Chapter 5 Basic Biology, Life History, and Baseline for Winter-run and Spring-run Chinook Salmon and Coho Salmon

This chapter provides information on the basic biology, life history, and status of winter-run and spring-run Chinook salmon, and Coho salmon in the study area. In general, the major factor affecting all listed salmonids in the Central Valley and Coho salmon on the Trinity River is the loss of spawning and rearing habitat due to large dams. For example, access to approximately 58 percent of the original winter-run Chinook salmon habitat has been blocked by dam construction. The remaining accessible habitat occurs in the Sacramento River below Keswick Dam and in Battle Creek.

The Sacramento River winter-run Chinook salmon Evolutionarily Significant Unit (ESU) is restricted to one population entirely contained within the action area. Construction of the Livingston Stone National Fish Hatchery in 1996 has safeguarded the natural population since the critically low abundance of the 1990's. Improvements in Central Valley Project (CVP) operations since 1993 include: changes in operations to directly protect winter-run Chinook salmon, construction of a temperature control device on Shasta Dam in 1998, opening the gates at Red Bluff Diversion Dam (RBDD) for longer periods of time, and periodic closures of Delta Cross Channel (DCC) gates. These required actions have helped to bring the run to within 50 percent of the recovery goal. In addition, improvement of critical habitat from Central Valley Project Improvement Act (CVPIA) gravel augmentation projects and increased restrictions on recreational and commercial ocean harvest of Chinook salmon since 1994, likely have had a positive impact on winter-run Chinook salmon adult returns to the upper Sacramento River.

The Central Valley spring-run Chinook salmon ESU is comprised mainly of three self-sustaining wild populations (Mill, Deer and Butte Creeks) which are outside of the action area; however, all migratory life stages must past through the action area. In addition, spring-run Chinook salmon inhabit the Feather River and Clear Creek, which are within the action area. These three populations have been experiencing positive growth rates since the low abundance levels of the late 1980s. Restrictions on ocean harvest to protect winter-run Chinook salmon and improved ocean conditions have likely had a positive impact on spring-run Chinook salmon adult returns to the Central Valley. Abundance for the key indicator streams, Mill, Deer and Butte Creeks, have recently been at historical levels. Current risks to the remaining populations include stream habitat degradation, high water temperatures during the summer adult holding period, and the operations of the Feather River Hatchery.

The Trinity River portion of the Southern Oregon/Northern California Coast coho salmon ESU is predominately of hatchery origin. Termination of hatchery production of coho salmon at the Mad River and Rowdy Creek facilities has eliminated further potential adverse risks associated with hatchery releases from these facilities. Likewise, restrictions on recreational and commercial harvest of coho salmon since 1994 likely have had a positive impact on coho salmon adult returns.

Status

Sacramento River winter-run Chinook salmon were originally listed as threatened in August 1989, under emergency provisions of the Federal Endangered Species Act (ESA), and formally listed as threatened in November 1990 (55 FR 46515). The Sacramento River winter-run Chinook salmon ESU consists of only one population that uses spawning habitat confined to the upper Sacramento River in California's Central Valley. The National Marine Fisheries Service (NMFS) designated critical habitat for winter-run Chinook salmon on June 16, 1993 (58 FR 33212). They were reclassified as endangered on January 4, 1994 (59 FR 440) due to increased variability of run sizes, expected weak returns as a result of two small year classes in 1991 and 1993, and a 99 percent decline between 1966 and 1991. Critical habitat area was delineated as the Sacramento River from Keswick Dam, (River Mile [RM] 302) to Chipps Island (RM 0) at the westward margin of the Sacramento- San Joaquin Delta, including Kimball Island, Winter Island, and Brown's Island; all waters from Chipps Island westward to the Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and the Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge, and all waters of San Francisco Bay north of the San Francisco-Oakland Bay Bridge. The critical habitat designation identifies those physical and biological features of the habitat that are essential to the conservation of the species and that may require special management consideration and protection. Within the Sacramento River this includes the river water, river bottom (including those areas and associated gravel used by winter-run Chinook salmon as spawning substrate), and adjacent riparian zone used by fry and juveniles for rearing. In the areas west of Chipps Island, including San Francisco Bay to the Golden Gate Bridge, this designation includes the estuarine water column and essential foraging habitat and food resources utilized by winter-run Chinook salmon as part of their juvenile outmigration or adult spawning migrations.

Central Valley spring-run Chinook salmon were listed as threatened on June 18, 2005 (70 FR 37160). This ESU consists of spring-run Chinook salmon occurring in the Sacramento River Basin. Critical habitat was designated for spring-run Chinook on September 2, 2005 (70 FR 52488).

Southern Oregon/Northern California Coast (SONCC) coho salmon were listed as threatened under the ESA on June 18, 2005 (70 FR 37160). This ESU consists of populations from Cape Blanco, Oregon, south to Punta Gorda, California, including coho salmon in the Trinity River. NMFS designated critical habitat for SONCC coho salmon on May 5, 1999 (64 FR 24049) as accessible reaches of all rivers (including estuarine areas and tributaries) between the Elk River in Oregon and the Mattole River in California, inclusive). The critical habitat designation includes all waterways, substrate, and adjacent riparian zones, excluding: 1) areas above specific dams identified in the Federal Register notice (including Lewiston Dam); 2) areas above longstanding, natural impassable barriers (*i.e.*, natural waterfalls in existence for at least several hundred years); and 3) Indian tribal lands.

NMFS listed winter-run Chinook as threatened under emergency provisions of the ESA on August 4, 1989 (54 FR 32085), and formally listed the species as threatened on November 5, 1990 (55 FR 46515). The State of California listed winter-run Chinook as endangered in 1989 under the California Endangered Species Act (CESA). On January 4, 1994, NMFS reclassified the winter-run Chinook as an endangered species. The Central Valley spring-run Chinook salmon ESU is listed as a threatened species under both the California and the Federal ESAs. The State and Federal listing decisions were finalized in February 1999 and September 1999, respectively. The fall and late-fall runs of Chinook salmon are currently Federal Species of Concern, but have not been listed. They are included in this consultation to cover Essential Fish Habitat (EFH) consultation requirements as specified in the Magnuson Stevens Fisheries Conservation and Management Act, as amended in 1996.

Taxonomy

Chinook salmon (*Oncorhynchus tshawytscha*) (Walbaum) is one of nine *Oncorhynchus* species distributed around the North Pacific Rim (California Department of Fish and Game [DFG] 1998). The Chinook is most closely related to the coho salmon (*Oncorhynchus kisutch*) (Walbaum). The Chinook is physically distinguished from other salmon species by its large size (occasionally exceeding 50 pounds.), the presence of small black spots on both lobes of the caudal fin, black pigment along the base of the teeth, and a large number of pyloric cecae (Moyle 2002). The anal fin of Chinook fry and parr is not sickle-shaped with the leading edge longer than the base as seen in coho salmon fry and parr (Pollard et al. 1997). Juvenile characteristics are highly variable, however, and in areas where several salmon species co-occur, reliable identification can be dependent on branchiostegal and pyloric cecae counts. The Chinook, like other Pacific salmon, is anadromous. Adults spawn in fresh water and juveniles emigrate to the ocean where they grow to adulthood. Upon their return to freshwater, adults spawn and then die. On the North American coast, spawning populations of Chinook salmon are known to be distributed from Kotzebue Sound, Alaska, to central California (Healey 1991). The southernmost populations of Chinook salmon occur in the Sacramento-San Joaquin River systems.

Central Valley Chinook Salmon Biology and Life History

Chinook salmon stocks exhibit considerable variability in size and age of maturation, and at least some portion of this variation is genetically determined. The relationship between fish size and length of migration may also reflect the earlier timing of river entry and the cessation of feeding for Chinook salmon stocks that migrate to the upper reaches of river systems. Body size, which is correlated with age, may be an important factor in migration and redd (nest) construction success. Roni and Quinn (1995) reported that under high-density conditions on the spawning ground, natural selection may produce stocks with exceptionally large returning adults.

Among Chinook salmon, two distinct types have evolved: stream and ocean-rearing types (Groot and Margosis 1991). The stream-type is found most commonly in headwater streams. Stream-type Chinook salmon have a longer freshwater residency, and perform extensive offshore migrations before returning to their natal streams in the spring or summer months. Stream-type juveniles are much more dependent on freshwater stream ecosystems because of their extended residence in these areas. A stream-type life history may be adapted to areas that are more consistently productive and less susceptible to dramatic changes in water flow, allowing juveniles to survive a full year or more in freshwater and grow larger prior to smolting. At the time of saltwater entry, stream-type (yearling) smolts are much larger, averaging 73 to 134 millimeters (mm) depending on the river system, than their ocean-type (subyearling) counterparts and are, therefore, able to move offshore relatively quickly. Stream-type Chinook salmon are found migrating far from the coast in the central North Pacific (Healey 1991).

Ocean-type Chinook are commonly found in coastal streams in North America. Ocean-type Chinook typically migrate to sea within the first 3 months of emergence, but a few spend up to a year in freshwater prior to emigration. They also spend their ocean life in coastal waters. Ocean-type Chinook salmon return to their natal streams or rivers as spring-run, winter-run, summer-run, fall-run, and late-fall-run, but summer and fall-runs predominate. Ocean-type Chinook salmon tend to use estuaries and coastal areas more extensively for juvenile rearing. The development of the ocean-type life history strategy may have been a response to the limited carrying capacity of smaller stream systems and unproductive watersheds, or a means of avoiding the effects of seasonal floods. Ocean-type Chinook salmon tend to migrate along the coast. Populations of Chinook salmon south of the Columbia River drainage, including Central Valley stocks, appear to consist predominantly of ocean-type fish, although many Central Valley winter-run and spring-run juveniles do remain in their natal streams for up to a year.

The DFG (1998) recognizes four Chinook salmon runs in the Central Valley, which are differentiated by the timing of the adult spawning migration (fall-run, late-fall-run, winter-run, and spring-run). NMFS (1999) determined the four Central Valley Chinook races comprise only three distinct ESUs: the fall/late-fall-run, the spring-run, and the winter-run. NMFS (1999) determined that the Central Valley spring-run Chinook salmon ESU specifically comprises fish occupying the Sacramento River basin, which enter the Sacramento River between March and July and spawn between late August and early October.

Molecular data, including variability in multiple microsatellites (Banks et al. 2000), major histocompatibility complexes (Kim et al. 1999), and mitochondrial DNA (NMFS 1999) have been used to demonstrate genetic distinction between Central Valley Chinook salmon ESUs. This work complements long-recognized differences in life history (DFG 1998), but also adds to our understanding of Chinook salmon population genetics in the Central Valley. The historical Chinook phenotypes were differentiated by the timing of spawning migration, degree of sexual maturity when entering fresh water, spawning habitats, and to some degree, by the timing of the juvenile emigration (Moyle 1976, 2002; DFG 1998). However, recent results by Banks et al. (2000) suggest the spring-run phenotype in the Central Valley is actually shown by two genetically distinct subpopulations, Butte Creek spring-run and Deer and Mill Creeks spring-run. Spring-run acquired and maintained genetic integrity through spatio-temporal isolation from other Central Valley Chinook salmon runs. Historically, spring-run Chinook was temporally isolated from winter-run, and largely isolated in both time and space from the fall-run. As discussed below, much of this historical spatio-temporal integrity has broken down, due to spatial constraints on spawning habitat by dam construction, resulting in intermixed life history traits and hybridization in many remaining habitats.

Spawning

Spawning occurs in gravel beds that are often located at the tails of holding pools (US Fish and Wildlife Service [FWS] 1995a, as cited in DFG 1998). Adults have been observed spawning in water as shallow as 0.8 foot deep and in water velocities of 1.2 to 3.5 feet per second (Puckett and Hinton 1974, as cited in DFG 1998). Montgomery et al. (1999) reported adult Chinook tend to spawn in stream reaches characterized as low-gradient pool-riffle or forced pool-riffle reaches. Like steelhead, Chinook dig a redd (nest) and deposit their eggs within the stream sediment where incubation, hatching, and subsequent emergence take place. Optimum substrate for embryos is a gravel/cobble mixture with a mean diameter of 1 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). Spawning habitat requirements are similar for all races of Chinook salmon. Spawning habitat defined by habitat suitability models is generally found in riffles but when structure such as woody debris, boulders, pools, and overhanging vegetation is present salmonids often preferentially select these areas for spawning (Wheaton et al. 2004, Merz 2001).

Winter-run Life History and Habitat Requirements

The following information on winter-run Chinook salmon biology is from the proposed winter-run Chinook recovery plan (NMFS 1997).

Adult winter-run Chinook salmon return to freshwater during the winter but delay spawning until the spring and summer. Juveniles spend about 5 to 9 months in the river and estuary systems before entering the ocean. This life-history pattern differentiates the winter-run Chinook from other Sacramento River Chinook runs and from all other populations within the range of Chinook salmon (Hallock and Fisher 1985, Vogel 1985, DFG 1989).

In addition to their unique life-history patterns, the behavior of winter-run Chinook adults as they return to spawn differentiates the population. Adults enter freshwater in an immature reproductive state, similar to spring-run Chinook, but winter-run Chinook move upstream much more quickly and then hold in the cool waters below Keswick Dam for an extended period before spawning (Moyle et al. 1989.)

The habitat characteristics in areas where winter-run adults historically spawned suggest unique adaptations by the population. Before the construction of Shasta Dam, winter-run Chinook spawned in the headwaters of the McCloud, Pit, and Little Sacramento rivers and Hat Creek as did spring-run Chinook salmon. Scofield (1900) reported that salmon arriving “earlier” than spring-run (presumably winter-run) ascended Pit River Falls and entered the Fall River while the succeeding spring-run Chinook remained to spawn in the waters below. This indicates that winter-run Chinook, unlike the other runs, ascended to the highest portions of the headwaters, and into streams fed mainly by the flow of constant-temperature springs arising from the lavas around Mount Shasta and Mount Lassen. These headwater areas probably provided winter-run Chinook with the only available cool, stable temperatures for successful incubation egg over the summer (Slater 1963).

Adult Spawning Migration and Distribution

Sacramento River winter-run Chinook salmon enter San Francisco Bay from November through May or June. Their migration past RBDD at river mile 242 begins in mid-December and continues into early August. The majority of the run passes RBDD between January and May, with the peak in mid-March (Hallock and Fisher 1985). In general, winter-run Chinook spawn in the area from Redding downstream to Tehama. However, the spawning distribution, as determined by aerial redd surveys is somewhat dependent on the operation of the gates at RBDD, river flow, and probably temperature. At present, winter-run Chinook salmon are found only in the Sacramento River below Keswick Dam.

Timing of Spawning and Fry Emergence

Winter-run Chinook spawn from late-April through mid-August with peak spawning in May and June. Fry emergence occurs from mid-June through mid-October. Once fry emerge, storm events may cause en masse emigration pulses. Martin et al. (2001) evaluated brood years (BYs) 1995 through 1999 and found that emergence began in July during all BYs with peak dispersal occurring in September and October (based on RBDD data through 2007).

Juvenile Emigration

From 1995 through 1999, the pre-smolt/smolt emigration (greater than 45 mm fork length) started in September with 100 percent of production passing RBDD 2 to 3 months prior to the next brood year. Between 44 and 81 percent of winter-run production used areas below RBDD for nursery habitat and the relative use above and below RBDD appeared to be influenced by river discharge during fry emergence (Martin et al. 2001). Emigration past Red Bluff (RM 242) may begin in late July, generally peaks in September, and can continue until mid-March in drier years (Vogel and Marine 1991). Juveniles are found above Deer Creek from July through September and spread downstream to Princeton (RM 164) between October and March (Johnson et al. 1992). The peak emigration of winter-run through the Delta generally occurs in January and extends through April (USFWS data at Sacramento and DFG data at Knights Landing). Winter-run are detected leaving the Delta from September to June with a peak in March and April (USFWS trawl data at Chipps Island). Distinct emigration pulses appear to coincide with high precipitation and increased turbidity (Hood 1990 and Data Assessment Team).

Scale analysis indicates that winter-run Chinook smolts enter the ocean at an average fork length of about 118 mm, while fall-run smolts average about 85-mm fork lengths (DFG unpublished data). This suggests that winter-run juveniles reside in fresh and estuarine waters for 5 to 9 months, exceeding freshwater residence of fall-run Chinook by 2 to 4 months.

It is believed that winter-run Chinook salmon, like all Central Valley Chinook, remain localized primarily in California coastal waters. Coded wire tag (CWT) returns indicate that only 4 percent of winter-run hatchery production recoveries from ocean waters occurred in Oregon (Regional Mark Information System [RMIS] database). The majority of ocean tag recoveries were from the Monterey Bay, San Francisco Bay, and North Coast regions.

Historical and Current Distribution and Abundance of Winter-run Chinook Salmon

Following is a summary of original winter-run distribution from Yoshiyama et al. (2001):

> The winter-run, unique to the Central Valley (Healey 1991), originally existed in the upper Sacramento River system (Little Sacramento, Pit, McCloud, and Fall rivers) and in Battle Creek. There is no evidence that winter runs naturally occurred in any of the other major drainages before the era of watershed development for hydroelectric and irrigation projects. The winter-run typically ascended far up the drainages to the headwaters (CFC 1890). All streams in which winter-run were known to exist were fed by cool, constant springs that provided the flows and low temperatures required for spawning, incubation,

and rearing during the summer season (Slater 1963) when most streams typically had low flows and elevated temperatures.

Access to approximately 58 percent of the original winter-run habitat has been blocked by dam construction (Table 5-1). The remaining accessible habitat occurs in the Sacramento River below Keswick Dam and in Battle Creek. Shasta and Keswick dams blocked access to the original winter-run spawning habitat in the Sacramento River. The population now spawns downstream of Keswick Dam. Until recent years, salmon passage was not allowed above the Coleman Hatchery barrier weir located on Battle Creek. In recent years, there has been no winter-run spawning observed in Battle Creek but winter-run Chinook were detected above the weir in 2006 (high flow year). All winter-run production occurs in the Sacramento River (DFG 2003).

Table 5-1 Historical upstream limits of winter-run Chinook salmon in the California Central Valley drainage (from Yoshiyama et al. 2001).

Stream	Upstream Distributional Limit	Miles of Stream Historically Available	Miles of Stream Currently Available	Miles Lost	Percent Lost
Mainstem Sacramento River	none	299	286	13	4
Pit River	Mouth of Fall River	99	0	99	100
Fall River	Source springs near Dana, about 9 miles above mouth				
McCloud River	Lower McCloud Falls	50	0	50	100
Upper (Little) Sacramento River	Vicinity of Box Canyon Dam (Mt. Shasta City) and Lake Siskiyou (Box Canyon Reservoir)	52	0	52	100
Battle Creek North Fork	Falls 3 miles above Volta Powerhouse	43	43*	0	0
Digger Creek	Vicinity of Manton, possibly higher				
South Fork	Falls near Highway 36 crossing				
Total		543	329	214	39

* Yoshiyama et al. (2001) lists Battle Creek as having unobstructed passage for winter-run but according to Kier Associates (2000) the fish ladders around existing dams are ineffective and need replacement. Length of habitat below/above the lower barriers was not given.

Yearly winter-run escapement was estimated by counts in traps at the top of fish ladders at RBDD and more recently has been estimated using carcass counts (Figure 5-1). Escapements have declined from that which occurred in the 1960’s and 1970’s. The low escapements during dry years in the early 1990’s prompted the listing. Escapement subsequently increased after RBDD operations were modified and temperature control shutters were installed on Shasta Dam.

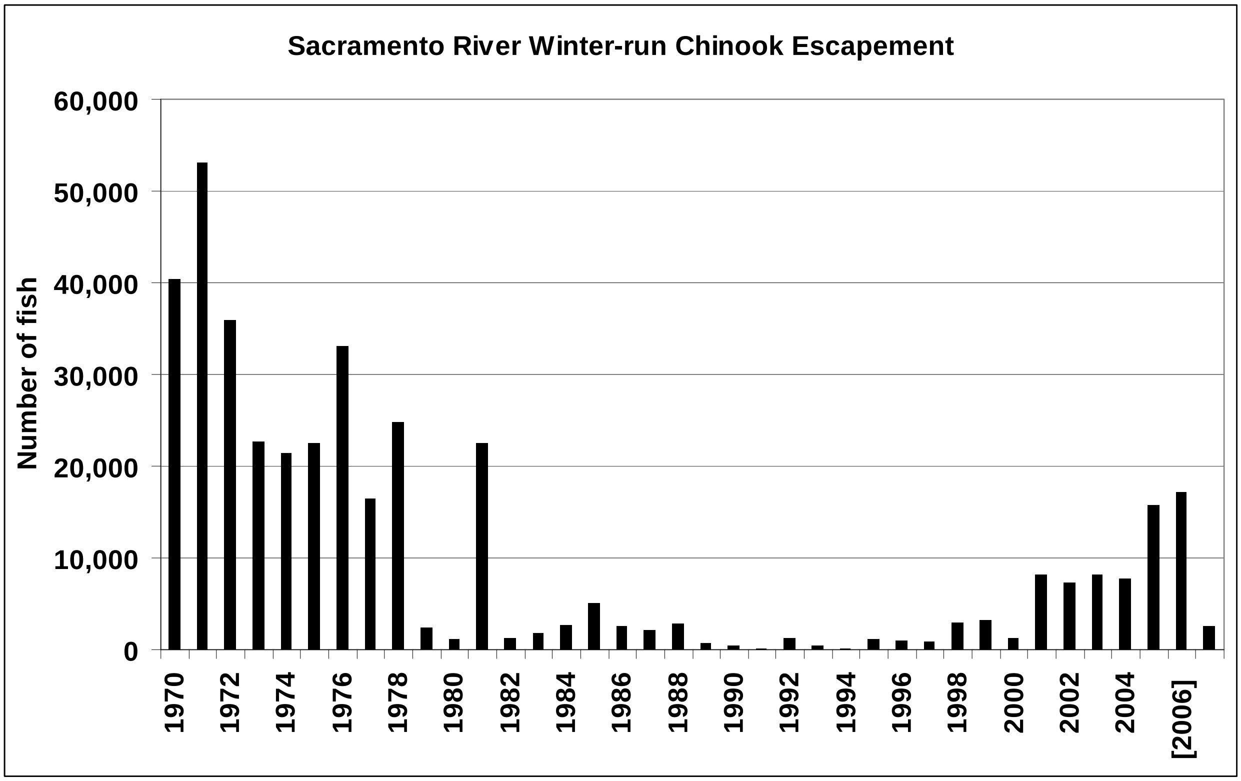
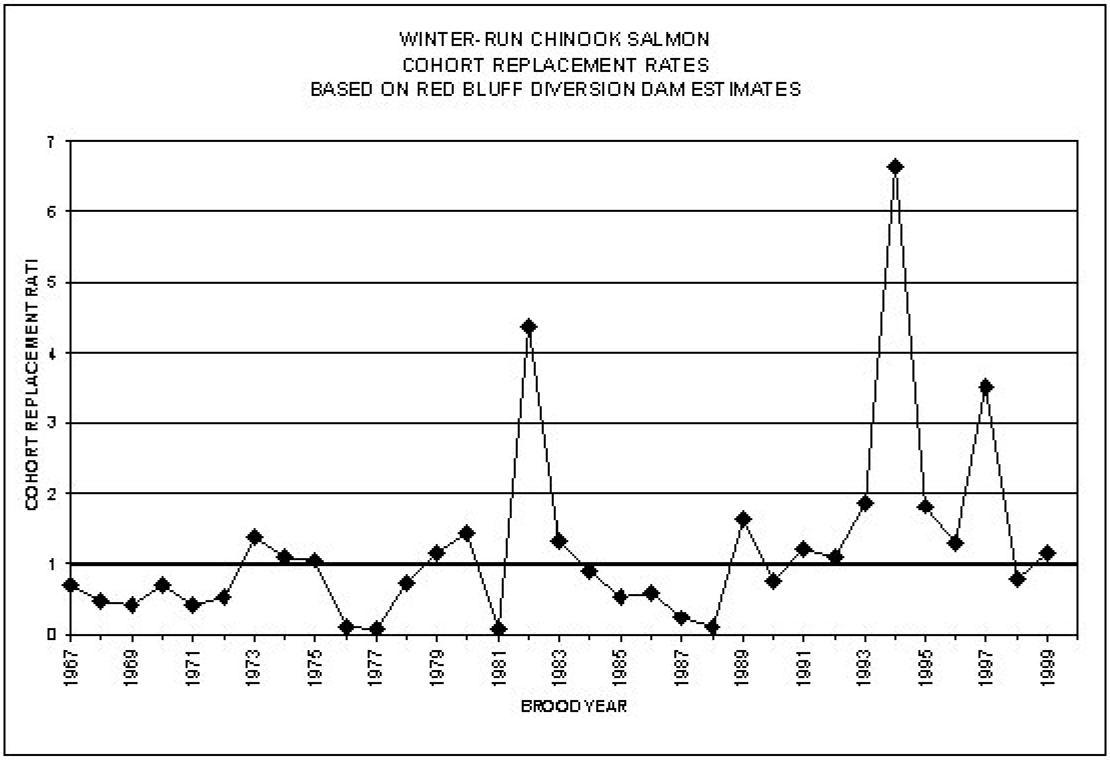


Figure 5-1 Sacramento River winter-run Chinook escapement. (brackets indicate preliminary data).

The Cohort Replacement Rate (CRR) is a parameter used to describe the number of future spawners produced by each spawner and is thus a measure of whether the population is increasing or decreasing. This spawner-to-spawner ratio is defined as the number of naturally produced and naturally spawning adults in one generation divided by the number of naturally spawning adults (regardless of parentage) in the previous generation. As such, the ratio describes the rate at which each subsequent generation, or cohort, replaces the previous one, and can be described as a natural CRR. When this rate is 1.0, the subsequent cohort exactly replaces the parental cohort and the population is in equilibrium, neither increasing nor decreasing. When the rate is less than 1.0, subsequent cohorts fail to fully replace their parents and abundance declines. If the ratio is greater than 1.0, there is a net increase in the number of fish surviving to reproduce naturally in each generation and abundance increases.

Figure 5-2 and Table 5-2 show that winter-run CRRs were generally less than 1 for the data up to 1990, i.e., the population was declining. CRRs have been mostly greater than 1 every year since 1990, indicating a generally increasing population in recent years. The winter-run population declined in 2007, consistent with the larger decline in fall-run Chinook.



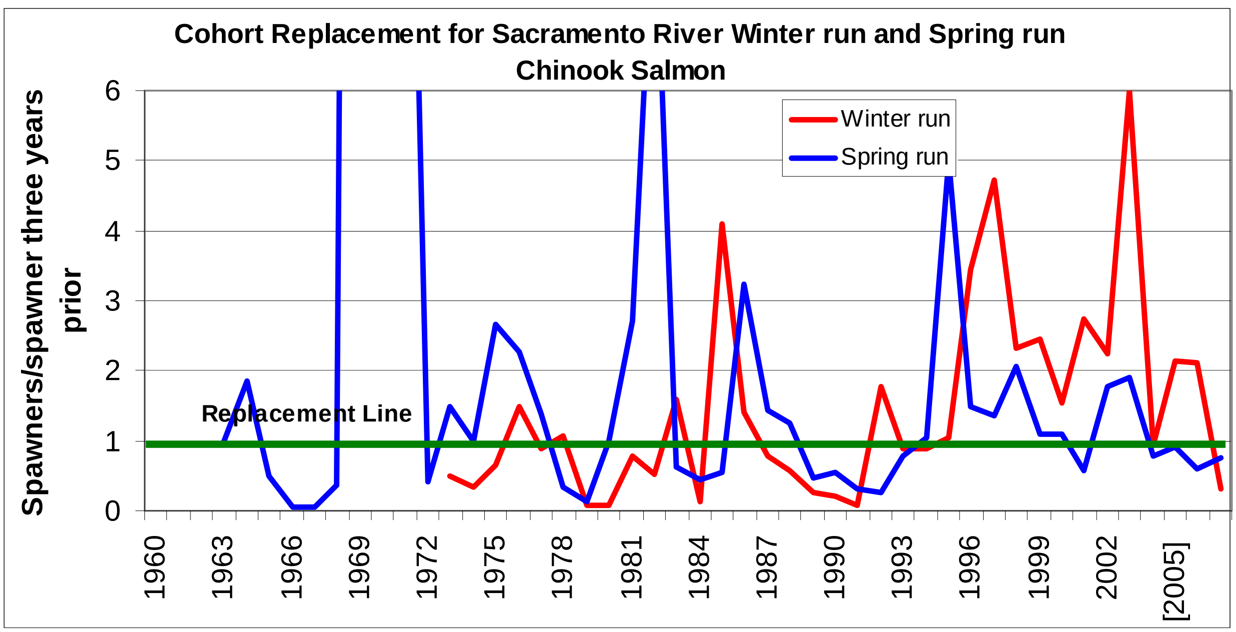


Figure 5-2 Sacramento River winter-run and spring run Chinook salmon cohort replacement rates (brackets indicate that the escapement estimate is preliminary).

Rates in the top chart were calculated by taking the BY escapement and dividing it by the sum of grilse 2 years later, 3-year olds 3 years later, and 4-year olds 4 years later; assuming that 95 percent of adults are 3-year olds and 5 percent are 4 years old, i.e., the 1999 CRR is based on adult returns in 2000 - 2002 (age distributions based on 2001 scale data).

Table 5-2 Sacramento River winter-run and Central Valley spring-run escapements and cohort replacement rates. Brackets around years indicate preliminary data (data from DFG's Grandtab spreadsheet dated 3-7-2008).

	Escapement		Cohort Replacement Rates	
Year	Winter run	Spring run	Winter run	Spring run
1960		11,068		
1961		4,327		
1962		3,642		
1963		10,817		0.98
1964		8,021		1.85
1965		1,788		0.49
1966		427		0.04
1967		476		0.06
1968		663		0.37
1969		21,378		50.07
1970	45,673	7,672		16.12
1971	53,089	9,281		14.00
1972	35,929	8,844		0.41
1973	22,651	11,430	0.50	1.49
1974	18,536	9,251	0.35	1.00
1975	23,079	23,578	0.64	2.67
1976	33,529	25,840	1.48	2.26
1977	16,470	12,730	0.89	1.38
1978	24,885	8,126	1.08	0.34
1979	2,339	3,116	0.07	0.12
1980	1,142	12,464	0.07	0.98
1981	19,795	22,105	0.80	2.72
1982	1,233	27,890	0.53	8.95
1983	1,827	7,958	1.60	0.64
1984	2,762	9,599	0.14	0.43
1985	5,048	15,221	4.09	0.55
1986	2,596	25,696	1.42	3.23
1987	2,186	13,888	0.79	1.45
1988	2,885	18,933	0.57	1.24
1989	696	12,163	0.27	0.47
1990	430	7,683	0.20	0.55
1991	211	5,927	0.07	0.31
1992	1,240	3,044	1.78	0.25
1993	387	6,075	0.90	0.79
1994	186	6,187	0.88	1.04
1995	1,297	15,238	1.05	5.01
1996	1,337	9,082	3.45	1.49
1997	880	8,448	4.73	1.37
1998	3,002	31,471	2.31	2.07
1999	3,288	9,835	2.46	1.08
2000	1,352	9,234	1.54	1.09
2001	8,224	17,698	2.74	0.56
2002	7,348	17,409	2.23	1.77
2003	8,105	17,570	5.99	1.90
2004	7,784	13,986	0.95	0.79
[2005]	15,730	16,117	2.14	0.93
[2006]	17,153	10,652	2.12	0.61
[2007]	2,488	10,571	0.32	0.76

The number of grilse in the population is probably over-estimated in the current RBDD counts. Current RBDD estimates are based on the late portion of the run, passing the dam after May 15 when the dam gates are closed. Historically, when dam counts were made year-round, there was a greater proportion of grilse in the later portion of the run. The proportion of grilse tends to be highly variable from year-to-year. The carcass count escapement data are believed to provide better abundance estimates, but there is not enough carcass survey data yet to draw any conclusions. Table 5-3 shows a comparison between RBDD fish ladder counts and carcass counts.

Table 5-3 Comparison of RBDD winter-run Chinook escapement vs. carcass count (Peterson estimate) winter-run escapement

	Grilse RBDD	Adult RBDD	Total RBDD	Carcass Count
1996	629	708	1,337	820
1997	352	528	880	2,053
1998	924	2,079	3,002	5,501
1999	2,466	822	3,288	2,262
2000	789	563	1,352	6,670
2001	3,827	1,696	5,523	12,797
		Mean	2,564	5,017
		Standard Deviation	1,748	4,416

Aerial redd counts provide information on spatial distribution of spawners and number of redds constructed by winter-run Chinook. DFG has conducted yearly aerial redd surveys for Chinook spawning in the upper Sacramento River since 1969. The surveys attempted to enumerate winter-run redds beginning in the 1980s. Table 5-4 shows the distribution of redds by reach summarized by time. RBDD gate operations were changed from 1989 through 1993 to the current September 15 through May 15 gates-up operation. Redd distribution showed a clear shift to nearly all redds now occurring in locations upstream of RBDD. New fish ladders at the Anderson-Cottonwood Irrigation District (ACID) diversion dam began operating in 2001. Almost no winter-run redds were counted upstream of the ACID dam prior to 2001. Surveys counted 484 winter-run redds upstream of the ACID dam in 2001 and 297 redds in 2002. Table 5-5 shows winter-run spawning distribution 2001-2005. The spawning distribution over this period is used in the temperature model for assessing water temperature effects on spawning and incubating Chinook salmon eggs.

Table 5-4 Sacramento River winter-run Chinook salmon spawning distribution from aerial redd surveys grouped by 1987-92, 1993-2005, and all years combined.

	years 87-92	yearly average	% distrib	years 93-2005	yearly average	% distrib	years 87-2005	overall average	% distrib.
Keswick to A.C.I.D. Dam.	17	3	1	2,563	197	33	2,580	136	27
A.C.I.D. Dam to Highway 44 Bridge	411	69	23	2,282	176	30	2,693	142	28
Highway 44 Br. to Airport Rd. Br.	544	91	30	2,566	197	33	3,110	164	33
Airport Rd. Br. to Balls Ferry Br.	159	27	9	127	10	2	286	15	3
Balls Ferry Br. to Battle Creek.	62	10	3	65	5	1	127	7	1
Battle Creek to Jellys Ferry Br.	88	15	5	15	1	0	103	5	1
Jellys Ferry Br. to Bend Bridge	166	28	9	55	4	1	221	12	2
Bend Bridge to Red Bluff Diversion Dam	23	4	1	0	0	0	23	1	0
Red Bluff Diversion Dam to Tehama Br.	226	38	12	17	1	0	243	13	3
Tehama Br. To Woodson Bridge	124	21	7	0	0	0	124	7	1
Woodson Bridge to Hamilton City Br.	4	1	0	0	0	0	4	0	0
Hamilton City Bridge to Ord Ferry Br.	0	0	0	0	0	0	0	0	0
Ord Ferry Br. To Princeton Ferry.	0	0	0	0	0	0	0	0	0
Total	1,824	304	100	7,690	592	100	9,514	501	100

Table 5-5 Sacramento River winter-run and spring-run redd distribution 2001 through 2005 (winter) and 2001-2004 (spring).

	Winter Redds	Percent	Spring redds	Percent
Keswick to A.C.I.D. Dam.	1,931	42%	9	5%
A.C.I.D. Dam to Highway 44 Bridge	1,269	27%	38	19%
Highway 44 Br. to Airport Rd. Br.	1,332	29%	63	32%
Airport Rd. Br. to Balls Ferry Br.	68	1%	35	18%
Balls Ferry Br. to Battle Creek.	5	0%	21	11%
Battle Creek to Jellys Ferry Br.	2	0%	30	15%
Jellys Ferry Br. to Bend Bridge	8	0%	3	2%
Bend Bridge to Red Bluff Diversion Dam	0	0%	0	0%
Red Bluff Diversion Dam to Tehama Br.	9	0%	1	1%
Tehama Br. To Woodson Bridge	0	0%	0	0%
Woodson Bridge to Hamilton City Br.	0	0%	0	0%
Hamilton City Bridge to Ord Ferry Br.	0	0%	0	0%
Ord Ferry Br. To Princeton Ferry.	0	0%	0	0%
	4,624	100%	200	100.0%

Spring-Run Life History and Habitat Requirements

Adult Upstream Migration, Holding, and Spawning

Adult Sacramento River spring-run Chinook probably begin to leave the ocean for their upstream migration in late January to early February based on time of entry to natal tributaries (DFG 1998). They enter the Feather River as immature adults from March to September (DFG 1998; Sommer et al. 2001). Spring-run in other tributaries sometimes hold downstream and migrate later in the summer (Marcotte 1984). Spring-run Chinook are sexually immature when they enter freshwater. Their gonads mature during the summer holding period. Adult Chinook salmon of any race do not feed in freshwater. Stored body fat reserves are used for maintenance and gonadal development. During their upstream migration, adults require sufficient streamflow to provide olfactory and other orientation cues to locate their natal streams. Adequate streamflow is also necessary to allow adult passage to holding and spawning habitat. The timing of the spring-run migration is believed to be an adaptation that allowed the fish to use high spring outflow to gain access to upper basin areas (NMFS 1998).

The most complete historical record of spring-run Chinook migration timing and spawning is contained in reports to the U.S. Fish Commissioners of Baird Hatchery operations on the McCloud River (Stone 1893, 1895, 1896a, 1896b, 1896c, 1898; Williams 1893, 1894; Lambson 1899, 1900, 1901, 1902, 1904, all as cited in DFG 1998). Spring-run Chinook migration in the upper Sacramento River and tributaries extended from mid-March through the end of July with a peak in late May and early June. Baird Hatchery intercepted returning adults and spawned them from mid-August through late September (Table 5-6). Peak spawning occurred during the first half of September. The average time between the end of spring-run spawning and the onset of fall-run spawning at Baird Hatchery was 32 days from 1888 through 1901.

Table 5-6 Dates of spring-run and fall-run Chinook salmon spawning at Baird Hatchery on the McCloud River (DFG 1998).

Year	Spring-run	Fall-run	Reference
1888	8/15-9/24	10/29-12/15	Stone 1893
1889	8/27-9/26	No egg take	Williams 1893
1890	8/15-9/23	11/6-11/25	Williams 1893
1891	8/31-9/19	10/30-11/10	Williams 1894
1892	8/13-9/12	10/20-11/26	Stone 1895
1893	8/22-9/15	10/21-11/28	Stone 1896
1894	8/24-9/30	10/22-11/23	Stone 1896
1895	8/26-9/30	10/18-11/14	Stone 1896
1896	8/2-9/20	No egg take	Stone 1898
1897	8/14-9/20	10/8-12/8	Lambson 1897
1898	8/15-9/17	11/5-12/27	Lambson 1900
1899	8/21-9/27	10/18-11/9	Lambson 1901
1900	8/18-9/22	No egg take	Lambson 1902
1901	8/16-9/25	10/25-11/25	Lambson 1904

Adult Holding

Spring-run adults may hold in their natal tributaries for up to several months before spawning (DFG 1998). Pools in the holding areas need to be sufficiently deep, cool (about 64 F or less), and oxygenated to allow over-summer survival. Adults tend to hold in pools near quality spawning gravel. DFG (1998) characterized these holding pools as having moderate water velocities (0.5 to 1.3 feet per second) and cover, such as bubble curtains.

Spawning

Spawning occurs in gravel beds that are often located at the tails of holding pools (FWS 1995a, as cited in DFG 1998). Adult Chinook have been observed spawning in water greater than 0.8 foot deep and in water velocities of 1.2 to 3.5 feet per second (Puckett and Hinton 1974, as cited in DFG 1998). Montgomery et al. (1999) reported adult Chinook tend to spawn in stream reaches characterized as low-gradient pool-riffle or forced pool-riffle reaches. Like steelhead, Chinook dig a redd and deposit their eggs within the stream sediment where incubation, hatching, and subsequent emergence take place. Optimum substrate for embryos is a gravel/cobble mixture with a mean diameter of 1 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).

Currently, adult Chinook that DFG consider spring-run, spawn from mid to late August through early October, with peak spawning times varying among locations (Figure 5-3). For instance, in Deer Creek, spawning begins first at higher elevations, which are the coolest reaches. Spawning occurs progressively later in the season at lower elevations as temperatures cool (Harvey 1995, 1996, 1997, all as cited in DFG 1998). Water temperatures between 42 F and 58 F are considered most suitable for spawning.

Sex and Age Structure

Fisher (1994) reported that 87 percent of spring-run adults are 3-year olds based on observations of adult Chinook salmon trapped and examined at RBDD between 1985 and 1991. Studies of CWT'ed Feather River Hatchery spring-run recovered in the ocean fishery indicated harvest rates average 18 to 22 percent for 3-year-old fish, 57 to 85 percent for 4-year-old fish, and 97 to 100 percent for 5-year-old fish (DFG 1998). These data are consistent with Fisher's (1994) finding that most of the spawning population are 3-year olds.

Fecundity

DFG (1998) developed a regression model to predict Sacramento River Chinook fecundity from fork length. Using this model, they estimated Central Valley spring-run fecundity ranged from 1,350 to 7,193 eggs per female, with a weighted average of 4,161 eggs per female. These values are very similar to the fecundity of spring-run estimated for the Baird Hatchery in the latter nineteenth century using the number of females spawned and total egg take. Baird Hatchery estimates ranged from 3,278 to 4,896 eggs and averaged 4,159 eggs per female between 1877 and 1901.

Egg and Larval Incubation

Egg survival rates are dependent, in part, on water temperature. Chinook salmon eggs had the highest survival in the American River when water temperatures were 53 to 54 degrees Fahrenheit (°F) (Hinze et al. 1959, as cited in Boles et al. 1988). Incubating eggs from the Sacramento River showed reduced viability and increased mortality at temperatures greater than 58°F, and suffered 100 percent mortality at temperatures greater than 65°F (Seymour 1956 as cited in Boles et al. 1988). Healey (1979) observed greater than 82% mortality in Sacramento River fall-run Chinook eggs at temperatures over 57 F and that post-hatching mortality was higher in warmer water. He concluded that Sacramento River fall-run eggs are no more tolerant of high water temperatures than more northern Chinook stocks. Velson (1987) (as cited in DFG 1998) found developing Chinook salmon embryos also experienced 100 percent mortality at temperatures less than or equal to 35°F. The time for incubating eggs to reach specific embryonic developmental stages is determined by water temperature. At an incubation temperature of 56°F, eggs would be in the gravel approximately 70 days. Chinook eggs and alevins are in the gravel (spawning to emergence) for 900 to 1,000 accumulated temperature units. One accumulated temperature unit is equal to a temperature of 1°C for 1 day. Expressed in degrees Fahrenheit, the range is 1,652 to 1,832 accumulated temperature units.

Juvenile Rearing and Emigration

Juvenile spring-run rear in natal tributaries, the Sacramento River mainstem, nonnatal tributaries to the Sacramento River, and the Delta (DFG 1998). Emigration timing is highly variable (Figure 5-3). Juvenile spring-run from Mill and Deer creeks are thought to emigrate as yearlings in greater proportions than spring-run from other tributaries (DFG 1998).

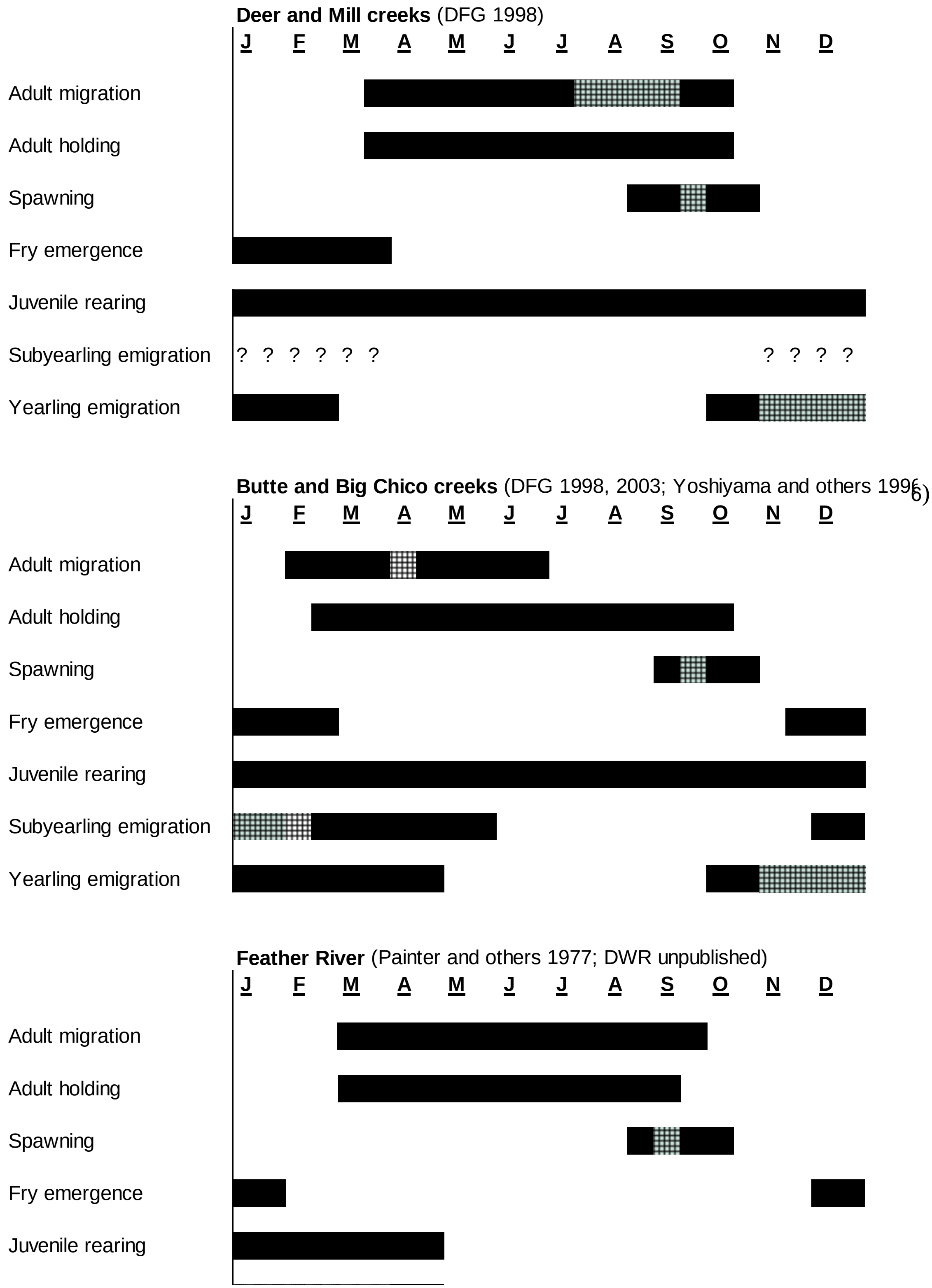


Figure 5-3 Spring-run Chinook salmon life cycle for various Central Valley streams. Cross hatching indicates period of peak occurrence.

This was apparently not the typical historical emigration pattern for the majority of Central Valley spring-run Chinook (NMFS 1998). Yearling emigration occurs from October through March and may be triggered in part by precipitation events. In some years however, under certain flow and/or water temperature conditions, greater proportions of juveniles in Mill and Deer Creeks may emigrate as fry or fingerlings soon after emergence. The bulk of Butte and Big Chico Creek production emigrates as fry from natal tributaries in December and January (Brown 1995 as cited in DFG 1998). Some also emigrate as fingerlings from February through May, and as yearlings from October through February. In contrast, no yearling emigration has been detected in the Feather River (DWR 1999c, 1999d). Instead, rotary screw trap (RST) data from 1998 to 2000 suggest that emigration of spring-run sized Chinook salmon from the Feather River peaks in December and is followed by another pulse of juvenile young-of-the-year (YOY) emigrants at Live Oak in April and May (DWR 2003, Seesholtz et al. 2004).

Juvenile rearing habitat must provide adequate space, cover, and food supply (DFG 1998). Optimal upstream habitat includes abundant instream and overhead cover (for example, undercut banks, submergent and emergent vegetation, logs, roots, other woody debris, and dense overhead vegetation) to provide refuge from predators, and a sustained, abundant supply of invertebrate and larval fish prey. Further downstream, fry use low-velocity areas where substrate irregularities and other habitat features create velocity refuges and they may increasingly rely on turbidity as cover (Gregory and Levings 1998).

Juvenile Chinook, including spring-run, also rear in ephemeral habitats including the lower reaches of small intermittent streams (Maslin et al. 1997) and in floodplain areas (Sommer et al. 2001b). Growth rates and mean condition factors were higher for juvenile Chinook rearing in intermittent tributaries than in the heavily channelized Sacramento River (Moore 1997). Similarly, growth rates and bioenergetic status were found to be significantly higher for juvenile Chinook rearing in the intermittent habitat of the Yolo Bypass floodplain than in the adjacent reach of the Sacramento River (Sommer et al. 2001b). These results highlight the importance of off-channel seasonal rearing habitats to young Central Valley salmon.

It is not known how similar the rearing patterns of Central Valley spring-run are to the fall-run because the Delta rearing patterns of spring-run Chinook have not been studied. Juvenile emigration is thought to alternate between active movement, resting, and feeding. The amounts of time spent doing each are unknown (DFG 1998), but studies have generally shown feeding is most intense during daylight or crepuscular periods (Sagar and Glova 1988). Juvenile outmigration monitoring results from throughout the Central Valley and elsewhere indicate that active emigration is most prevalent at night. Juvenile fall-run salmon may rear for up to several months within the Delta before ocean entry (Kjelson et al. 1982). Rearing within the Delta occurs principally in tidal freshwater habitats. Juveniles typically do not move into brackish water until they have smolted, after which NMFS studies indicate they move quickly to the ocean.

Chironomidae (midges) are typically cited as an important prey for juvenile Chinook upstream of the Delta (Sasaki 1966; Merz and Vanicek 1996; Moore 1997; Sommer et al. 2001b), whereas crustaceans may be more important in the western Delta (Sasaki 1966; Kjelson et al. 1982). Juvenile Chinook diets often vary by habitat type, resulting in differences in caloric intake and growth rate (Rondorf et al. 1990; Moore 1997; Sommer et al. 2001b). However, it remains unclear whether these spatial differences in feeding and growth translate into improved survival (Sommer et al. 2001b).

Before entering the ocean, juvenile Chinook smolt, a physiologic transformation that prepares them for the transition to salt water (Moyle 1976, 2002). The transformation includes lowered swimming stamina and increased buoyancy, which make the fish more likely to be passively transported by currents (Saunders 1965, Folmar and Dickhoff 1980, Smith 1982, all as cited in DFG 1998). It is believed to be optimal for smoltification to be completed as fish near the low-salinity zone of an estuary (DFG 1998). Too long a migration delay after the process begins may cause the fish to miss a biological window of optimal physiological condition for the transition (Walters et al. 1978, as cited in DFG 1998). Chinook salmon that complete the juvenile and smolt phases in the 55 to 61°F range are optimally prepared for saltwater survival (Marine and Cech 2004). The optimal thermal range during smoltification and seaward migration was estimated to be 50 to 55°F (Boles et al. 1988), based largely on studies of steelhead and coho salmon in the Northwest.

Ocean Distribution

CWT recoveries from harvested hatchery-released adult spring-run Chinook provide information on ocean distribution and harvest of adult spring-run. Table 5-7 shows that most recoveries of hatchery-released spring-run (all from Feather River Hatchery) occur off the California Coast but some do occur along the Oregon Coast. Recent CWT studies conducted on Butte Creek spring-run have shown 12 percent were harvested in the Garibaldi to Coos Bay area, 14 percent from Crescent City to Fort Bragg, 44 percent from Fort Ross to Santa Cruz, and 30 percent from Monterey to Point Sur (DFG 2003).

Table 5-7 Recovery locations of hatchery-released spring-run and estimated number recovered, 1978 – 2002 (RMIS database). All are from the Feathery River Hatchery. Location identifiers with less than 8 recoveries (48 of them) are not shown.

Sum of estimated_number	run_year																						
recovery_location_name	1978	1979	1980	1981	1983	1984	1985	1986	1987	1988	1989	1990	1993	1994	1995	1996	1998	1999	2000	2001	2002	Grand Total	percentag
FORT ROSS-PIGEON PT	787	1,981	539	51	12	177	248	400	412	488	404		11	96	236	8	129	568	430			**6,976**	**23.3%**
FEATHER RIVER																			414	42	4,412	**4,867**	**16.2%**
PIGEON PT.-POINT SUR	159	478	219	14		116	33	375	320	260	186	17		5	216	22		244	970	744	315	**4,693**	**15.7%**
FEATHER R HATCHERY																			342	749	420	**1,511**	**5.0%**
NEWPORT TROLL 4						6	3	60	58	104	66				60	6		37	63	773	236	**1,470**	**4.9%**
PT.REYES-PIGEON PT.																				631	829	**1,460**	**4.9%**
C.VIZCAINO-NAVARR.HD	87	424	71	8		9	16	84	15	140	24				6	5		11	23	57	89	**1,068**	**3.6%**
FORT ROSS-POINT SUR											139	10		24	45			551	280			**1,049**	**3.5%**
COOS BAY TROLL 5						5	18	106	60	118	58	4						107	108	298	108	**989**	**3.3%**
POINT SUR-CA/MEX.BOR						4		141	95	60				10	168	3			146	76	41	**744**	**2.5%**
PT.ARENA-PT.REYES																				476	239	**715**	**2.4%**
SPAN.FLAT-C.VIZCAINO						15	18	81	85	149	44	3			3			14	33	60	55	**560**	**1.9%**
BIG LAG.-CENTERV.BEA	8	147	15		3		20	11	53	3	18	3			5			35	29	54	33	**438**	**1.5%**
NAVARRO HD-FORT ROSS							5	32	154	44	11			2					2			**249**	**0.8%**
COLUSA TO RBDD																				239		**239**	**0.8%**
GARIBALDI TROLL 3								14	11	10	5				12			15	19	94	38	**218**	**0.7%**
AMERICAN RIVER																			43		126	**169**	**0.6%**
SPAN.FLAT-PT.ARENA																				32	135	**167**	**0.6%**
CA/OR BOR-FA.KLAM.RC	18	20	4	4		31	17	6	14	8	16								14	5		**157**	**0.5%**
WINCHESTER B TROLL 5							4	29	15	33	18							11	12	25	5	**153**	**0.5%**
LOW FLOW AREA																				153		**153**	**0.5%**
WINCHESTER B SPORT 5					4		3		14	26	2								10	56	29	**144**	**0.5%**
BROOKINGS SPORT 6					3	2	22	3	28	27	4	2				2		3	7	18	21	**142**	**0.5%**
NAVARRO HD-PIGEON PT										40	66											**106**	**0.4%**
PIGEON PT-CA/MEX.BOR															11			2	38		37	**88**	**0.3%**
MARINE AREA 2						1	6	9	10	19	2						3	19		9	8	**85**	**0.3%**
AMER.R. TO COLUSA																				40	40	**80**	**0.3%**
SIUSLAW BAY TROLL 5									12	29	14							10	6			**71**	**0.2%**
HIGH FLOW AREA																				66		**66**	**0.2%**
SPAN.FLAT-NAVARRO HD										41	11								8			**60**	**0.2%**
PORT ORFORD TROLL 5								3	3	1	5							5	2	23	11	**53**	**0.2%**
C.VIZCAINO-FORT ROSS										28	10							13				**50**	**0.2%**
CA/OR BDR.- HMBT.JET																				27	21	**48**	**0.2%**
PT.REYES-PT.SUR																				40	4	**44**	**0.1%**
NEWPORT TROLL 5							1		11		1							2	3	12	13	**44**	**0.1%**
MARINE AREA 4									4	7	3	3						12	3	7	2	**40**	**0.1%**
BROOKINGS TROLL 6								12	9	4				2				6	2	3		**38**	**0.1%**
NEWPORT SPORT 4					3		3	3											6	12	7	**34**	**0.1%**
COOS BAY TROLL	6	17	11																			**34**	**0.1%**
BROOKINGS TROLL		30		2																		**32**	**0.1%**
BATTLE CREEK																				17	15	**32**	**0.1%**
COOS BAY SPORT 5								4		4									5	4	15	**32**	**0.1%**
ASTORIA TROLL 2							2	5		9										10		**27**	**0.1%**
MARINE AREA 1	4	3						5		3								3			7	**25**	**0.1%**
YUBA RIVER																			2		21	**23**	**0.1%**
COOS BAY TROLL 4															7					10	4	**22**	**0.1%**
PT.ARENA-PIGEON PT.																					20	**20**	**0.1%**
ASTORIA SPORT 2																				15	4	**19**	**0.1%**
PT.SN.PEDRO-PIGN.PT.																				6	14	**19**	**0.1%**
NEWPORT TROLL		19																				**19**	**0.1%**
RBDD TO ACID																				18		**18**	**0.1%**
TEHAMA-COLUSA FF		4	8	2		1	2															**17**	**0.1%**
NEWPORT TROLL 3								2	1		6									5	3	**17**	**0.1%**
WSPT LONG BE											14							3				**17**	**0.1%**
1A PLUS 1B										16												**16**	**0.1%**
DEPOE BAY SPORT 4								2	2	2								1			10	**16**	**0.1%**
FLORENCE SPORT 5									4	9	2											**15**	**0.0%**
SWTR 114-000						8				4												**13**	**0.0%**
1A (BUOY10 - BRIDGE)																				6	6	**12**	**0.0%**
WSPT CREE IS																			12			**12**	**0.0%**
OCEAN SPORT AREA 72						4			4	2												**10**	**0.0%**
MARINE AREA 3										9								1				**10**	**0.0%**
FA.KLA.RC-BIG LAGOON										10												**10**	**0.0%**
SWTR 111-000										10												**10**	**0.0%**
CLEAR CREEK																				7	3	**9**	**0.0%**
PACIFIC CITY TROLL 3									3	6												**9**	**0.0%**
SWTR 021-000						9																**9**	**0.0%**
HIGH SEAS 1 47N 124W																			9			**9**	**0.0%**
MARINE AREA 5 TROLL									7	2												**8**	**0.0%**
SWTR 023-234						8																**8**	**0.0%**
COLEMAN NFH			1						5	2												**8**	**0.0%**
OCEAN SPORT AREA 82							3		2		2											**8**	**0.0%**
NWTR 025-000										4								4				**7**	**0.0%**

Historical and Current Distribution and Abundance of Spring-Run Chinook Salmon

Spring-run Chinook salmon populations once occupied the headwaters of all major river systems in the Central Valley up to any natural barrier (Yoshiyama et al. 1996, 1998). DFG (1998) reported that historically spring-run abundance was second only to fall-run abundance in the Central Valley, but NMFS (1998) indicated spring-run may actually have been the most abundant run in the Central Valley during the nineteenth Century. The gill-net fishery, established around 1850, operated in the Delta and initially targeted spring- and winter-run Chinook salmon due to their fresher appearance and better meat quality than fall-run, which return to freshwater in a more advanced spawning condition (Stone 1874, as cited in DFG 1998). Early gill-net landings reported in excess of 300,000 spring-run per year (CFC 1882, as cited in DFG 1998). Commercial fishing along with residual effects of mining probably contributed to spring-run declines by the early part of the twentieth century (DFG 1998).

Recent estimates indicate roughly 2,000 miles of salmon spawning and rearing habitat were available before dam construction and mining, but 82 percent of that habitat is unavailable or inaccessible today (Yoshiyama et al. 1996). The available habitat may be less when the quality of remaining habitat is considered. Stream reaches below major dams may be accessible to spring-run, but competition and/or introgression with fall-run may render these reaches marginally useful to the spring-run. Moreover, it is possible that spring-run prefer to spawn in smaller channels similar to their historical upstream habitat, rather than the existing broad, low-elevation reaches available below dams. Most of these habitat modifications were in place before more recent declines occurred however, suggesting other factors and gradual habitat degradation below dams have also affected spring-run abundance in the Central Valley.

Currently, the bulk of the remaining spring-run Chinook are produced in Deer, Mill, and Butte creeks, the Feather River, and perhaps the mainstem Sacramento River. Small numbers of spring-run have intermittently been observed in the recent past in other Sacramento River tributaries as well (DFG 1998). Of the three tributaries producing naturally spawned spring-run (Mill, Deer, and Butte Creek), Butte Creek has produced an average of two-thirds of the total production over the past 10 years. Some distribution and abundance data are presented below for current spring-run producing streams. Additional details on these and other streams can be found in DFG (1998) and NMFS (1998).

Estimation methods for spring-run in the tributaries have varied through the years. Confidence intervals are usually not developed on the escapement estimates making comparison of estimates between years problematic. The recent (last 10 years) preferred method is a snorkel survey in tributaries other than Mill Creek. Snorkel surveys are good for identifying population trends when experienced observers use consistent methods, but they usually underestimate the actual number of fish present. Comparisons during 2001 and 2002 on Butte Creek of the snorkel survey with a rigorous Schaefer carcass survey suggest that the snorkel survey underestimates by as much as 50 percent (DFG 2003). The underestimate is probably greater on a stream like Butte Creek with fish in higher densities than in some of the other tributaries.

Clear Creek

Prior to European settlement, Clear Creek supported spring-run, fall-run, and late-fall-run Chinook salmon and steelhead. Absent from Clear Creek for 30 years, approximately 30 adult spring-run Chinook salmon reappeared in the lower reaches of Clear Creek in 1999. Historical accounts of spring-run Chinook in Clear Creek are sparse and population estimates are nonexistent. Spring-run were observed in Clear Creek upstream of Saeltzer Dam in 1956 for the first time since 1948. Construction of Whiskeytown Dam in 1963 permanently eliminated access to the upper reaches of the creek to salmon. Previous observations of spring-run indicate that they likely held over and spawned in cooler water present in the upper watershed upstream of Whiskeytown Dam. A waterfall at French Gulch restricted upstream migration to periods of high runoff in the spring.

Attempts to re-establish the spring-run Chinook on Churn Creek have been made. In 1991, 1992, and 1993, 200,000 juvenile spring-run Chinook salmon from the Feather River Hatchery were planted in Clear Creek. A number of these fish returned to Clear Creek in the fall of 1995 rather than in the spring as expected. They may have remained in the cooler Sacramento River until Clear Creek cooled or they may be offspring of hybrid spawning of spring- and fall-run for several generations at Feather River Hatchery. FWS conducts snorkel surveys for spring run in Clear Creek (Table 5-8).

Table 5-8 Clear Creek adult spring-run Chinook escapement, 1999-2006 (Source: FWS, unpublished data).

1999	2000	2001	2002	2003	2004	2005	2006
30	19	9	66	25	98	69	70

The FWS operates a rotary screw trap at river mile 1.7 on Clear Creek, upstream of the sheet pile dam associated with the ACID canal siphon crossing. Spring-run-sized juvenile Chinook salmon are enumerated in the trap according to length criteria developed for the upper Sacramento River. In late 1999, approximately 2,300 spring-run sized juvenile Chinook were collected in the trap after many Chinook had spawned in lower Clear Creek during September. In late 2000, 41 spring Chinook juveniles were collected in the trap. During 2001, the first spring-run-sized juvenile was captured in the trap on November 14. The estimated number of potential spring-run captured in the trap in 2001 was 1,083 in November and December (DFG 2002). The estimate for 2002 was 7,722 and the estimate in 2003 was 11,144 (DFG 2004). Currently a segregation weir is installed yearly after spring run have migrated upstream. This weir prevents fall run from migrating upstream to the spawning area used by spring run, thereby preventing fall run from spawning over the top of spring run redds.

Denton (1986) used the PHABSIM module of the IFIM approach to estimate optimal Clear Creek flows for salmon and steelhead. The resultant estimate of optimal flows from the IFIM study is shown in Figure 5-4. The timing of these flows was based on the fall-run Chinook life cycle, but the recommended steelhead flows would provide the needed flows for spring-run, except potentially in April and May when an extra 25 cubic feet per second (cfs) would be required to bring the flows up to the salmon recommendation. The recommended spawner attraction flow releases shown in October and November could be provided around April and May for spring-run.

Although the optimum flows that were recommended for fall-run of 250 cfs may provide a maximum amount of suitable spring-run spawning and rearing habitat because the number of spring-run in Clear Creek is low, the population does not appear to be currently habitat-limited as long as temperatures are suitable. The section of Clear Creek from the mouth to the former Saeltzer Dam is fall and late-fall Chinook habitat. The Clear Creek Road Bridge to Whiskeytown Dam reach is the section of creek more suitable for spring-run Chinook because temperatures are cooler than in the downstream reach in the summer. The IFIM study showed higher flow needs in the downstream habitat than in the upstream habitat. Optimal flows for salmon in the upstream reach where spring-run are located were 62 cfs for spawning and 75 cfs for rearing from the IFIM study (Denton 1986). Optimal steelhead flows in the same upstream reach were 87 cfs for spawning and 112 cfs for juvenile rearing.

Flows in Clear Creek likely resulted from a general flow schedule developed for salmon and steelhead maintenance. The schedule was intended as an interim flow release schedule for monitoring purposes to be fine-tuned as the fishery effects were determined (Denton 1986). Studies are underway by a Clear Creek flow group to fine-tune the flow schedule.

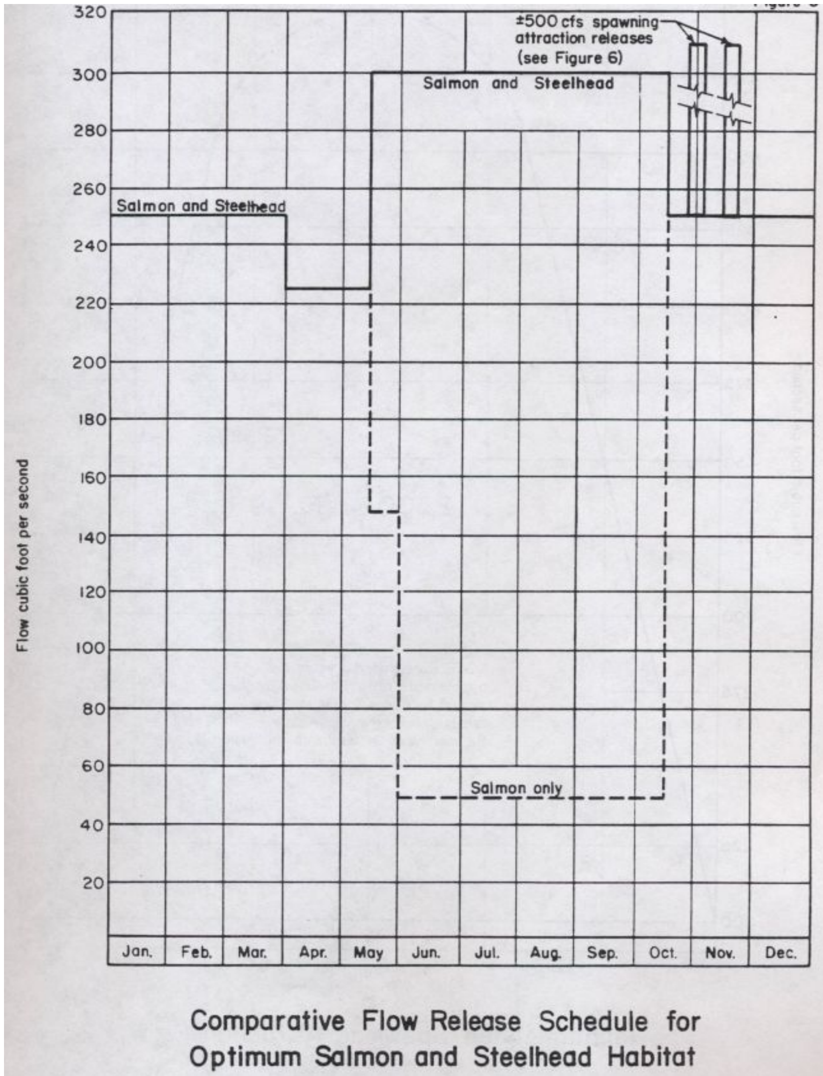


Figure 5-4 Clear Creek flows for optimum salmon and steelhead habitat.

Sacramento River Mainstem

Some spring-run Chinook may spawn in the Sacramento River between RBDD and Keswick Dam. Sacramento River main-stem spring-run abundance has declined sharply since the mid-1980s (Figure 5-5). The criteria for run classification at RBDD have changed so no conclusions can be reached about spring-run abundance changes in the Sacramento River. The variable abundance estimates may be an artifact of the counting methods used in different years and categorization of fish between runs. The 5-year geometric mean abundance reported by NMFS (1998) was 435 fish. There is evidence that the spring-run that pass RBDD are spring-run/fall-run hybrids (Figure 5-6). Historically, the onset of fall-run spawning occurred well after spring-run had completed spawning. The increasing overlap in spring-run and fall-run spawning periods is evidence that introgression is occurring. Because spring-run and fall-run Chinook now use the same spawning riffles, fall-run spawners may reduce survival of eggs in the spring-run redds. This redd displacement is called superimposition. The criteria used to distinguish spring-run from fall-run between 1970 and 1988 (timing) probably resulted in many fall-run fish being classified as spring-run (DFG 2003), so the increasing overlap may be simply an artifact of the variable run classification.

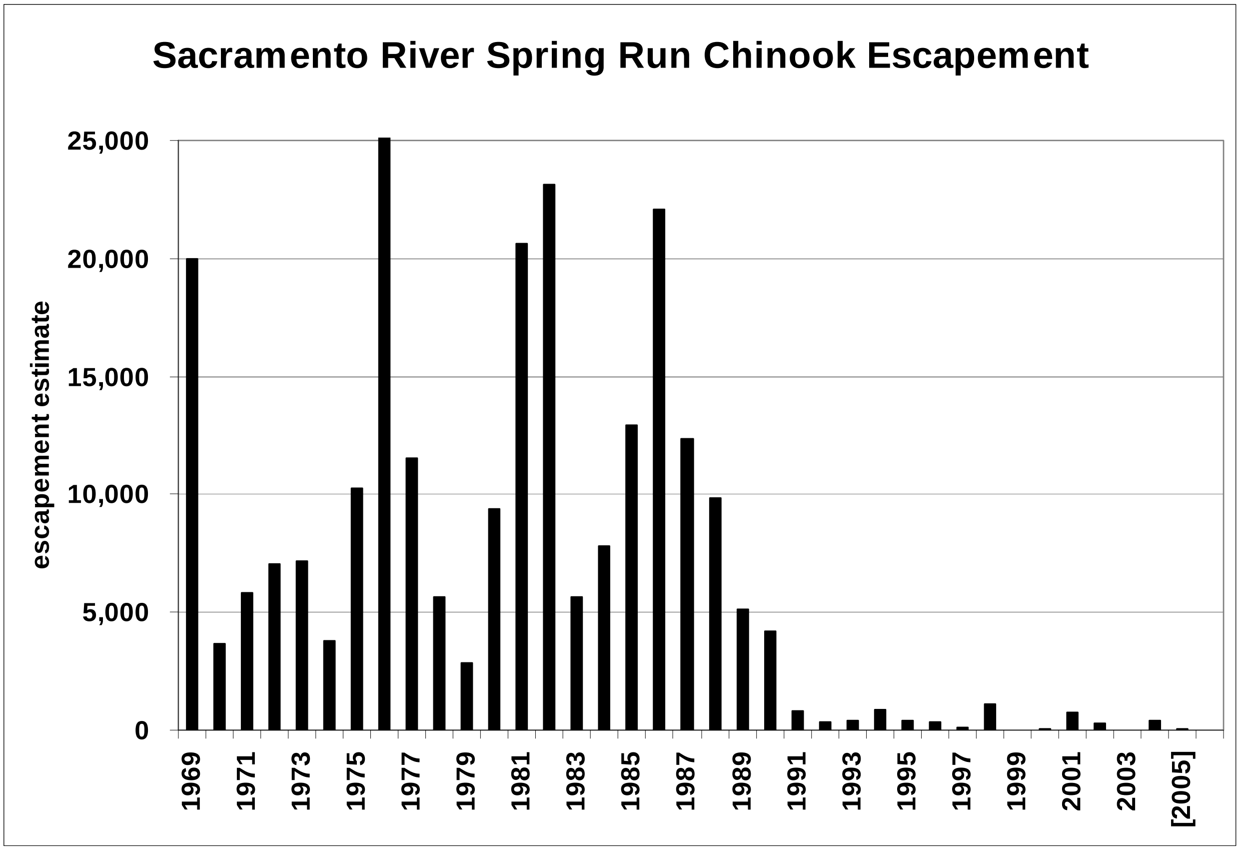


Figure 5-5 Estimated adult spring-run Chinook salmon population abundance in the upper Sacramento River. Brackets indicate the data for that year is preliminary.

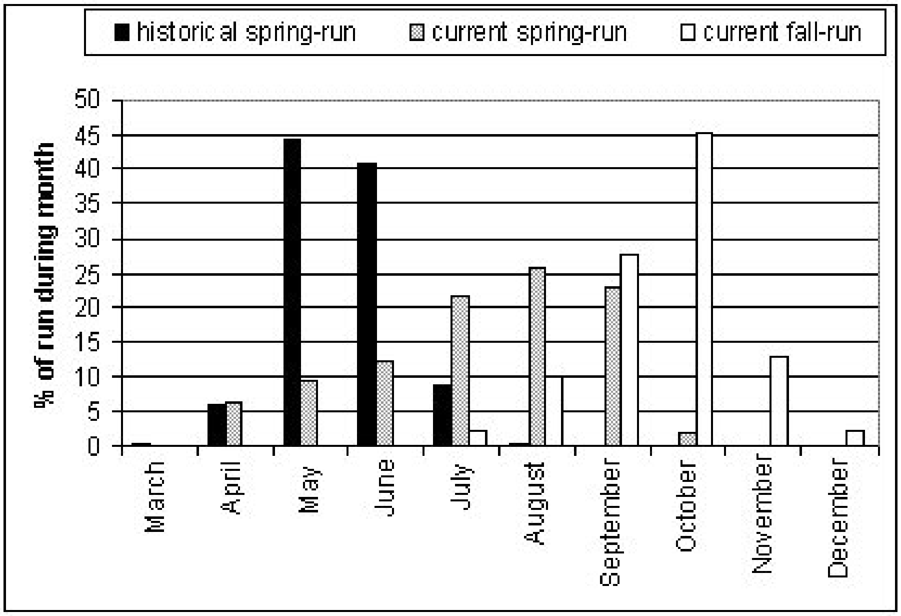


Figure 5-6 Migration timing of spring-run and fall-run Chinook salmon.

Historical distribution of timing is based on composite data from Mill and Deer Creeks, Feather River, and the upper Sacramento River prior to Shasta Dam. Present distributions are for spring-run and fall-run timing past RBDD (1970-1988). Data were taken from DFG 1998.

Cohort Replacement Rates Used for Mill, Deer, and Butte Creeks

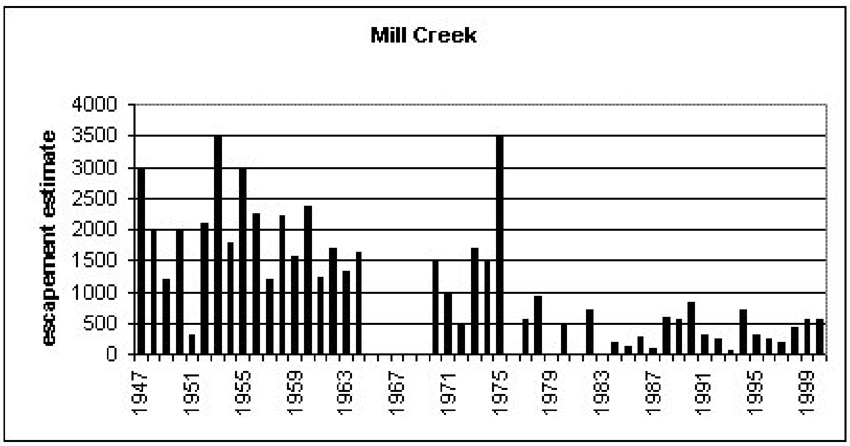
DFG (1998) evaluated spring-run Chinook population trends by examining the strength of BY lineages with a CRR. The varied methods used over the years to estimate population abundance in each tributary left few data adequate for such analyses. DFG (1998) considered the more recent data for Mill, Deer, and Butte Creeks to be the most consistent and robust. Individual brood year data are lacking altogether on rates of grilse (2-year old) returns, age structure, and sex ratio of returning adults. In estimating CRR, DFG (1998) assumed the following: (1) spawning adults return as 3-year olds; (2) there is a 1:1 male to female sex ratio; and (3) there is not much variation in these factors between BYs. The CRR for spring-run was estimated by dividing the number of returning adults in a given BY by the number of returning adults 3 years prior. Values greater than 1.0 suggest the cohort abundance is increasing, while values less than 1.0 indicate cohort abundance is decreasing. A value around 1.0 suggests the cohort has replaced itself. CRR data are provided in the discussions of abundance in Mill, Deer, and Butte Creeks, and also for the Feather River.

Mill Creek

The present range and distribution of spring-run Chinook salmon in Mill Creek is the same as it was historically (DFG 1998). Adults migrate upstream and hold in a 20-mile reach from the

Lassen National Park boundary downstream to the confluence of Little Mill Creek. There are no early records of population size for Mill Creek. Spring-run counts were initiated by FWS in 1947 (DFG 1998). Although some of these counts were incomplete, they ranged from 300 to 3,500 fish from 1947 to 1964. The average run size for the 1947 to 1964 period was about 1,900 fish (geometric mean = 1,717).

During the 1990s, the geometric mean spring-run escapement to Mill Creek was 299, an order of magnitude lower than 1947 to 1964 (Figure 5-7). The Mill Creek spring-run population trend during the 1990s was somewhat uncertain. The mean CRR for 1990-99 was 2.2, indicating a population increase (Table 5-9). However, the more conservative geometric mean CRR was only 1.05, suggesting the population was merely replacing itself. More recent cohorts show a trend of CRR less than 1.0 (Table 5-9) reflecting a declining trend in recent adult abundance.This agrees with the 1990 through 1999 3-year running average escapement, which shows no consistent trend of either increase or decrease (Figure 5-8). The escapement has increased since the 1990s.



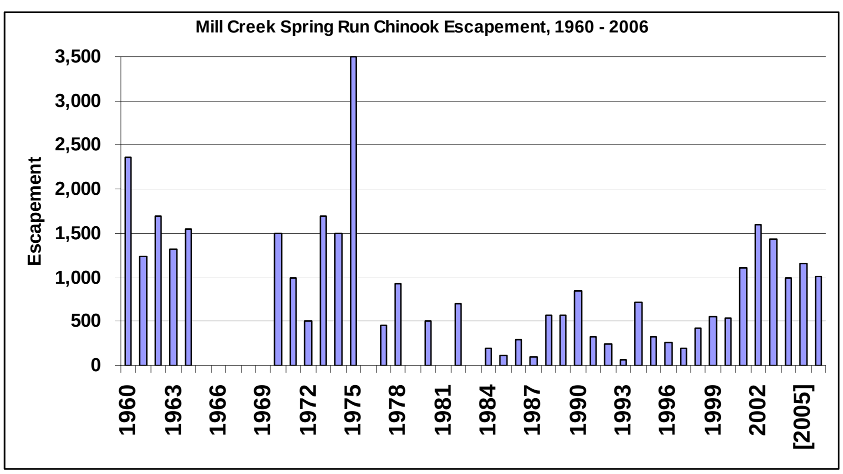


Figure 5-7 Adult spring-run Chinook counts in Mill Creek. Figure on top shows escapement back to 1947.

Table 5-9 Mill Creek spring-run Chinook salmon CRR.

Cohort	BY	CRR
1	1957	1203/1789 = 0.7
2	1958	2212/2967 = 0.7
3	1959	1580/2233 = 0.7
1	1960	2368/1203 = 2.0
2	1961	1245/2212 = 0.6
3	1962	1692/1580 = 1.1
1	1963	1315/2368 = 0.6
2	1964	1628/1245 = 1.3
3	1990	844/89 = 9.5
1	1991	319/572 = 0.6
2	1992	237/563 = 0.4
3	1993	61/844 = 0.1
1	1994	723/319 = 2.3
2	1995	320/237 = 1.4
3	1996	252/61 = 4.1
1	1997	200/723 = 0.3
2	1998	424/320 = 1.3
3	1999	560/252 = 2.2
1	2000	544/200 = 2.7
2	2001	1100/424 = 2.6
3	2002	1,594/560 = 2.8
1	2003	1,426/544 = 2.6
2	2004	998/1,100 = 0.9
3	2005	1,150/1,594 = 0.7
1	2006	1,002/1,426 = 0.7

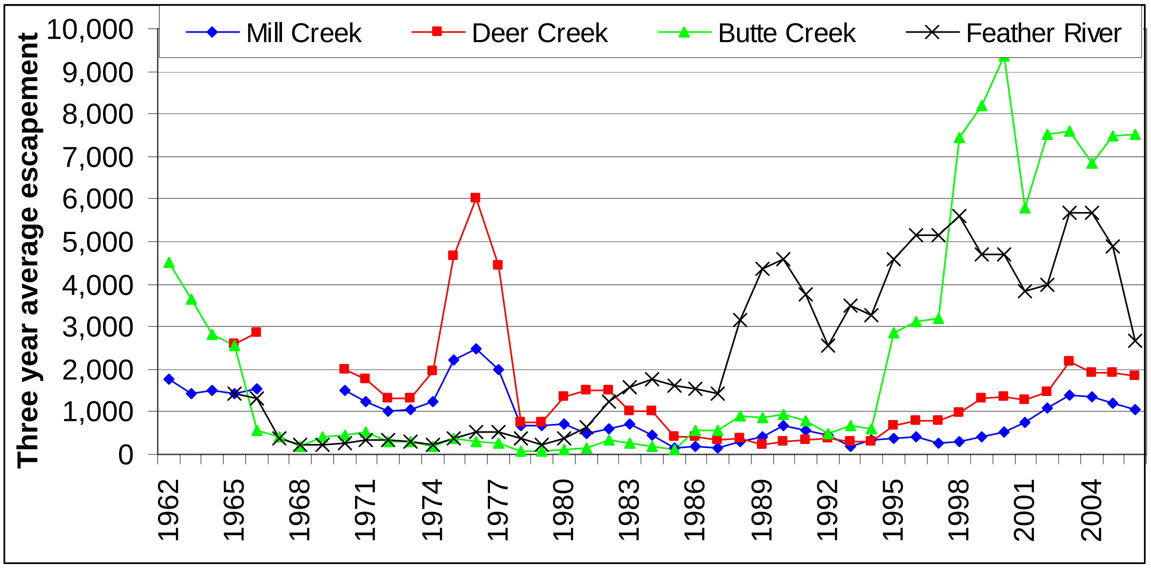


Figure 5-8 Three-year running average abundance of returning adult spring-run Chinook salmon in highest producing Central Valley spring run streams.

Deer Creek

The present spring-run range in Deer Creek has been extended beyond the historical range (DFG 1998). A fish ladder was constructed around Lower Deer Creek Falls in 1943, opening an additional 6 miles of holding and spawning habitat. The present habitat is a 22-mile reach extending from Dillon Cove to Upper Deer Creek Falls. Approximately 20 percent of the spawning now occurs in the 6-mile extension. A fish ladder constructed around Upper Deer Creek Falls allows steelhead passage, but not spring-run passage. Spring-run are excluded because the reach lacks the large holding pools needed to sustain a large salmon population. There are no early records of spring-run population size for Deer Creek either, but counts were initiated by FWS in 1940 (DFG 1998). As with Mill Creek, some counts were incomplete, but ranged from 268 to 4,271 fish between 1940 and 1964. The average run size for the 1940 through 1964 period was about 2,200 fish (geometric mean of 2,290). Again, as in Mill Creek, recent counts are lower, with a geometric mean escapement of 906 for the 1990 through 2006 period.

The mean Deer Creek CRR was 1.9 during 1990 through 2006, suggesting that, like Mill Creek, the population may be rebounding (Table 5-10). In addition, the geometric mean CRR of 1.5, and the 1990 through 2006 3-year running average escapement (Figure 5-8) also suggest a slight population increase during since the 1980's.

Table 5-10 Deer Creek spring-run Chinook salmon CRR

Cohort	BY	CRR
1	1990	458/200 = 2.3
2	1991	448/371 = 1.2
3	1992	209/77 = 2.7

Cohort	BY	CRR
1	1993	259/458 = 0.6
2	1994	485/448 = 1.1
3	1995	1295/209 = 6.2
1	1996	614/259 = 2.4
2	1997	466/485 = 1.0
3	1998	1879/1295 = 1.5
1	1999	1591/614 = 2.6
2	2000	637/466 = 1.4
3	2001	1622/1879 = 0.9
1	2002	2,185/1,591 = 1.4
2	2003	2,759/637 = 4.3
3	2004	804/1,622 = 0.5
1	2005	2,239/2,185 = 1.0
2	2006	2,432/2,759 = 0.9

Butte Creek

The present range of spring-run Chinook salmon in Butte Creek does not differ substantially from its historical range and is limited to the reach below the PG&E Centerville Head Dam downstream to the Parrott-Phelan Diversion Dam (DFG 1998). It is likely the historical limit of travel for spring-run salmon and steelhead during most years was a natural barrier (Quartz Bowl Barrier) 1 mile below the PG&E Centerville Head Dam. The only time recent DFG surveys have found fish above the Quartz Bowl barrier is when flows were atypically high into late-May. Even then, there were only 25 fish noticed out of an estimated total population of 22,000 (DFG 2003). There are numerous additional large impassable natural barriers immediately above the Centerville Head Dam. As with the above-mentioned streams, there are no early accounts of the number of spring-run in Butte Creek. During 1954, a counting station was maintained at the Parrott-Phelan Diversion Dam to record adult spring-run salmon passing through the fish ladder (Warner 1954 as cited in DFG 1998). From May 7 through 27, 1954, 830 fish were observed. Various census techniques have been employed to evaluate the Butte Creek spring-run population since 1954 (DFG 1998). The population has fluctuated significantly, from a low of 10 in 1979 to a high of 20,259 in 1998. The fluctuation may be explained in part by the variety of survey techniques used, but the population appears to have been nearly extirpated numerous times between the 1960s and the early 1990s.

The Butte Creek spring-run increased dramatically during the last decade. CRRs have been highly variable, but usually greater than 1.0 since 1993, ranging from 0.5 to 10.3, with a mean of 3.1 and a geometric mean of 2.2 (Table 5-11). The 3-year running average escapement for 1990 through 2006 suggests a comparatively rapid abundance increase as well (Figure 5-8).

Table 5-11 Butte Creek spring-run Chinook salmon CRR.

Cohort	BY	CRR
1	1993	650/100 = 6.5
2	1994	474/100 = 4.7
3	1995	7,500/730 = 10.3
1	1996	1,413/650 = 2.2
2	1997	635/474 = 1.3
3	1998	20,259/7,500 = 2.7
1	1999	3,600/1,413 = 2.5
2	2000	4,118/635 = 6.5
3	2001	9,605/20,259 = 0.5
1	2002	8,785/3,600 = 2.4
2	2003	4,398/4,118 = 1.1
3	2004	7,390/9,605 = 0.8
1	2005	10,625/8,785 = 1.2
2	2006	4,579/4,398 = 1.0

Feather River

Historically, the Feather River spring-run population was similar in magnitude to the size of the present hatchery run (Figure 5-9). Spring-run ascended the very highest streams and headwaters of the Feather River watershed prior to the construction of hydropower dams and diversions (Clark 1929, as cited in DFG 1998). Prior to Oroville Dam (1946-63), available population estimates ranged from 500 to 4,000 fish and averaged 2,200 per year (Painter et al. 1977, Mahoney 1958, 1960, all as cited in DFG 1998; DFG 1998). However, Feather River spring-run had probably been significantly affected by hydropower facilities in the upper watershed well before the completion of Oroville Dam. For instance, DFG (1998) found substantial overlap in the spawning distributions of fall-run and spring-run Chinook upstream of the Oroville Dam site.

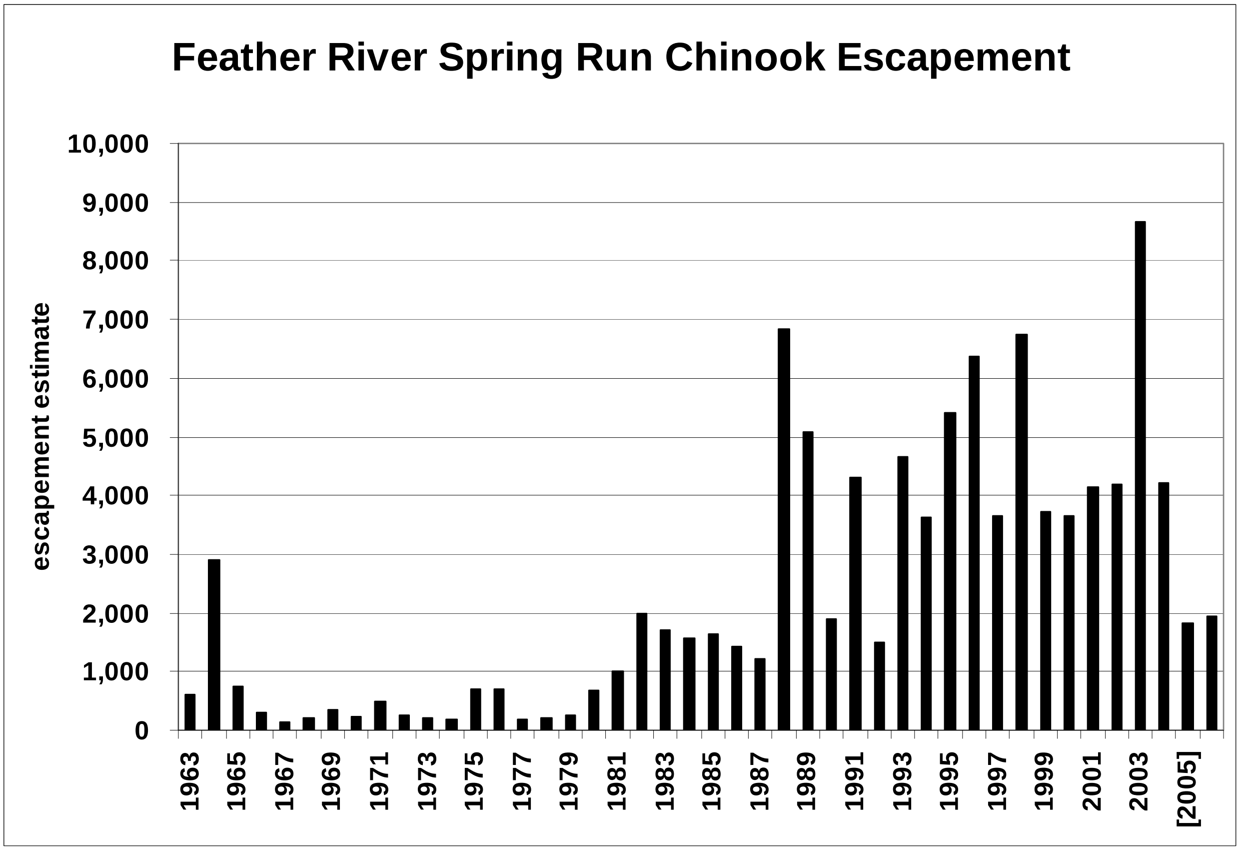


Figure 5-9 Estimated adult spring-run Chinook salmon population abundance in Feather River. Brackets indicate data is preliminary.

Following construction of Oroville Dam in 1967, the spring-run population dropped to 146 fish, but averaged 312 fish per year between 1968 and 1974 (Menchen 1968; Painter et al. 1977, both as cited in DFG 1998). The highest post-Oroville Dam population estimate was recorded in 1998 (8,430 adults) based on numbers of fish returning to Feather River Hatchery (FRH). The Feather River spring-run Chinook salmon CRR is presented in Table 5-10. All post-Oroville spring-run population estimates are based on counts of salmon entering FRH. The 10-year average from 1992 to 2002 was 4,727 adults returning to the FRH (NMFS 2004).

DWR initiated fish studies in the lower Feather River in 1991. The focus and methods used for these studies were altered in 2003 as a result of consultations with NMFS, DFG, and others to gather information needed to relicense the Oroville facilities with the Federal Energy Regulatory Commission (FERC) http://orovillerelicensing.water.ca.gov/documents.html.

Since the signing in 2006 of the Settlement Agreement for the FERC relicensing process, the monitoring program refocused on increasing our understanding of the listed fish species in the Lower Feather River. The present program consists of several elements to monitor salmonid spawning, rearing, and emigration, including spring-run Chinook salmon, and to document any potential impacts of project operations on fish species. A wide variety of equipment and monitoring methods are used including rotary screw traps, fyke traps, snorkel surveys, electrofishing, radio and acoustic tagging, carcass surveys, redd mapping, etc. Reports

summarizing the results and findings are prepared and submitted to the regulatory agencies annually.
http://wwwdes.water.ca.gov/ecological_studies_branch/frp_program/technicalreports.htm.

Like several of the other spring-run streams, both the mean (1.4) and the geometric mean (1.2) CRR for FRH spring-run suggest the population has been increasing slightly in the recent past (Table 5-12). The 3-year running average escapement suggests the same (Figure 5-8).

Table 5-12 Feather River Spring-run Chinook Salmon CRR.

Cohort	BY	CRR
1	1991	3448/6833 = 0.50
2	1992	1670/5078 = 0.33
3	1993	4672/1893 = 2.50
1	1994	3641/3448 = 1.06
2	1995	5414/1670 = 3.24
3	1996	6381/4672 = 1.37
1	1997	3653/3641 = 1.00
2	1998	8430/5414 = 1.56
3	1999	3731/6381 = 0.59
1	2000	3657/3653 = 1.00
2	2001	2468/8430 = 0.29
3	2002	4,189/3,731 = 1.1
1	2003	8,662/ 3,657 = 2.4
2	2004	4,212/ 2,468 = 1.7
3	2005	1,835/ 4,189 = 0.4
1	2006	1,952/ 8,662 = 0.2

Since the construction of Oroville Dam however, spring-run salmon have been restricted to the area downstream of the fish barrier dam near Oroville, where the intermixing with the fall-run observed by DFG (1959, as cited in DFG 1998) has probably increased (Figure 5-10 and Figure 5-11). Based on an assessment of FRH operations, the Feather River population was considered a likely hybrid of spring- and fall-run populations (Brown and Greene 1993). However, initial genetic studies of spring- and fall-run from FRH and Feather River found no distinction between spring- and fall-run (Dr. Dennis Hedgecock, presentation at the 1999 Salmon Symposium in Bodega Bay).

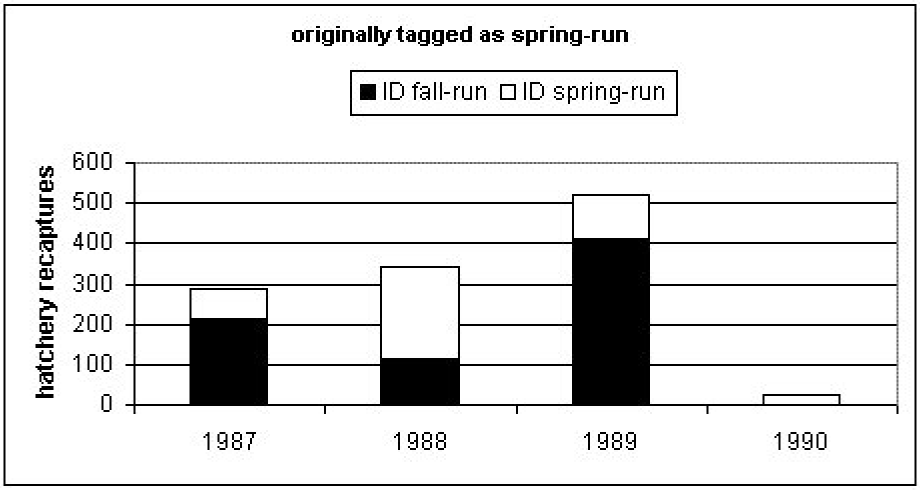


Figure 5-10 The disposition of Chinook salmon spawned, tagged, and released as spring-run from FRH.

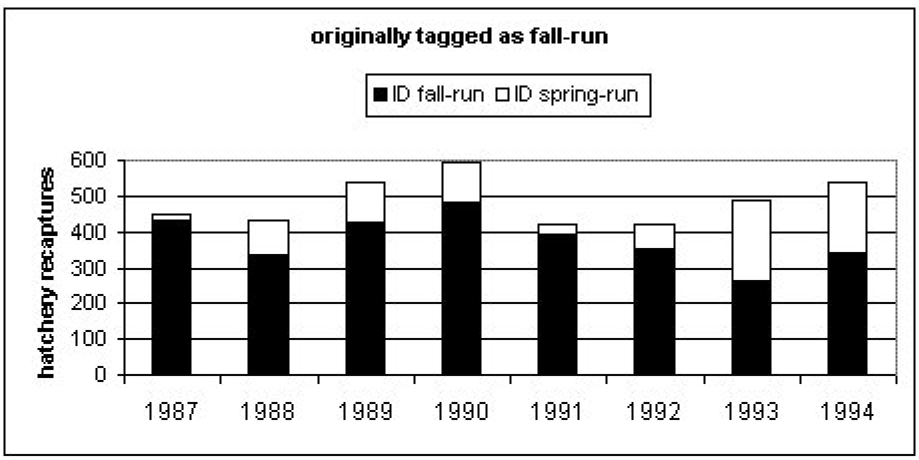


Figure 5-11 The disposition of Chinook salmon spawned, tagged, and released as fall-run from FRH.

Trinity River Coho Salmon

Coho Salmon (*Oncorhynchus kisutch*) in the Trinity River are in the Southern Oregon/Northern California Coast coho salmon ESU, which was listed as threatened under the ESA on June 18, 2005 (70 FR 37160). The Southern Oregon/Northern California Coast coho ESU extends from Punta Gorda on the south to Cape Blanco in Oregon.

Life History

Coho salmon exhibit a 3-year life cycle in the Trinity River and are dependent on freshwater habitat conditions year round because they spend a full year residing in freshwater. Most coho salmon enter rivers between August and January with some more northerly populations entering as early as June. Coho salmon river entry timing is influenced by a number of factors including genetics, stage of maturity, river discharge, and access past the river mouth. Spawning is concentrated in riffles or in gravel deposits at the downstream end of pools with suitable water depth, velocity, and substrate size. Spawning in the Trinity River occurs mostly in November and December.

Coho salmon eggs incubate from 35 to more than 100 days depending on water temperature, and emerge from the gravel 2 weeks to 7 weeks after hatching. Coho eggs hatch after an accumulation of 400 to 500 temperature units measured in degrees Celsius and emerge from the gravel after 700 to 800 temperature units. After emergence, fry move into areas out of the main current. As coho grow they spread out from the areas where they were spawned.

During the summer, juvenile coho prefer pools and riffles with adequate cover such as large woody debris with smaller branches, undercut banks, and overhanging vegetation and roots. Juvenile coho overwinter in large mainstem pools, beaver ponds, backwater areas, and off-channel pools with cover such as woody debris and undercut banks. Most juvenile coho salmon spend a year in freshwater with some northerly populations spending 2 full years in freshwater. Coho in the Trinity River are thought be be exclusively three year lifecycle fish (one year in freshwater). Because juvenile coho remain in their spawning stream for a full year after emerging from the gravel, they are exposed the full range of freshwater conditions. Most smolts migrate to the ocean between March and June with most leaving in April and May.

Coho salmon typically spend about 16 to 18 months in the ocean before returning to their natal streams to spawn as 3- or 4-year olds, age 1.2 or 2.2. Trinity River coho are mostly 3-year olds. Some precocious males, called jacks, return to spawn after only 6 months in the ocean.

Trinity River Coho Population Trends

Coho salmon were not likely the dominant species of salmon in the Trinity River before dam construction. Coho were, however, widespread in the Trinity Basin ranging as far upstream as Stuarts Fork above Trinity Dam. Wild coho in the Trinity Basin today are not abundant and the majority of the fish returning to the river are of hatchery origin. An estimated 2 percent (200 fish) of the total coho salmon run in the Trinity River were composed of naturally produced coho from 1991 through 1995 at a point in the river near Willow Creek (FWS 1998). This in part prompted the threatened status listing in 1997. Recapture estimates of coho salmon run size conducted since 1977 are shown in Figure 5-12. These estimates included a combination of hatchery produced and wild coho. Figure 5-13 shows the estimated natural and hatchery contribution to the coho run in 1997 – 2005. About 10 percent of the coho were naturally produced since 1995.

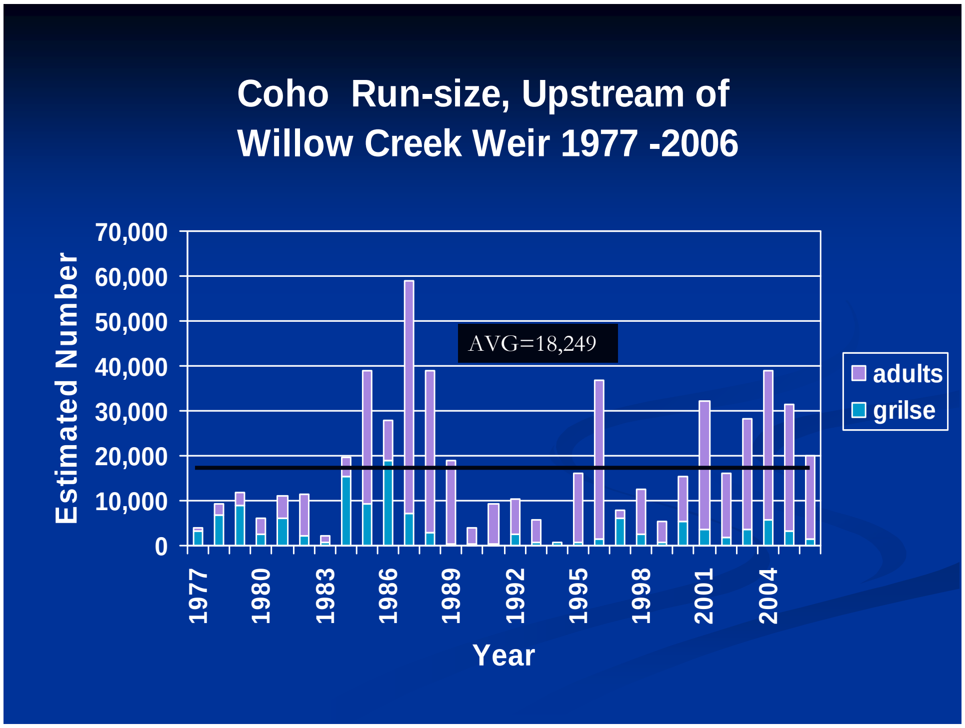


Figure 5-12 Trinity River adult coho salmon escapement, 1977 – 2006.

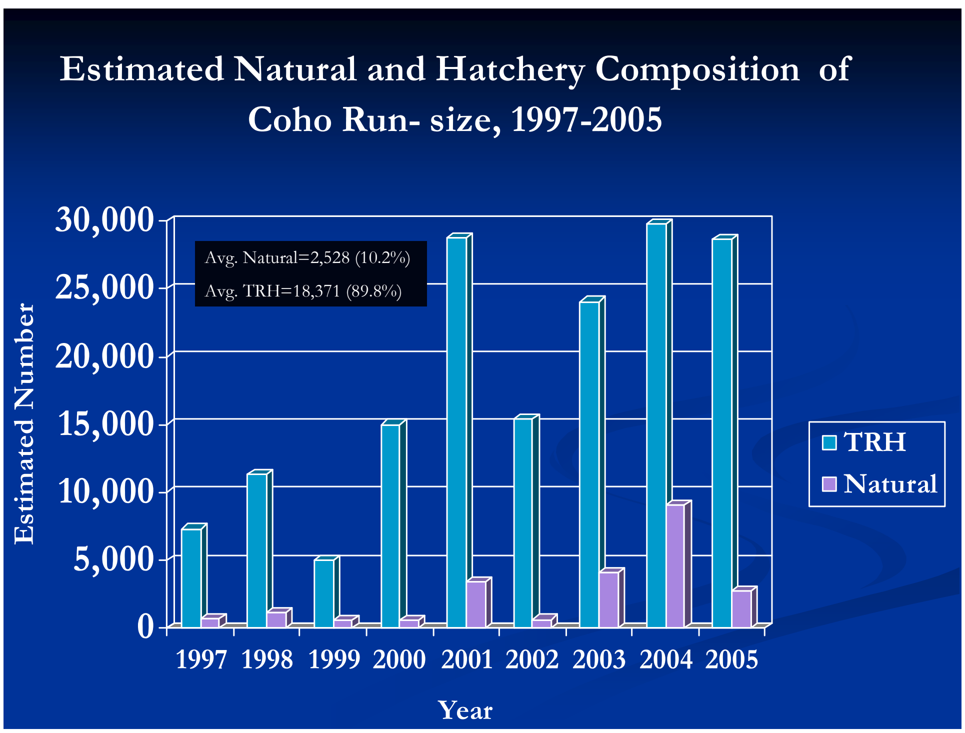


Figure 5-13 Trinity River adult coho salmon escapement 1997 – 2005 separated into hatchery and naturally spawned fish.

Critical Habitat

The spring run Chinook critical habitat potentially affected by CVP and SWP operations includes the Sacramento River up to Keswick Dam, Clear Creek up to Whiskeytown Dam, the Feather River up to the fish barrier dam, and the American River up to Watt Avenue. Winter run Chinook salmon critical habitat includes the Sacramento River from Keswick Dam downstream to the Delta and includes the northern Delta and northern part of San Francisco Bay to the Golden Gate Bridge (Figure 5-14).

Spawning Habitat

Winter run Chinook in spawn only in the Sacramento River mostly (99%) upstream of Balls Ferry based on current aerial redd survey data collected since passage was provided past the ACID diversion dam. Spawning occurs May through July with the peak in early June.

Spring run Chinook in the Sacramento River spawn mostly (99%) upstream of Jellys Ferry bridge, based on current aerial redd survey data (2001-2004) that was collected under current river conditions. Spring run spawning is not as concentrated in the upstream area immediately above and below ACID Dam as is the winter run spawning distribution. Spring run in Clear Creek spawn mostly upstream of a weir that is installed each year near Igo to prevent putative spring run from spawning with fall run. Spring run in the Feather River spawn primarily in the low flow channel with the highest concentration in the uppermost mile, near the hatchery fish ladder (DWR 2006, Brad Cavallo personal communication). The section of the American River denoted as critical habitat (up to Watt Avenue) serves only as juvenile rearing habitat. There is no spring run spawning in the American River. The Stanislaus River and San Joaquin River contain no spring run critical habitat.

Freshwater Rearing Habitat

Winter run begin to emerge in August and continue into October. A majority of the winter run fry move downstream past Red Bluff soon after emergence. A small proportion remains upstream into the winter and spring. The fry that move downstream early move slowly, and probably sporadically, stopping in suitable habitat to feed and grow. They begin to reach the Delta as early as November but generally peak past the first of the year.

Spring run in the Sacramento River start to emerge from the gravel in December. Many Chinook emigrate as fry but a small proportion of spring run rear for up to a year in the upstream portion of the river. Because of the timing overlap with the abundant fall run, separation of the juveniles of the run based on size is inaccurate, making spring run rearing habitats difficult to differentiate from fall run, but they likely use the same habitats. Rearing for most of the spring run occurs during the winter when water temperatures are suitable throughout the system. Some spring run hang out in the rivers near the spawning habitat until they are ready to emigrate. When they emigrate, either as fry or juveniles, they gradually make their way towards the ocean during winter and spring. Emigration from the upper rivers to the ocean generally takes about one to three months. The spring run juveniles that remain in the rivers over the summer are confined to the upstream areas of the rivers where cool water temperatures are maintained by dam releases. This includes over 100 miles of the Sacramento River, 10 miles in Clear Creek, and about 8 miles in the Feather River. The lower American River is classified as critical habitat for spring run rearing up to Watt Avenue. This area contains suitable water temperatures for Chinook rearing from about December through April of most years.

Freshwater Migration Corridors

Adult winter run migrate up to the spawning area during the winter and spring months. The juveniles emigrate downstream between August and May. Spring run Chinook emigrate during the winter and spring months (December through May). Strategic closure of the DCC gates, in tandum with river monitoring, helps facilitate the outmigration of juvinile Chinook salmon. Flows probably play a greater role in assisting emigration for spring run than for steelhead, due to their smaller size. Pulse flows that occur during precipitation events tend to stimulate downstream movement along the Sacramento River. The higher water velocities during the higher flow events assist juvenile Chinook in reaching the estuary safely. Once Chinook salmon reach the ocean their growth increases substantially in most years with abundant food resources.

Estuarine Areas

Winter and spring run Chinook use the San Francisco estuary as a rearing area and migration corridor between their upstream rearing habitat and the ocean. The San Francisco Bay estuarine system includes the waters of San Francisco Bay, San Pablo Bay, Grizzley Bay, Suisuin Bay, Honker Bay, and can extend as far upstream as Sherman Island during dry periods. Chinook gradually make their way downstream moving with the tidal currents. At times, juvenile Chinook likely remain for extended periods in areas of suitable habitat when food such as anchovies, young herring, large zooplankters and other aquatic invertebrates is available.

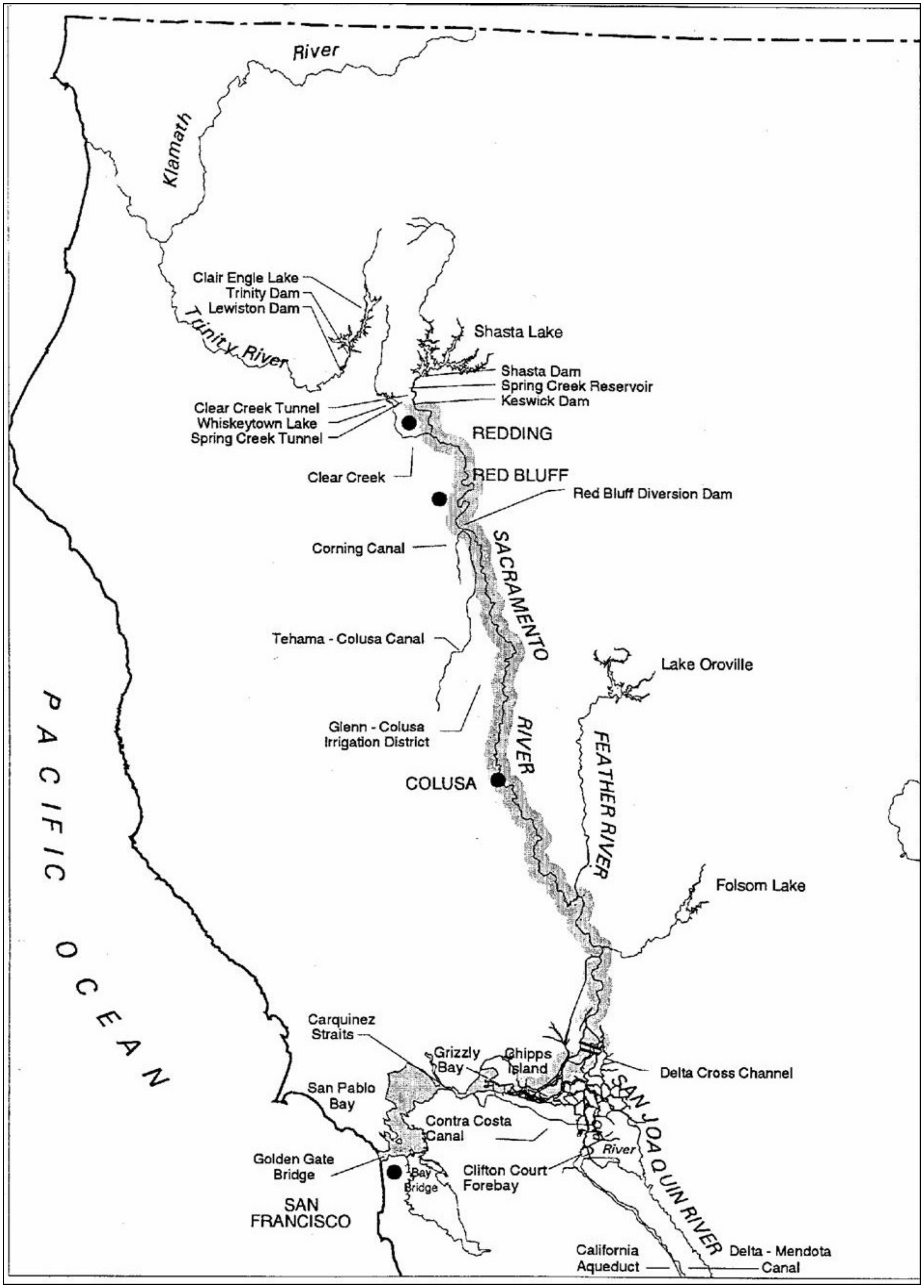
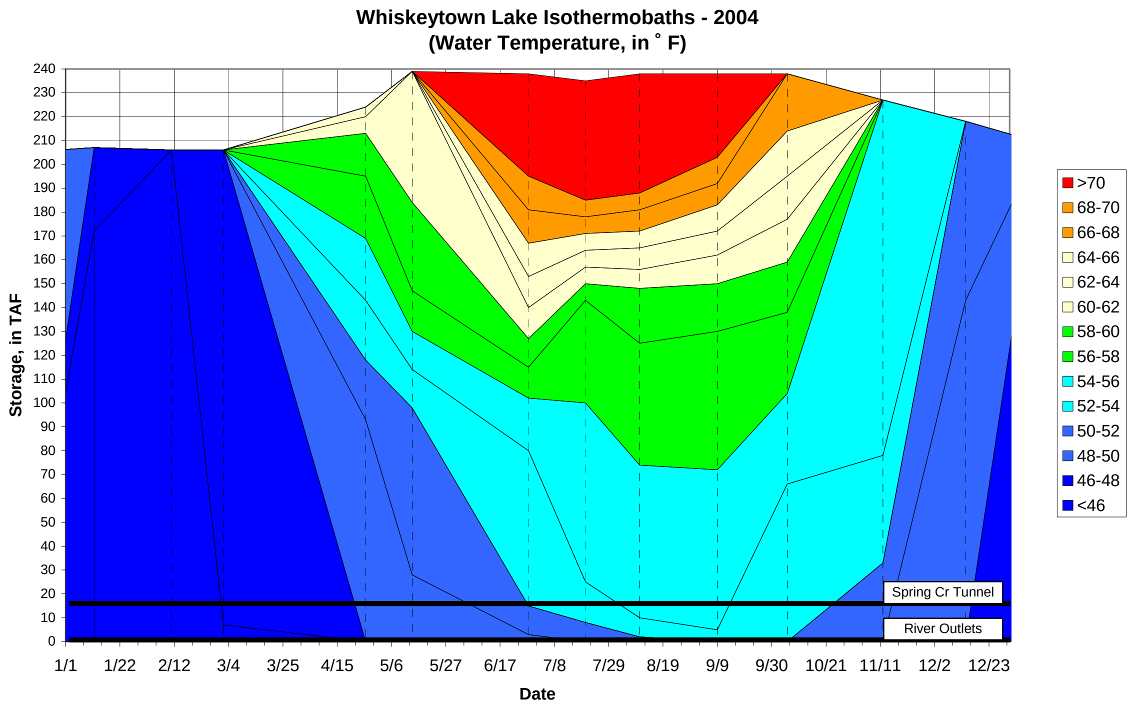


Figure 5-14 Winter Run Chinook salmon critical habitat.

Effect of Reduced Trinity River Diversions on Clear Creek Critical Habitat for Spring run and Steelhead

Implementation of the Trinity River Restoration Program Record of Decision increased flows in the lower Trinity River and decreased diversions into the Sacramento River Basin. Now less water passes through Whiskeytown Reservoir than prior to the Trinity decision. Because less cool Trinity River water passes through Whiskeytown Reservoir there may be increased heating of the water as it passes through with the lower thermal mass. This appeared to result in a slightly warmer release into lower Clear Creek in 2005 than in prior years. The warmer temperatures occurred primarily during September and October (Figure 5-15). This period coincides with the incubation period for spring run Chinook salmon when the target temperature is a mean daily average of 56 °F or below at Igo (NMFS 2004). The mean of the mean daily temperatures during the period June 1 through September 15 in 1996 through 2004 was 58.1 °F and in 2005 it was also 58.1 °F. The mean of the mean daily temperatures during the period September 15 through October 31 in 1996 through 2004 was 54.2 °F. The mean of the mean daily temperatures for this same period in 2005 was 56.7 °F. The warmer temperatures that occurred in the latter part of the temperature control season in 2005 are a tradeoff for the improved flow and temperature conditions being provided in the Trinity River.

The higher temperatures occurred during the spring run incubation period and on average exceeded the 56 °F target temperature by 0.7 °F. Chinook salmon eggs in other rivers (eg. American River) survive at high rates, at least in the hatchery, when spawned at 60 °F as long as the water temperature quickly declines to 56°F. Temperatures in Clear Creek dropped to 50 °F by the end of November in 2005. Therefore, effects of the slightly higher temperatures during early incubation for spring run Chinook in 2005 were expected to be negligible. Similar temperature conditions will likely occur in future years. A larger volume of water from the Trinity River goes to the Sacramento River through the Spring Creek tunnel than goes to Clear Creek. The Spring Creek tunnel water is used primarily to help cool the Sacramento River during the heat of the summer for winter run Chinook spawning and incubation. The higher volume going to the Sacramento River necessitates operating the system primarily for Sacramento River temperature targets. Clear Creek receives the same temperature water as what goes to the Sacramento. This has generally provided suitable Clear Creek temperature conditions most of the time in the past. Daily temperature fluctuation in Clear Creek at Igo peaks in June and July when days are the longest at around 8 °F difference between the high and low temperature for the day (Figure 5-15).



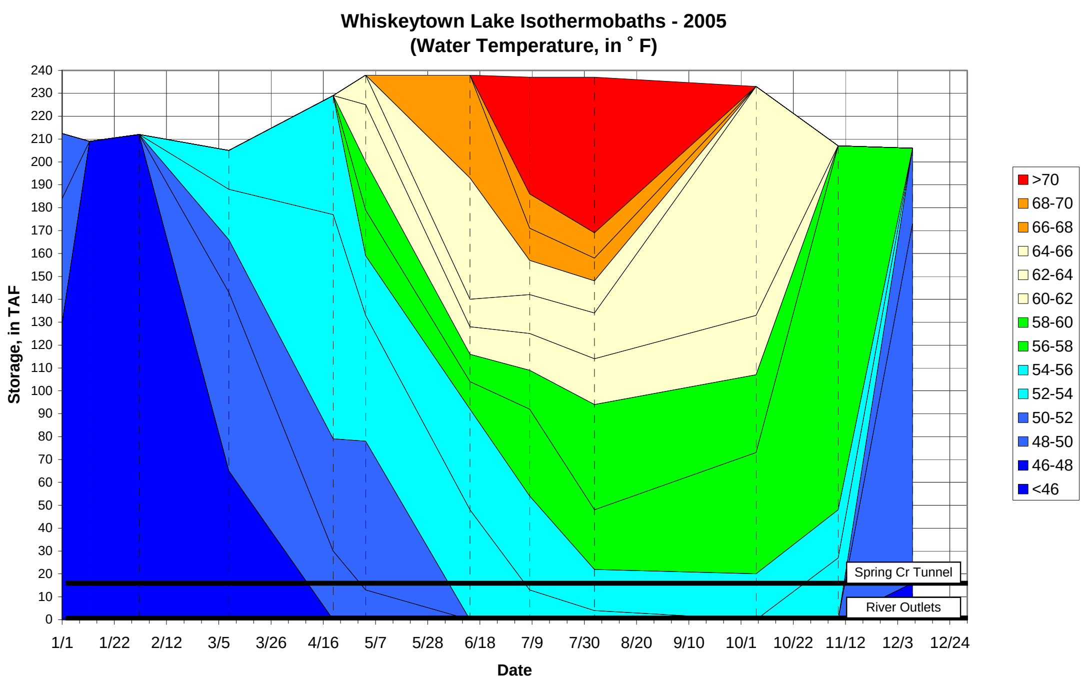


Figure 5-15 Whiskeytown Lake Isothermobaths, 2004 (top) and 2005 (bottom)

Table 5-13 Spring Creek tunnel release volume, 1999-2004 compared to 2005.

Spring Creek Tunnel Volume (thousand acre feet)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
2005	28.7	26.2	60.2	10.0	60.2	47.7	51.7	70.2	68.7	62.6			
2004	54.4	111.7	202.6	123.8	19.4	89.0	133.6	89.8	95.0	156.3	8.7	26.3	1110.6
2003	84.0	84.1	86.7	47.7	114.2	109.4	92.8	150.7	137.1	122.4	65.9	49.5	1144.5
2002	71.1	27.6	23.2	7.2	41.1	103.8	131.2	131.0	57.8	80.8	16.4	84.0	775.2
2001	36.9	68.9	75.2	18.7	32.0	92.4	159.2	154.0	108.2	121.6	0.0	53.9	921.0
2000	42.0	89.8	148.9	122.3	158.7	167.6	193.8	203.4	117.5	31.6	5.4	16.8	1297.8
1999	102.0	86.0	130.6	100.0	95.1	128.9	142.0	95.5	91.0	31.7	45.8	38.8	1087.4
AVG 99-04 =	65.1	78.0	111.2	70.0	76.8	115.2	142.1	137.4	101.1	90.7	23.7	44.9	1056.1
2005 % Diff	-56%	-66%	-46%	-86%	-22%	-59%	-64%	-49%	-32%	-31%			

Consideration of the Risks Associated with Hatchery Raised Mitigation Fish

Reclamation funds the operation of Coleman Hatchery, Livingston Stone Hatchery, Nimbus Hatchery, and Trinity River Hatchery. DWR funds the operation of the Feather River Hatchery. The FWS operates Coleman and Livingston Stone Hatcheries and DFG operates Feather River, Nimbus, and Trinity Hatcheries. These hatcheries are all operated to mitigate for the anadromous salmonids that would be produced by the habitat if not for the dams on each respective river. Reclamation and DWR have discretion over how the hatcheries are operated but generally leave operational decisions on how to meet mitigation goals up to the operating agency.

Most hatchery production releases from the American and Feather Rivers are released in San Pablo Bay. The bay releases have been suspected of causing increased rates of returning adults straying into tributaries other than their tributary of origin. Examination of CWT data from the American River from 2001 and 2002 shows that straying was not as high as was suspected. Out of a contribution from Nimbus Hatchery to the Central Valley escapement of nearly 80,000 Chinook in run years 2002-2004 only about 2.8 percent (2,193 fish) returned to rivers other than the American (Table 5-14). This is well within a straying rate that could be considered normal for wild fish. The highest percentage of strays from the American (0.7%) occurred in the Feather/Yuba River system.

Table 5-14 Contribution of Nimbus Hatchery Chinook from brood year 2000 and 2001 to Central Valley rivers.

Contribution of Nimbus Hatchery Fish from BY 2000 and BY 2001 to Central Valley Rivers

Sum of Contribution	runyr					
sampsite	2002	2003	2004	Grand Total	Percent of total	
ABRB			142	142	0.2%	Sacramento River (abov
AMN	2,406	49,887	12,604	64,897	82.3%	American River, in-river
BUT		25	21	46	0.1%	Butte Creek
FEA	214			214	0.3%	Feather River
FRH		14	3	17	0.0%	Feather River Hatchery
GUAD		7		7	0.0%	?
LFC			90	90	0.1%	Feather Low Flow Chan
MER		76	52	128	0.2%	Merced
MOK	166	564	55	784	1.0%	Mokelumne
MRFI			65	65	0.1%	Mokelumne River hatch
MRH	116	50	22	188	0.2%	Merced Hatchery?
NFH	1,797	6,769	2,777	11,343	14.4%	Nimbus Hatchery
SAA	397			397	0.5%	Carquinez to American
STA		110	56	166	0.2%	Stanislaus
TUO	7	81	11	99	0.1%	Tuolumne
YUB	27	220		247	0.3%	Yuba
Grand Total	5,130	57,802	15,897	78,829	100.0%	

Total straying of Nimbus hatchery fish 2002-2004
(sum of contribution recovered in rivers other than American)
2,193
2.8% recovered in other rivers compared to American

Feather River Spring-Run Chinook Straying and Genetic Introgression

Prior to the construction of numerous dams (including the Oroville Dam) on the Feather River, spawning spring- and fall-run Chinook salmon were temporally and spatially separated—i.e., spring-run Chinook salmon spawned earlier and in higher reaches of the watershed compared to fall-run Chinook salmon. Although data are limited, there is a general consensus that there were once genetically distinct Chinook salmon runs in the Feather River system (Lindley et al. 2004; Yoshiyama et al. 2001).

Today, the Fish Barrier Dam blocks the early-returning (arriving in April through June) run of sexually immature adult Chinook salmon in the Feather River from moving upstream to historical spawning habitat. As there is overlap in the timing of spawning, this spring-run Chinook salmon now spawns in the same location as the more numerous later-returning fall-run Chinook salmon. Findings of recent genetic studies using microsatellite markers suggest that: (1) Feather River Hatchery (FRH) produced spring-run Chinook salmon are genetically similar to fall-run Chinook salmon and (2) phenotypic in-river spring-run Chinook salmon are genetically more similar to fall-run Chinook salmon than to spring-run Chinook salmon populations in Mill, Deer, and Butte creeks (Banks et al. 2000; Hedgecock et al. 2001; DWR 2004a).

A review of available literature suggests two opportunities for genetic introgression in the Feather River:

- Introgression between spring- and fall-run Chinook salmon in the Feather River;
- Introgression between hatchery-produced and wild spring-run Chinook salmon in the Feather River; and
- Straying and introgression between Feather River spring-run Chinook salmon and spring-run Chinook salmon in other systems.

Introgression Between Spring- and Fall-Run Chinook Salmon.

Under the No-Action Alternative, conditions will continue to promote the commingling of spring-run and early maturing fall-run Chinook salmon on common spawning grounds, leading to increased opportunities for genetic introgression (hybridization) between spring- and fall-run Chinook salmon in the Feather River. In fact, data collected over the past 5 years by DWR on spawning populations of Chinook salmon in the Feather River do not show a bimodal peak that would be expected if there were temporally distinct spawning populations (DWR 2004a). In addition, under the No-Action Alternative, continued hatchery practices—specifically, the inability to distinguish between spring- and fall-run Chinook salmon when artificially spawning—will continue to be an additional contributor to the observed genetic introgression. Data on the returns of tagged fish suggest that there may have been considerable cross-fertilization between nominal spring- and fall-run Chinook salmon at the FRH (DWR 2004a) over the past several years, and probably since the hatchery began operation in 1967.

Introgression Between Hatchery-Produced and Wild Spring-Run Chinook Salmon.

One of the key questions about Feather River Chinook salmon involves the genetic and phenotypic existence of a spring run, and the potential effects of the FRH on this run. The Feather River's nominal spring run is part of the spring-run ESU and is thus listed as threatened. Conversely, the hatchery population is not included in the ESU. The nominal spring- and fall-run Chinook salmon in the Feather River are genetically similar and are most closely related to CV fall-run Chinook salmon. There is a significant phenotypic spring run that arrives in the Feather River in May and June and enters the FRH when the ladder to the hatchery was opened. Observations of these early arriving Chinook salmon cast doubt on the presence of a Feather River spring-run, as opposed to a hatchery spring-run. Nonetheless, under the No-Action Alternative, conditions will continue the commingling of hatchery-produced and wild spring-run Chinook salmon, leading to increased opportunities for domestication of wild populations.

Due to the lack of pre-Oroville Facilities genetic data, the genetic identity of the historic Feather River spring-run Chinook salmon cannot be definitively ascertained. However, it appears that the early arriving, immature Chinook salmon run in the Feather River does not resemble current day spring-run populations in Mill, Deer, and Butte creeks. There are no data on the potential effects (e.g., reduced fitness) of inbreeding or outbreeding of FRH-produced Chinook salmon. In addition, there are no data indicating that spring-run timing on the Feather River is an inheritable trait and the loss of this phenotype would adversely affect the recovery of the CV spring-run Chinook salmon ESU (DWR 2004a). Nonetheless, under the No-Action Alternative, continued operation of the Oroville Facilities is anticipated to continue to contribute to the ongoing genetic introgression currently observed under existing conditions.

Straying and Introgression with Spring-Run Chinook Salmon in Other Systems.

As part of existing operations, FRH-produced Chinook salmon are transported and released into San Pablo Bay. This hatchery practice was intended to reduce/avoid the mortality associated with migrating through the Sacramento-San Joaquin Delta. However, data suggest that the practice of releasing to San Pablo Bay increased the incidence of straying of FRH-produced Chinook salmon (DWR 2004a). Straying can lead to increased competition for spawning habitat and exchange of genetic material between hatchery and naturally spawning Chinook salmon (Busack and Currens 1995).

To analyze the role that hatcheries play in influencing straying rates, DFG used mark-and-recapture data (coded wire recoveries) in the ocean fisheries to reconstruct the 1998 fall-run Chinook salmon cohort from the FRH (Palmer-Zwahlen et al. 2004). This analysis was used to determine the rate at which fish released in the estuary return to the Feather River and to other streams (the stray rate). DFG estimated that of the approximately 44,100 FRH-produced fish that returned to the Central Valley, 85 percent returned to the Feather River (including the FRH), 7 percent were caught in the lower Sacramento River sport fishery, and 8 percent strayed to streams outside the Feather River basin. If salmonids returned to the Feather River in the same proportion as observed in other river systems, the straying rate would be estimated to be approximately 10 percent (DWR 2004a). Although tags from FRH-produced fish were collected in most Central Valley streams sampled, about 96 percent of the 12,438 tags recovered during the 1997 to 2002 period were collected in the Feather River or at the FRH.

A lower percentage of in-basin releases than bay releases survived to reenter the estuary as adults (0.3 percent versus 0.9 percent); however, these fish returned to the Feather River with greater fidelity (approximately 95 percent as compared to around 90 percent for bay releases). Although the straying rate from bay releases is less than might be expected based on earlier studies, it is still higher than natural straying rates and higher than the 5 percent straying rate recommended as a maximum by NMFS. Before rendering definitive conclusions, it should be noted that there are several limitations in the existing data:

- Cohort analysis was only for one broodyear;
- Tag recovery efforts on most Central Valley streams do not provide statistically reliable estimates of the number of tagged fish in the spawning populations; and
- There is a significant inland sport fishery and, in recent years, sampling of this fishery and collecting tags has been spotty because of budget cuts.

It should be noted that based on tag return and genetic data, minimal interbreeding appears to have occurred between FRH spring-run Chinook salmon and spring-run Chinook salmon in Butte, Mill, and Deer creeks. Only a few FRH-produced Chinook salmon have been collected in the lower portions of Deer, Mill, and Butte creeks, in sections supporting fall-run spawning activity. In addition, the genetic structure of spring-run Chinook salmon in the Feather River is distinct from spring-run Chinook salmon from Deer, Mill, and Butte creeks.

Feather River Spring-Run Chinook Susceptibility to Disease

Susceptibility to disease is related to a variety of factors, including fish species, fish densities, the presence and amounts of pathogens in the environment, and water quality conditions such as temperature, DO, and pH. Oroville Facilities operations have the potential to affect all of these factors at the FRH and in the Feather River downstream of the Oroville Facilities.

Several endemic salmonid pathogens occur in the Feather River basin, including *Ceratomyxa shasta* (salmonid ceratomyxosis), *Flavobacterium columnare* (columnaris), the infectious hematopoietic necrosis (IHN) virus, *Renibacterium salmoninarum* (bacterial kidney disease [BKD]), and *Flavobacterium psychrophilum* (cold water disease) (DWR 2003a). Of the fish pathogens occurring in the Feather River basin, those that are main contributors to fish mortality at the FRH (IHN and ceratomyxosis) are of highest concern for fisheries management in the region. Although all of these pathogens occur naturally, the Oroville Facilities have the opportunity to produce environmental conditions that are more favorable to these pathogens than under historic conditions:

- Impediments to fish migrations may have altered the timing, frequency, and duration of exposure of anadromous salmonids to certain pathogens;
- Out-of-basin transplants may have inadvertently introduced foreign diseases; and
- Water transfers, pumpback operations, and flow manipulation can result in water temperature changes, which potentially increase the risk of disease.

The transmission of disease from hatchery fish to wild fish populations is often cited as a concern in fish stocking programs. There is, however, little evidence of disease transmission between hatchery fish and wild fish (Perry 1995). Further, the FRH has implemented disease control procedures (e.g., disinfecting procedures) that are intended to minimize both the outbreak of disease in the hatchery and the possibility of disease transmission to wild fish populations.

Field surveys indicated that IHN was not present in juvenile salmonids or other fish in the Feather River watershed (DWR 2004a). Eighteen percent of the adults returning to the Feather River watershed were infected with IHN, but there were no clinical signs of disease in these fish. The hypothesis advanced by DFG pathologists for the cause of the recent IHN epizootics at the FRH is that planting Chinook salmon in Lake Oroville (in the hatchery water supply) resulted in the virus entering the hatchery. Hatchery conditions can then lead to stress and the infections can rapidly escalate to clinical disease, as evidenced by high mortality. No additional epizootics have been observed since the plantings of Chinook salmon in the reservoir were brought to an end. Whether the cessation of stocking Chinook salmon will prevent future IHN outbreaks at the FRH is uncertain, as the cause of specific disease outbreaks in Oroville Facilities waters is poorly understood (DWR 2004a).

Under the No-Action Alternative, continued operations of the Oroville Facilities are anticipated to result in potential exposures to pathogens similar to that currently observed under existing conditions.

Summary of the Environmental Baseline

Environmental baseline, as defined in 50 CFR 402.02, "includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action are that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process." The prior information in this chapter provides the status of winter run Chinook, spring run Chinook, and coho salmon in the action area, which has resulted from the past and present impacts of activities in the action area. The Sacramento River winter-run Chinook salmon ESU is restricted to one population entirely contained within the action area. Construction of the Livingston Stone National Fish Hatchery in 1996 has safeguarded the natural population since the critically low abundance of the 1990's. Improvements in CVP operations since 1993 include: changes in operations pursuant to the 1993 winter-run Chinook salmon biological opinion, construction of a temperature control device on Shasta Dam in 1998, opening the gates at RBDD for longer periods of time, and periodic closures of DCC gates. These required actions have helped to bring the winter-run Chinook population to within 50 percent of the recovery goal. In addition, improvement of critical habitat from CVPIA gravel augmentation projects and increased restrictions on recreational and commercial ocean harvest of Chinook salmon since 1994, likely have had a positive impact on winter-run Chinook salmon adult returns to the upper Sacramento River (NOAA Fisheries 2003, 69 FR 33102).

The spring-run Chinook salmon ESU is comprised mainly of three self-sustaining wild populations (Mill, Deer and Butte creeks) which are outside of the action area; however, all migratory life stages must past through the Project action area. These three populations have been experiencing positive growth rates since the low abundance levels of the late 1980s. Restrictions on ocean harvest to protect winter-run Chinook salmon and improved ocean conditions have likely had a positive impact on spring-run Chinook salmon adult returns to the Central Valley (NOAA Fisheries 2003, 69 FR 33102). Abundance for the key indicator streams, Mill, Deer and Butte Creeks, are at historical levels. Current risks to the remaining populations include continuing habitat degradation related to water development and use, high water temperatures during the summer adult holding period, and the operations of the Feather River Hatchery.

The Trinity River portion of the Southern Oregon/Northern California Coast coho salmon ESU is predominately of hatchery origin. Termination of hatchery production of coho salmon at the Mad River and Rowdy Creek facilities has eliminated further potential adverse risks associated with hatchery releases from these facilities. Likewise, restrictions on recreational and commercial harvest of coho salmon since 1994 likely have had a positive impact on coho salmon adult returns to SONCC coho salmon streams (NOAA Fisheries 2003, 69 FR 33102). The DFG developed a state-wide coho salmon recovery plan in 2004.

Chapter 6 describes the factors that affect the species and critical habitat in the action area. A large factor affecting the listed salmonids is the loss of spawning and rearing habitat upstream of impassable dams. High water temperatures in these lower elevations are a stressor to adult and juvenile life stages. The limiting factors that affect the likelihood of survival are high temperatures, low flows, limited spawning and rearing habitat, blocked or delayed passage, unscreened diversions, and flow fluctuations.

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