that occurred historically. These releases have allowed anadromous fisheries populations to persist in the remaining accessible habitat below Goodwin Dam.

Predation by introduced striped bass and native pikeminnows may be a significant stressor to juvenile fish rearing in the river. Cooler water lowers the metabolic rate of predators and likely reduces the effect of predation. Gravel mining along the river has created backwater areas where there is no flow, allowing the water to become warmer. Predators such as striped bass, pikeminnows, and largemouth bass do well in these backwater areas and may use them as refuge habitat from the cooler water areas.

Aceituno (1993) applied the instream flow incremental methodology to the Stanislaus River between Riverbank and Goodwin Dam (24 river miles) to help to determine instream flow needs for Chinook salmon and steelhead. Table 16-6 gives the resulting instream flow recommendations for Chinook salmon.

Studies are underway in the Stanislaus to determine the best spring time flow regimes to maximize survival of juvenile Chinook. The studies utilize survival estimates from marked hatchery fish released at various flows (Table 16-7). These tests took place during the VAMP flows which occur after the peak outmigration period from the Stanislaus River.

Table 16-6 Instream flows (cfs) that would provide the maximum weighted usable area of habitat for Chinook salmon in the Stanislaus River between Goodwin Dam and Riverbank[1].

Life Stage	*Dates*	*Number of days*	*Flow at Goodwin (cfs)*	*Dam release (af)*
Spawning	October 15 - December 31	78	200	46,414
Egg Incubation/Fry Rearing	January 1 - February 15	46	150	13,686
Juvenile Rearing	February 15 - October 15	241	200	95,605
Total		365		155,705

1 Source: Aceituno 1993.

Table 16-7 Stanislaus River summary of past smolt survival tests.

Stanislaus River Summary of Past Smolt Survival Tests

Year	tag codes	Rel. Start	Rel. End	Flow at OBB (cfs)	Avg. Temp at Ripon1	Rel. Location	# Released	Release Length (mm)	Recoveries at Oakdale	Survival to Oak RST	Recoveries at Caswell	Survival to Cas RST	Recoveries at Mossdale2	Riverwide Survival
1986		28-Apr	28-Apr	1200	62	Knights Ferry			na	na	na	na		
		28-Apr	28-Apr	1200	62	Naco West			na	na	na	na		0.59
1988	b6-11-05, -06	26-Apr	26-Apr	900	60	Knights Ferry	71,675	75.2	na	na	na	na	278	0.54
	b6-11-03, -04	26-Apr	26-Apr	900	60	Naco West	68,788	79.6	na	na	na	na	828	
1989	b6-14-09,-10	20-Apr	20-Apr	900	64	Knights Ferry	103,863	77.4	na	na	na	na	471	0.37
	b6-01-01, -14-11	19-Apr	19-Apr	900	64	Naco West	74,073	76.5	na	na	na	na	860	
	b6-14-12	3-May	3-May			Naco West	46,169	72.4	na	na	na	na	173	
1999		1-Jun	1-Jun	1300	60	Knights Ferry	25,536		156	0.77	35	0.07		
		1-Jun	1-Jun	1300	60	RM 40	4,975	84.4	na	na	10	0.10		
		2-Jun	2-Jun	1300	60	RM 40	4,403	83.2	na	na	7	0.08		
					60	RM 40 (combined)	9,378	83.8	na	na	17	0.09		
		1-Jun	1-Jun	1300	60	RM 38	4,981	85.3	na	na	8	0.08		
		2-Jun	2-Jun	1300	60	RM 38	5,007	84.8	na	na	8	0.08		
					60	RM 38 (combined)	9,998	85.1	na	na	16	0.08		
2000		18-May	19-May	1500	61	Knights Ferry	77,438		546	0.73	127	0.13		
		20-May	20-May	1500	61	Two Rivers	50,547		na	na	na	na		0.57

1 1986-1989 from CDFG reports. 1999 and 2000 from SPCA Caswell.
2 1988 & 1989 from Demko's files of Mossdale catch.

Feather River

The lower Feather River has two runs of Chinook salmon, the fall-run and spring-run. Adult fall-run typically return to the river to spawn during September through December, with a peak from mid-October through early December. Spring-run enter the Feather River from March through June and spawn the following autumn (Painter et al. 1977). Fry from both races of salmon emerge from spawning gravels as early as November (Painter et al. 1977; DWR unpublished data) and generally rear in the river for at least several weeks. Emigration occurs from December to June, with a typical peak between January and March (Figure 16-20). The vast majority of these fish emigrate as fry (DWR unpublished data), suggesting that rearing habitat is limiting or that conditions later in the season are less suitable. Risks for late migrating salmon include higher predation rates and high temperatures. The primary location(s) where these fish rear is unknown, however in wetter years it appears that many young salmon rear for weeks to months in the Yolo Bypass floodplain immediately downstream of the Feather River before migrating to the estuary (Sommer et al. 2001b).

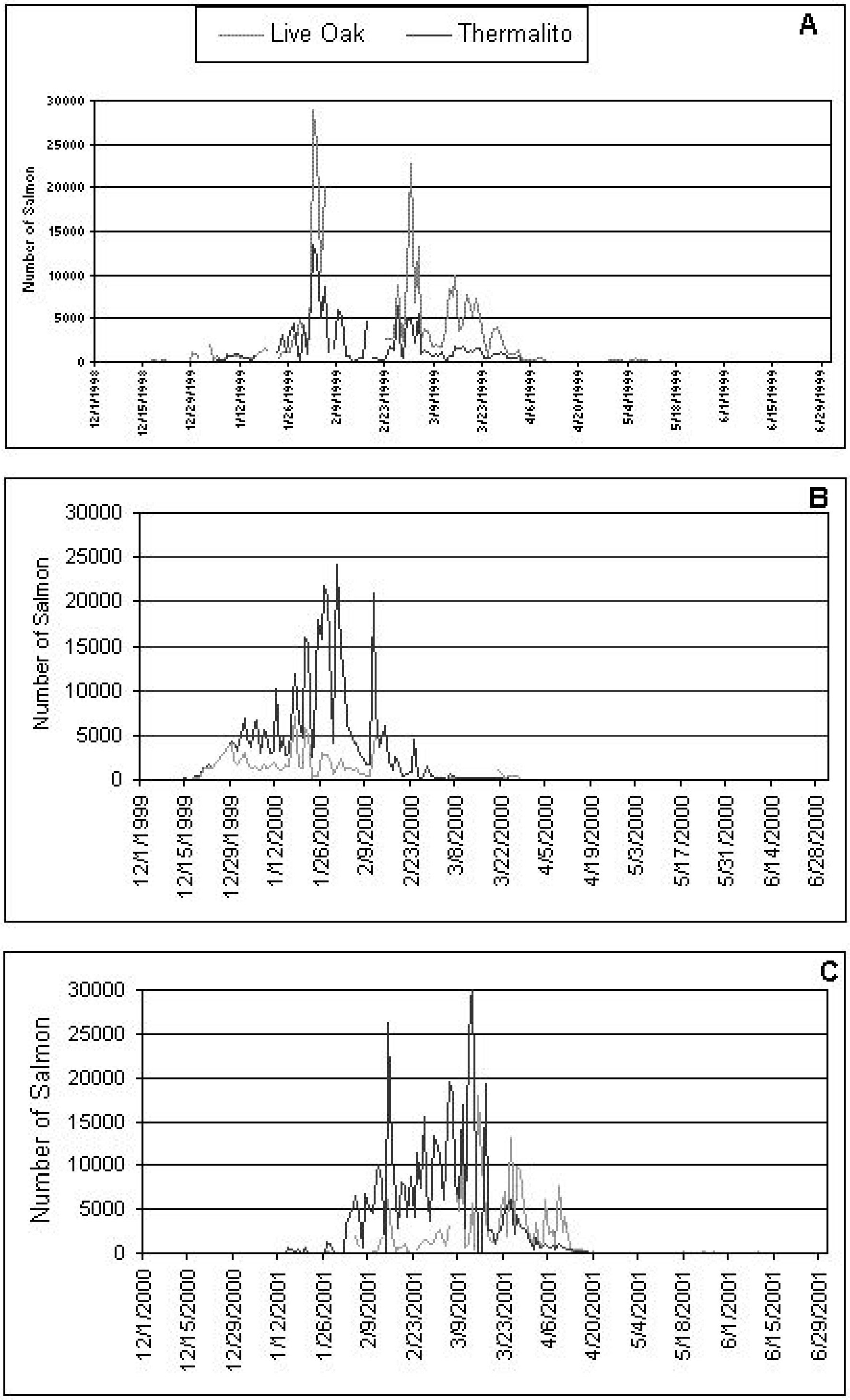


Figure 16-20 Daily catch distribution of fall-run Chinook salmon caught at Live Oak and Thermalito rotary screw traps during 1998, 1999, and 2000 (trapping years a, b, and c, respectively).

Historical distribution and abundance of Chinook salmon in the Feather River is reviewed by Yoshiyama et al. (2001). They note that fall-run historically spawned primarily in the mainstem river downstream of the present site of Lake Oroville, while spring-run ascended all three upstream branches. Fry (1961) reported fall-run escapement estimates of 10,000 to 86,000 for 1940-59, compared to 1,000 to about 4,000 for spring-run. Recent fall-run population trends continue to show annual variability, but are more stable than before Oroville Dam was completed (Figure 16-21). Pre-dam escapement levels have averaged approximately 41,000 compared to about 46,000 thereafter (see also Reynolds et al. 1993). This increase appears to be a result of hatchery production in the system.

Hatchery History and Operations

Feather River Hatchery was opened in 1967 to compensate for the loss of upstream habitat by the construction of Oroville Dam. The facility is operated by the DFG and typically spawns approximately 10,000 adult salmon each year (Figure 16-21). Until the 1980s, the majority of the young hatchery salmon was released into the Feather River (Figure 16-22). However, the release location was shifted to the Bay-Delta Estuary to improve survival. DFG is now considering shifting the release of at least a portion of the hatchery fish back to the Feather River to reduce the potential for straying into other watersheds.

Hydrology

The Feather River drainage is located within the Central Valley, draining about 3,600 square miles of the western slope of the Sierra Nevada (Sommer et al. 2001a). The reach between Honcut Creek and Oroville Dam is of low gradient. The river has three forks, the North Fork, Middle Fork, and South Fork, which meet at Lake Oroville. Lake Oroville, created by the completion of Oroville Dam in 1967, has a capacity of about 3.5 million acre-feet (MAF) of water and is used for flood control, water supply, power generation, and recreation. The lower Feather River below the reservoir is regulated by Oroville Dam, Thermalito Diversion Dam, and Thermalito Afterbay Outlet. Under normal operations, the majority of the Feather River flow is diverted at Thermalito Diversion Dam into Thermalito Forebay. The remainder of the flow, typically 600 cfs, flows through the historical river channel, the “low flow channel” (LFC). Water released by the forebay is used to generate power before discharge into Thermalito Afterbay. Water is returned to the Feather River through Thermalito Afterbay Outlet, then flows southward through the valley until the confluence with the Sacramento River at Verona. The Feather River is the largest tributary of the Sacramento River.

The primary area of interest for salmon spawning is the low flow channel, which extends from the Fish Barrier Dam (river mile 67) to Thermalito Afterbay Outlet (river mile 59), and a lower reach from Thermalito Afterbay Outlet to Honcut Creek (river mile 44). There is little spawning activity in the Feather River below Honcut Creek.

The hydrology of the river has been considerably altered by the operation of the Oroville complex. The major change is that flow that historically passed through the LFC is now diverted into the Thermalito complex. Mean monthly flows through the LFC are now 5 percent to 38 percent of pre-dam levels (Figure 16-23). Mean total flow is presently lower than historical levels during February through June, but higher during July through January.

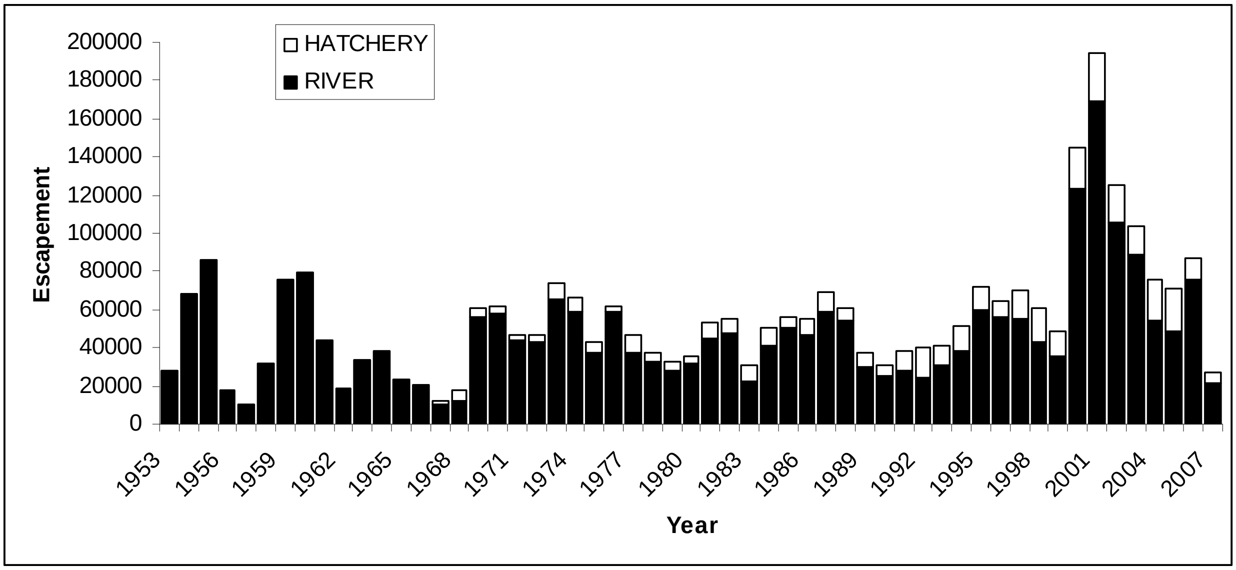


Figure 16-21 Escapement of fall-run Chinook salmon (1953-2007) in the FRH and river.

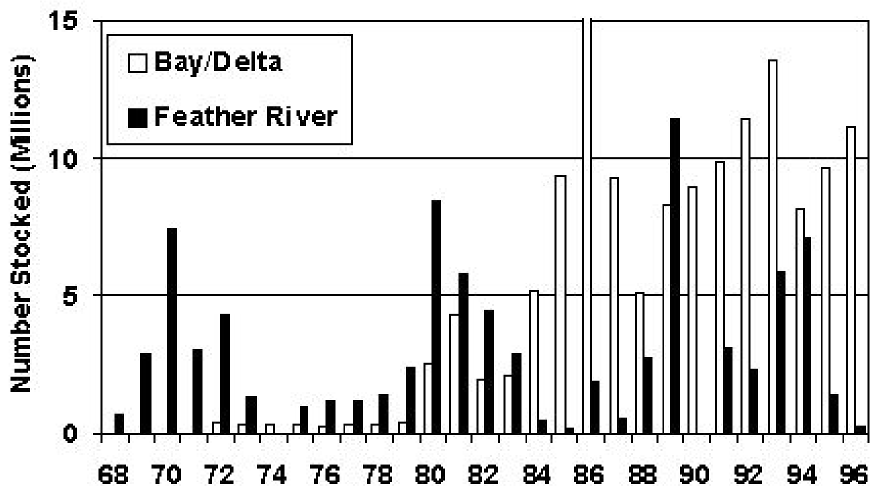


Figure 16-22 Stocking rates of juvenile salmon from the FRH into river and Bay-Delta locations.

Project operations have also changed water temperatures in the river. Compared to historical levels, mean monthly water temperatures in the LFC at Oroville are 2° F to 14° F cooler during May through October and 2° F to 7° F warmer during November through April. Pre-project temperature data are not available for the reach below Thermalito Afterbay Outlet, but releases from the broad, shallow Thermalito Afterbay reservoir probably create warmer conditions than historical levels for at least part of the spring and summer.

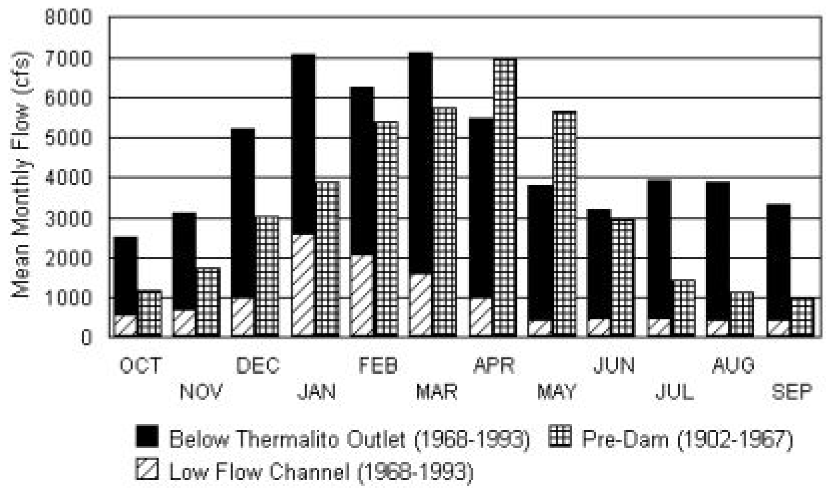


Figure 16-23 Mean monthly flows (cfs) in the Feather River for the pre-Oroville Dam (1902-67) and post-Oroville Dam (1968-93) periods.

Total flow in the post-dam period includes the portion from the low flow channel and the portion diverted through the Thermalito complex.

Spawning Distribution

Since the construction of Oroville Dam and FRH, there has been a marked shift in the spawning distribution of Chinook salmon in the lower Feather River. Salmon have shifted their spawning activity from predominantly in the reach below Thermalito Afterbay Outlet to the LFC (Figure 16-24) (Sommer et al. 2001a).

An average of 75 percent of spawning activity now occurs in the LFC with the greatest portion crowded in the upper three miles of the LFC. While there is evidence that this upper section of the LFC was also intensively used after the construction of the dam and hatchery, the shift in the spawning distribution has undoubtedly increased spawning densities. The high superimposition indices in the LFC suggest that there is not enough spawning habitat for the large numbers of salmon attempt to utilize the area. It must be observed; however, that the very success of the hatchery is responsible for the large population of adult fall-run spawners. Without the production of the FRH it would be impossible for salmon populations to regularly exceed the river's post-dam carry capacity. Therefore, the high density of hatchery produced salmon spawning at the upstream end of the low flow channel may be attributed to hatchery production levels, and potentially, to a tendency among hatchery fish to return to their place of origin.

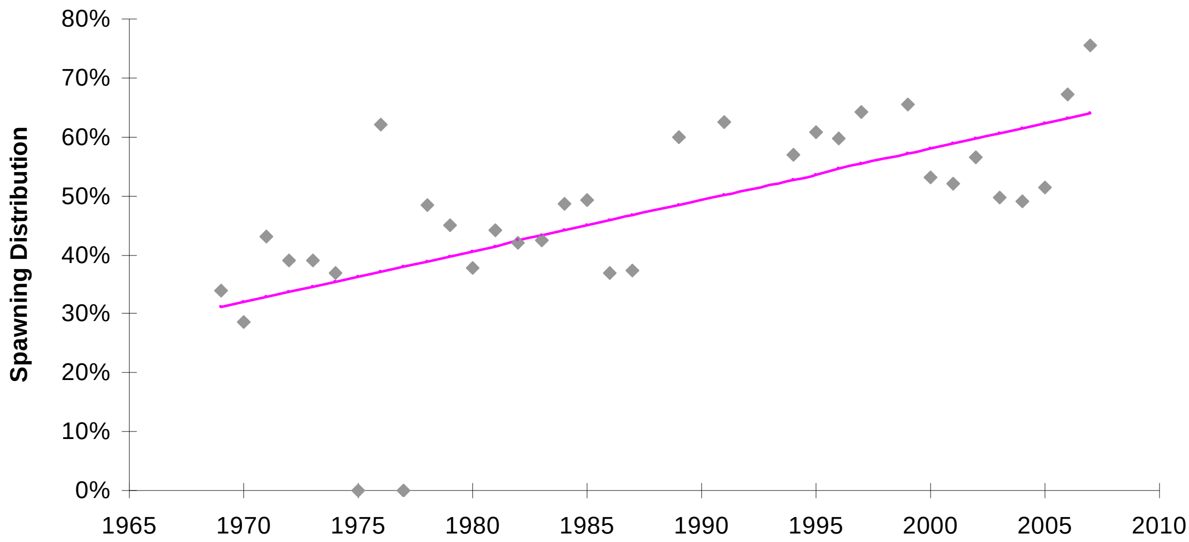


Figure 16-24 The percentage of salmon spawning in the Feather River low flow channel for 1969-2007. The increase is significant at the *P* < 0.001 level.

Currently several studies are underway to evaluate salmon and steelhead populations in the Feather River. Since fall 2000, DWR in cooperation with DFG has conducted salmon spawning escapement data on the Feather River. This survey takes place from September through December. The purpose of this survey is to measure the abundance and distribution of spawning effort among fall-run salmon on the Feather River. The escapement surveys also collects information about the size and sex distribution among the population, and on the rates of pre-spawning mortality among female salmon. DWR staff also operate two rotary screw traps on the Feather River. These traps are located upstream of the Thermalito Outlet and near Live Oak. These traps are operated from November through June and collect information about the abundance of juvenile salmonids and the factors which may influence their migration timing. During the spring and summer DWR also conducts snorkel surveys on the Feather River. The purpose of these surveys is to document abundance, distribution and habitat use among juvenile salmonids during this period of time when the effects of environmental stressors may be most acute.

Summary of effects on EFH for Chinook Salmon

Mortality model outputs for fall run and late fall run Chinook are included at the sections below.

Trinity River

The increased flows in the spring for the restoration program would aid outmigrating Chinook so smolt survival should increase. The habitat benefits provided through more natural geomorphic processes should benefit Chinook salmon.

Temperatures in the Trinity during the fall Chinook spawning period will be slightly increased in the future because more water would be released early in the season. The result will be slight changes in egg mortality based on model results shown in (Figure 16-25).

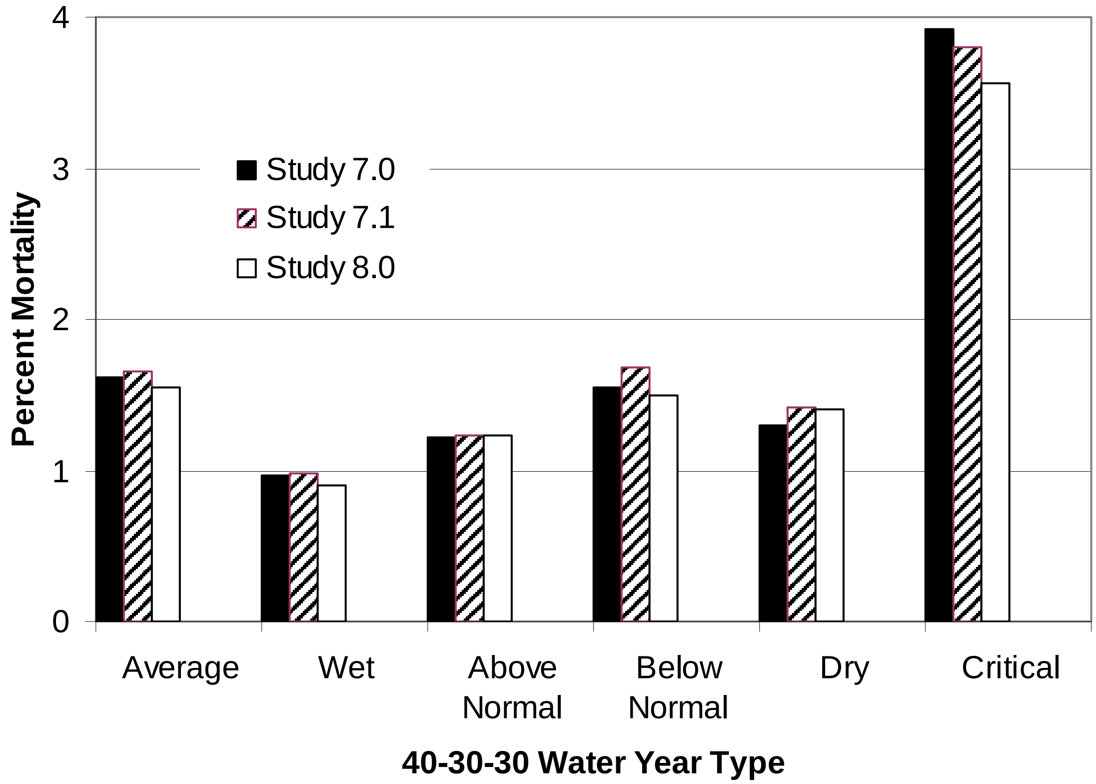


Figure 16-25 Percent mortality of Chinook salmon from egg to fry in the Trinity River based on water temperature by water year type.

Sacramento and San Joaquin Rivers, Delta, San Pablo Bay, and San Francisco Bay

Rearing juveniles migrate down the Sacramento and San Joaquin Rivers and into the Delta and estuaries while rearing. CV fall-run Chinook salmon use the Delta, San Pablo Bay, and San Francisco Bay as a migratory corridor when they move from the ocean to freshwater as adults and from freshwater to the ocean as juveniles. Most movement by adults occurs in deeper channels, while juveniles are more likely to use the shallow habitats, including tidal flats, for feeding. The lower Sacramento and San Joaquin Rivers are used as migratory corridors as the adults move towards their natal streams, which include most tributaries. However, adults use variable paths to reach their spawning grounds depending on time of year and year (McLaughlin and Jeff McLain 2001). Adult migration can be influence by cross-channel operations and salinity gate operations within the Suisun Marsh area (Stein 2000; Vincik 2002).

Upper Sacramento River

Fall/late fall-run spawning in the upper Sacramento River may be affected in some years when flows are dropped off in the fall as water demands decrease. Redd dewatering is possible in some years. This may be the most significant effect of project operations on fall/late fall-run in the upper Sacramento. See Figure 16-26 for Fall-run and Figure 16-27 for late fall-run mortality.

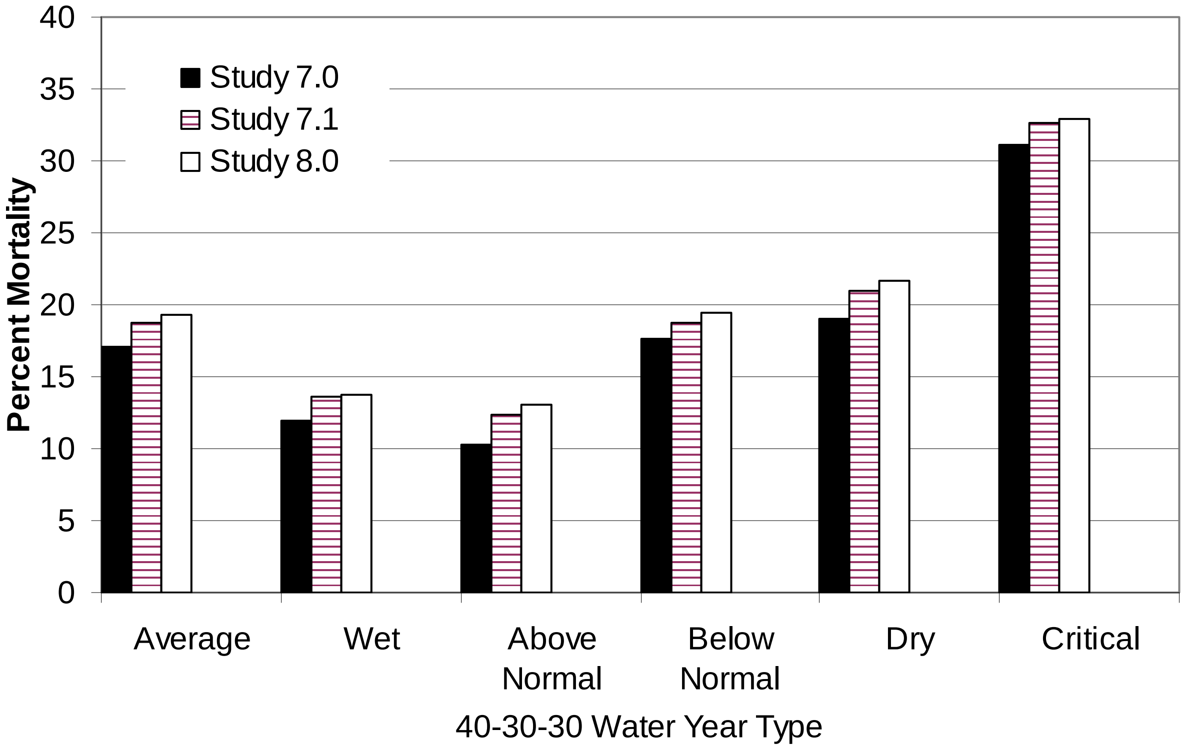


Figure 16-26 Sacramento River Fall-run Chinook Early Life-stage Mortality by Water Year Type

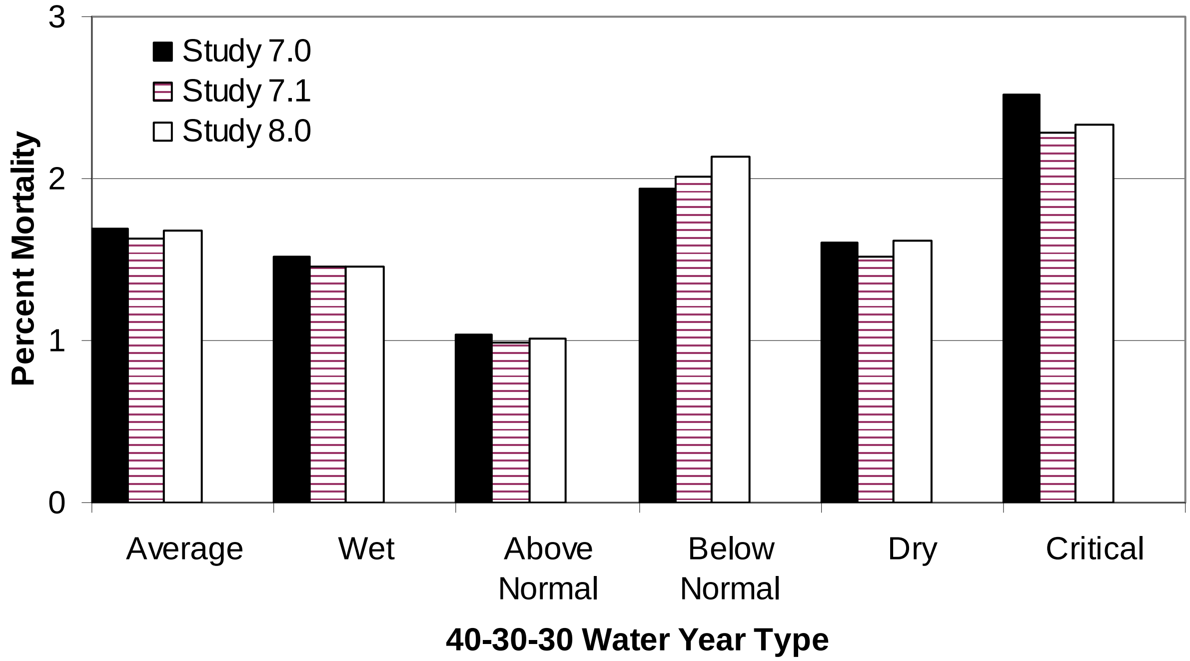


Figure 16-27 Sacramento River Late Fall-run Mortality by Year Type

Clear Creek

Temperatures and flows are generally suitable year round in Clear Creek for fall run Chinook. No adverse effects to EFH for fall run in Clear Creek are anticipated.

Feather River

Flow and water temperature conditions should be generally suitable for all fall–run Chinook salmon life history stages all year in the low flow channel, particularly in the upper low flow channel. Superimposition on spring–run Chinook salmon redds by fall–run Chinook may continue to be a problem. The reach below the Thermalito outlet will be less suitable. Water temperatures below Thermalito will be too warm for adult holding and spawning, but will be appropriate for juvenile rearing and emigration during winter and early spring. See Figure 16-28 .

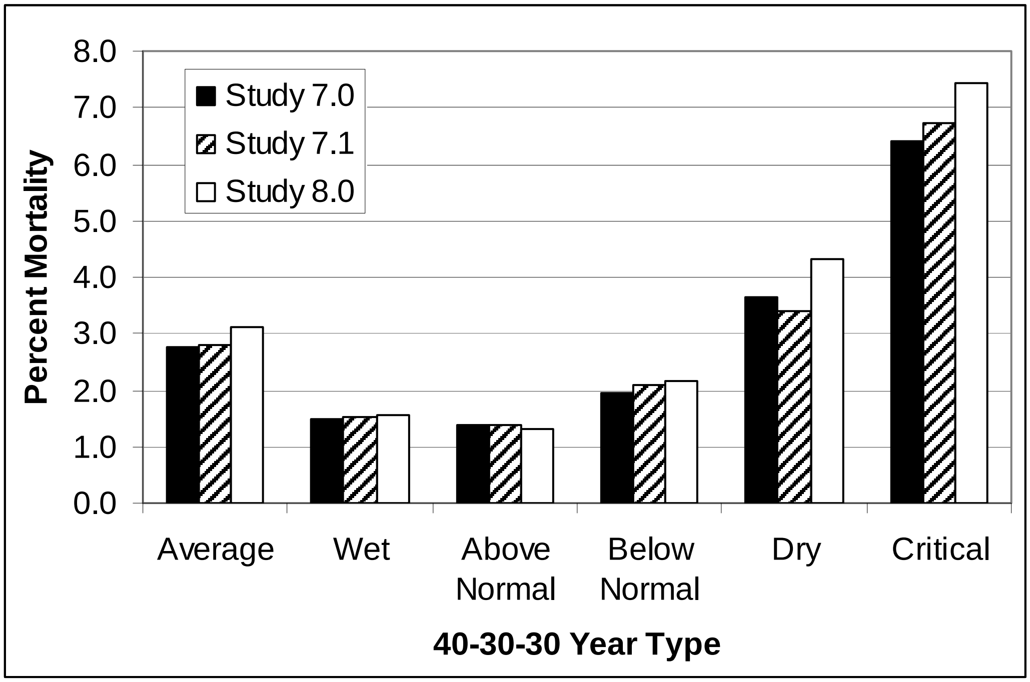


Figure 16-28 Feather River Chinook Salmon Mortality

American River

Flows are projected to be adequate for fall–run Chinook spawning in normal water conditions but if dry conditions occur, flows are projected to provide less than optimal spawning habitat for Chinook. Flows in the spring should be adequate for outmigration. Temperature goals for fall–run Chinook spawning and incubation are projected to be met in November of almost every year but meeting the goals will likely involve trade-offs between providing cool water for better steelhead rearing conditions during the summer and providing it for Chinook spawning in the fall. Water temperatures for Chinook rearing are forecast to exceed the preferred range generally starting in April. Most Chinook leave the river by early April. Temperatures will be higher in June through November under future operations due to increased upstream diversions, causing more temperature stress on migrating and holding adults in the fall. See Figure 16-29 .

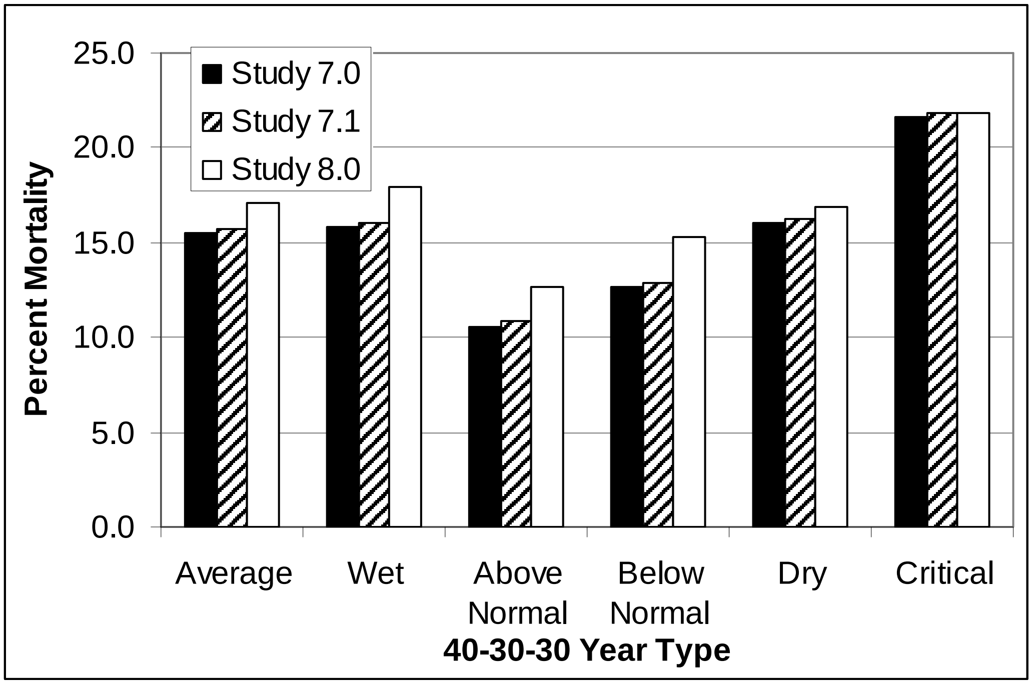


Figure 16-29 American River Chinook Salmon Mortality

Stanislaus River

Flows are projected to be adequate for fall–run Chinook spawning in nearly all years. Water temperatures are generally warm in the lower part of the river during the early part of the immigration period but are they are expected to be suitable for spawning and rearing in the upper river during the entire spawning and rearing period. Temperatures should be suitable for outmigration of fry and smolts, but when dry conditions occur, flows can be less than desired for optimal outmigration prior to the VAMP period. See Figure 16-30 .

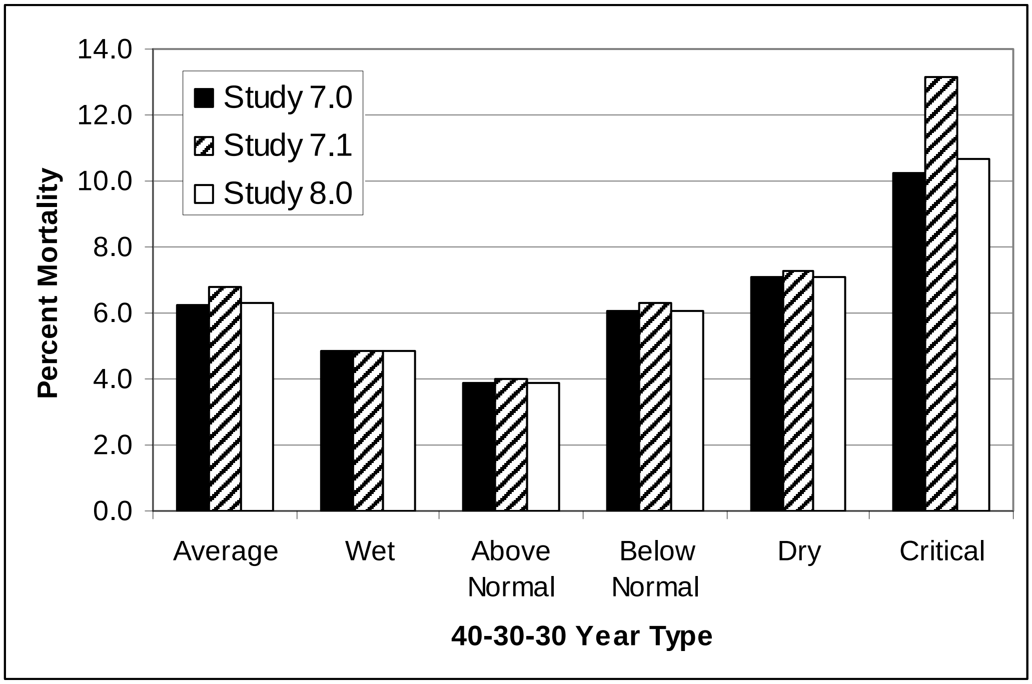


Figure 16-30 Stanislaus River Chinook Salmon Mortality

Delta

Fall and late fall-run Chinook take occurs at the Delta pumping facilities. Protective measures target winter-run and spring-run Chinook salmon, but the VAMP period is intended to focus on the fall and late-fall run through Delta migration peak.

Conclusion Chinook

CVP and SWP operations will adversely affect the EFH of fall run and late fall run Chinook salmon. Chinook salmon EFH in the Trinity River should benefit from the Trinity River ROD flows and other habitat improvement measures.

EFH Conservation Measures for Chinook Salmon

Currently, no recovery plan has been established for Central Valley fall or late fall-run Chinook salmon. However, the following are conservation measures being implemented that could be considered specifically addressing Essential Fish Habitat for Chinook salmon. Additional ongoing measures to improve Chinook salmon habitat are described in chapter 18.

Folsom Dam Temperature Shutter Mechanization

Folsom Dam restricts salmon and steelhead life cycles to the 23-mile lower American River precluding the fish from migrating to their upstream natal spawning grounds. Cold water is necessary to sustain existing spawning and rearing salmon and steelhead populations below the dam. To manage lower American River water temperature, cold water from varying depths in Folsom Lake is withdrawn via shutters located at different elevations on the penstock inlet. The restoration feature would modify and automate the temperature shutters to allow for the flexibility and timeliness needed to optimize management of the coldwater pool to sustain the downstream fishery, including fall-run Chinook. This project was congressionally authorized in 2003 as a part of a multi-purpose (flood control, ecosystem restoration, and dam safety) project and is awaiting appropriations

Spawning Gravel Enhancement

Reclamation manages spawning gravel injections below CVP dams on the Sacramento, American, and Stanislaus Rivers in cooperation with the Fish and Wildlife Service. This ongoing program is funded yearly and projects are implemented in the three rivers as the need is identified. Gravel augmentation can improve habitat quality for Chinook salmon (Merz and Setka 2004; Merz and Chan 2006; Elkins et al. 2007) and benefits have been documented in each of the rivers. Additionally, monitoring on the Stanislaus has identified benefits of enhanced rearing habitat created by the new gravel for juvenile salmon and steelhead.

Stanislaus Temperature Model

Reclamation cooperates with funding development of a sub-daily water temperature model on the Stanislaus River. The model can be used to identify optimization strategies for coldwater from New Melones Reservoir relative to life cycle needs of salmon and steelhead.

American River Group

Reclamation facilitates the American River Group, a group of stakeholders and biologists who makes recommendations to Reclamation relative to fisheries conditions in the river.

Sacramento River Temperature Control Task Group

This group makes recommendations on how to manage water temperatures throughout the summer in the upper Sacramento River relative to relative to fisheries conditions and coldwater pool storage in Shasta Reservoir.