Table 4–7 Salvage of unclipped steelhead, 1993 - 2003 at the CVP and SWP Delta fish salvage facilities and percent of salvage adipose clipped.

Unclipped Steelhead Salvage				Percent of salvage adipose clipped		
Year	CVP	SWP	Total	CVP	SWP	combined
1993	6,864	9,673	16,537	1	4	3
1994	974	337	1,311	3	7	4
1995	1,176	993	2,169	1	3	2
1996	1,966	3,117	5,083	8	2	4
1997	564	205	769	2	11	5
1998	420	41	461	44	47	45
1999	1,426	942	2,368	5	11	7
2000	1,666	2,257	3,923	44	65	58
2001	1,637	2,834	4,471	64	65	65
2002	959	686	1,645	42	68	56
2003	929	1,245	2,174	87	78	83
Grand Total	18,581	22,329	40,910	38	42	40

Table 4–8 Average monthly total (clipped and unclipped) steelhead salvage at the Delta fish facilities, 1981-2002.

	SWP	CVP	*Total*
January	438	475	913
February	1,465	917	2,382
March	1,687	1,223	2,910
April	1,488	573	2,060
May	302	270	572
June	56	27	84
July	14	75	89
August	4	0	4
September	0	0	0
October	24	0	24
November	149	16	165
December	171	259	430

This BA may be confounded by hatchery fish, which constitute the majority of steelhead in the Central Valley. Since 1998, Central Valley hatcheries have attempted to clip the adipose fins of all hatchery-produced steelhead, enabling us to estimate the proportion of naturally spawned steelhead smolts emigrating through the Delta. The proportions of adipose fin-clipped steelhead are shown in Table 4–7.

If hatcheries continue to clip the adipose fins of all hatchery-reared steelhead, the FWS Chipps Island Trawl may eventually also be a useful tool for devising an emigration abundance index specifically for naturally-spawned steelhead that can be compared to salvage or other potential influencing factors.

Yolo Bypass

The Yolo Bypass is the primary floodplain of the Sacramento River basin. It is a 59,000 acre leveed basin which conveys flood flows from the Sacramento Valley including the Sacramento River, Feather River, American River, Sutter Bypass and westside streams. The 40-mile long floodplain seasonally floods in winter and spring in about 60 percent of water years, when it is designed to convey up to 500,000 cfs. Under typical flood events, water spills into Yolo Bypass via Fremont Weir when Sacramento basin flows surpass approximately 75,000 cfs. Water initially passes along the eastern edge of the Bypass through the Toe Drain channel, a riparian corridor, before spreading throughout the floodplain. During dry seasons, the Toe Drain channel remains inundated as a result of tidal action. At higher levels of Sacramento Basin flow, the Sacramento Weir is also frequently operated by removal of flashboards. Westside streams such as Cache and Putah Creeks and Knight's Landing Ridge Cut may also be substantial sources of flow. The habitat types include agriculture, riparian, wetlands and permanent ponds.

DWR staff have been conducting fish studies in the Yolo Bypass for the past several years (Harrell and Sommer, In Press). They believe that Fremont Weir, the northernmost part of the Yolo Bypass, is a major impairment to fish passage in the lower Sacramento basin. The key problems are summarized below. Take authorization for the Yolo Bypass studies has already been authorized through a process separate from the OCAP.

Adult Passage During Low Flow Periods

Fyke trap monitoring by DWR since 2000 shows that adult salmon and steelhead migrate up through the Toe Drain in autumn and winter regardless of whether Fremont Weir spills (Harrell and Sommer, In Press). The Toe Drain does not extend all the way to Fremont Weir because there are several locations where the channel is blocked by roads or other higher ground. Even if the channel extended all the way to Fremont Weir, there are no facilities at the weir to pass upstream migrants at lower flows. Therefore, unless there is overflow into the Yolo Bypass, fish cannot pass Fremont Weir and migrate further upstream to reach the Sacramento River. DWR staff has evidence that this is a problem for fall-run, winter-run, and spring-run Chinook salmon and steelhead.

Adult Passage During High Flow Periods

During high flow events water spills from the Sacramento River via Fremont Weir. These flow events attract substantial numbers of upstream migrants through the Yolo Bypass corridor, which can often convey the majority of the Sacramento basin flow (Harrell and Sommer, In Press). At all but the highest flows (for example, 100,000 cfs), it appears that there is an elevation difference between Yolo Bypass and Sacramento River at the weir. This creates a 1.5-mile long migration barrier for a variety of species, but fish with strong jumping capabilities, such as salmonids, may be able to pass the barrier at higher flows. Although there is a fish ladder (maintained by DFG) at the center of the weir, the ladder is tiny, outdated and exceptionally inefficient. Field and anecdotal evidence suggests that this creates major problems for sturgeon and sometimes salmonids. These species are attracted by high flows into the basin, and then become "concentrated" behind Fremont Weir. They are subject to heavy legal and illegal fishing pressure.

Juvenile Passage

Yolo Bypass has the potential to strand salmonids as floodwaters recede (Sommer et al. 1998). Sixty-two juvenile steelhead were captured during the 1998-99 Yolo Bypass study (58 in 1998; four in 1999) (DWR unpublished data). Twenty-four (38.7 percent) were adipose fin-clipped; 54 (87 percent) of the steelhead were captured in a RST in the Yolo Bypass Toe Drain. The remainder were captured in beach seine hauls in the scour ponds immediately below the Fremont and Sacramento Weirs.

The 1998 Yolo Bypass Toe Drain RST CPUE for steelhead is shown in Figure 4–4. The data indicate steelhead emigrate off the floodplain near the end of drainage cycles. However, small sample size, hatchery releases, and improved gear efficiency during drainage events may confound results. Stranding estimates were not attempted because steelhead were not collected in beach seine hauls outside the scour ponds mentioned above. Although 50-foot beach seines are inefficient at sampling large fish, we do not believe steelhead were stranded in large numbers. Sommer et al. (1998) found most juvenile salmon emigrated off the floodplain as it drained. In later studies, they found that young salmon grew significantly faster in Yolo Bypass than the adjacent Sacramento River, with some evidence of higher survival rates (Sommer et al. 2001). The available evidence suggests steelhead show a similar response to floodplain drainage.

The stomach contents of eight adipose fin-clipped steelhead captured during the 1998 screw trap survey were examined before they were turned over to FWS for coded-wire-tag (CWT) extraction (Table 4–9). The diet data are biased by the artificial feeding opportunities present in the screw trap live box, but they support the hypothesis that steelhead may use the Yolo Bypass as a rearing habitat since they were feeding as they emigrated.

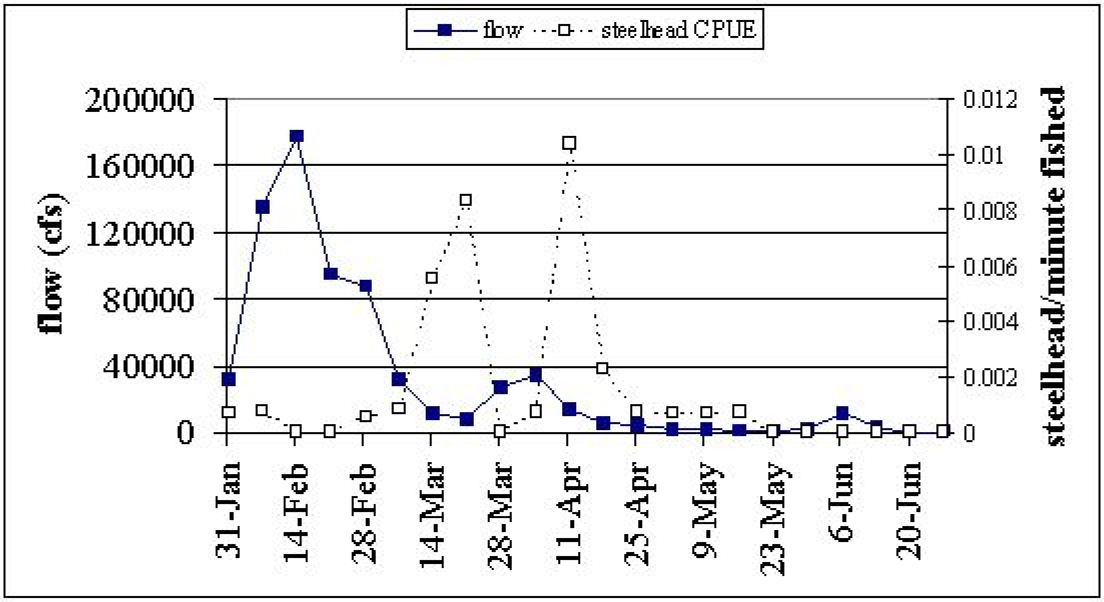

Figure 4–4 Steelhead catch per minute from the Yolo Bypass Toe Drain RST and total Yolo Bypass flow, 1998.

Table 4–9 Stomach contents of adipose fin-clipped steelhead captured in Toe Drain of Yolo Bypass 1998 (DWR unpublished data).

Collection date	*Water temperature (F)*	*Fork length (mm)*	*Stomach contents*
3/1	53	225	8 Chinook salmon (30-50 mm FL); 1 pikeminnow (50 mm FL); 1 unidentified fish; 1 dipteran pupa
3/6	52	217	Empty, but gut distended as if prey recently evacuated
3/6	52	247	4 Chinook salmon (40-50 mm FL); 2 inland silversides (70 mm FL)
3/7	51	234	Empty
3/10	55	234	Empty
3/10	55	206	Larval chironomid remains; Damselfly remains
3/10	55	238	Empty
4/17	61	208	1 damselfly nymph

Suisun Marsh Salinity Control Gates

Work completed by Edwards et al. (1996) and Tillman et al. (1996) found the Suisun Marsh Salinity Control Gages (SMSCG) have the potential to impede all four races of Chinook salmon immigrating through Montezuma Slough. However, population-level effects have not been demonstrated. No work has been completed to specifically test the effects of the SMSCG on immigrating adult steelhead, but it is reasonable to expect similar results. Information pertaining to effects of the SMSCG on Chinook salmon is presented in Chapter 5.

It is possible for SMSCG operations to affect adult steelhead immigration any time the gates are operated from September through May, given the life history of Central Valley steelhead. An evaluation of a method for minimizing gate effects through modification of the flashboards is currently in progress. Results from the first two years of the evaluation indicated that the modified flashboards were not successful in improving salmonid immigration. A third year of evaluation was conducted in 2000 in which DWR and DFG staff cooperatively and thoroughly analyzed all of the SMSCG tagging data collected to date. Following the evaluation, the regular flashboards are reinstalled as long as the gates are needed to control salinity. Based on the results showing that the modification was not successful, another solution was developed for evaluation. The modification implemented for study years 2001-03 is a continuously open boat lock, with full flashboards in when gate is operational. The effort to minimize the adverse effects of the SMSCG on salmonid immigration through Montezuma Slough is ongoing. Since the gates are operated only to meet salinity standards, avoidance measures (in other words, flashboards removed and gates out of water) are already in place during periods when the gates are not needed to control salinity.

Predation and Competition

Restriction of steelhead to main stem habitats below dams may expose eggs and rearing juveniles to higher predation rates than those encountered in historical headwater habitats (McEwan and Jackson 1996). Predatory fish are more abundant and diverse in main stem rivers than headwater streams. Thus predation loss is probably greater in main stem rivers than in the historical spawning areas (CALFED 1998). However, essentially nothing is known about predation on Central Valley steelhead. There are specific locations (e.g., dams, bridges, or diversion structures) where predation has become a significant problem for Chinook salmon (see Chapter 5 for more information). Some of these locations may also pose predation problems for rearing and migrating steelhead. During snorkel observations of juvenile steelhead in the American River, steelhead tended to hold in moderately swift currents in riffles during the summer. In most cases, adult striped bass and pikeminnows were holding within 100 feet downstream from these areas in deeper and slower moving water. When there was structure in faster currents such as bridge pilings or rootwads, adult pikeminnows were congregated in the eddies behind the structures. Steelhead were usually nearby. Anglers report that the most effective bait for stripers in the American River is a rainbow trout imitation.

Large man-made structures like diversion dams increase resting and feeding habitat for predatory fish. As an example, RBDD formerly impeded upstream passage of Sacramento pikeminnow and striped bass, resulting in increased densities of these two predators downstream of the dam. Current estimates of pikeminnow densities around RBDD were substantially lower than they were when the gates were left in year-round although some aggregations still occur (FWS 1998). Further, pikeminnow densities around RBDD appear to be much lower than the densities found to be a problem in the Columbia River system. Gate removal during March through May, the peak pikeminnow spawning migration period, is considered important in preventing the large aggregations that previously occurred. Approximately 81 percent of adult pikeminnow immigrants should pass during the gates-out period based on average run timing at RBDD (FWS 1998).

Predation rates on fishes are usually size-dependent, with the highest level of predation incurred by smaller size classes. The available data from the FWS Chipps Island Trawl indicate an extremely small percentage of steelhead emigrate as YOY (see above). Therefore, we expect most steelhead predation occurs upstream of the Delta, where the habitat use of small size classes has been shown to be affected by the presence of potential predators (Brown and Brasher 1995) and predation risk appears to be affected by habitat use (DWR unpublished). The small percentages of YOY steelhead emigrating through the Delta would presumably face the same predation pressures as Chinook salmon smolts (Dennis McEwan, personal communication, 1998). However, steelhead were not listed as a prey item for any Delta fish by DFG (1966), even though they were more abundant at that time. The lack of steelhead in the stomachs of Delta piscivores is consistent with the observation that few steelhead emigrate as YOY, and also suggests predation pressure on the relatively large steelhead smolts migrating through the Delta may typically be low. An IEP-funded study (#2000-083 Predator-Prey Dynamics in Shallow Water Habitats of the Sacramento-San Joaquin Delta) is in progress and planned to continue. No steelhead were found in any of the 519 striped bass stomachs and 234 largemouth bass stomachs examined.

The highest ocean mortality for steelhead occurs soon after their initial ocean entry (McEwan and Jackson 1996). Predation is presumed to be the principal cause of mortality, although this has not been studied. The effect may be more substantial during El Nino years when warm water off the California coast increases the metabolic demands of predators and attracts additional piscivorous species like Pacific mackerel.

Competition for spawning space between steelhead, resident rainbow trout, and Chinook salmon can be a source of egg mortality in main stem rivers below dams. Substantial superimposition of salmon redds has been documented in the Feather River at a time of year when some steelhead may be attempting to spawn (Sommer et al. 2001a). Superimposition of salmon redds has also been documented in the upper Sacramento River below Keswick Dam (DFG 1998), and may be a problem for steelhead there as well.

Competition between steelhead and other species for limited food resources in the Pacific Ocean may be a contributing factor to declines in steelhead populations, particularly during years of low productivity (Cooper and Johnson 1992, as cited in McEwan and Jackson 1996). Pacific hake and Pacific salmon may compete with steelhead for food resources. Releases of hatchery salmonids may also increase competition and decrease survival and/or growth of hatchery and wild fish in the ocean. During years of lowered ocean productivity, smolt-to-adult survival rates indicated increased competition and mortality occurred when large numbers of hatchery and wild smolts were present together (McCarl and Rettig 1983; Peterman and Routledge 1983; McGie 1984; Lin and Williams 1988, all as cited in Pearcy 1992). Recent studies are also finding evidence that the reduced returns of adult salmonids to streams throughout the North Pacific could be seriously limiting the input of marine derived nutrients to spawning and rearing streams (Gresh et al. 2000). The ecological importance of salmonid carcasses and surplus eggs to stream productivity and juvenile steelhead growth has recently been demonstrated experimentally (Bilby et al. 1996, 1998). Bilby et al. (1998) also presented evidence that juvenile steelhead may actively seek out areas of streams with abundant carcasses to prey on unspawned eggs.

Food Abundance in the Delta

Food supply limitation and changes to invertebrate species composition, which influence food availability for young fish in the estuary, have been suggested as factors in the decline of estuarine-dependent species such as delta smelt and striped bass (Bennett and Moyle 1996). However, food limitation for steelhead in the Delta or lower estuary has not been studied. Steelhead smolts tend to migrate through the Delta at the same time that many small Chinook are present. The abundance of the smaller Chinook likely provides a readily available food supply for outmigrating steelhead and may be an important food source during the early stages of ocean rearing.

Contaminants

The introduction of contaminants into steelhead habitat could negatively affect steelhead abundance and distribution directly or indirectly (McEwan and Jackson 1996). However, there is little direct information on individual impacts, and population-level effects are unknown.

Runoff from the Iron Mountain Mine complex into the upper Sacramento River is known to adversely affect aquatic organisms (USRFRHAC 1989). Spring Creek Dam was built to capture pollution-laden runoff from the Iron Mountain Mine complex so lethal effects of the pollutants could be attenuated by controlled releases from the reservoir. Spring Creek Reservoir has insufficient capacity to perform under all hydrologic conditions, and uncontrolled spills resulted in documented fish kills in the 1960s and 1970s. Greater releases from Shasta Reservoir are required to dilute the uncontrolled releases, diminishing storage needed to maintain adequate flows and water temperatures later in the year (McEwan and Jackson 1996).

The role of potential contaminant-related effects on steelhead survival in the Delta also has not been examined, but some common pollutants include effluent from wastewater treatment plants, and chemical discharges such as dioxin from San Francisco Bay petroleum refineries (McEwan and Jackson 1996). In addition, agricultural drainwater, another possible source of contaminants, can contribute up to 30 percent of the total inflow into the Sacramento River during the low flow period of a dry year.

During periods of low flow and high residence time of water through the Stockton deep water ship channel, high oxygen demand from algae concentrations can deplete dissolved oxygen to lethal levels. This can result in a barrier to upstream and downstream migrating steelhead and could kill steelhead present in the area of low dissolved oxygen.

Harvest

There is little information on harvest rates of Central Valley steelhead. Prior to listing in 1998, steelhead were vulnerable to over-harvest because anglers could catch them as juveniles and adults. McEwan and Jackson (1996) did not believe over-harvest had caused the overall steelhead decline, but suggested it could have been a problem in some places. For example, estimates of juvenile harvest, including hatchery produced juveniles from the American River and Battle Creek, were as high as 51 percent and 90 percent, respectively. The proportion of naturally spawned steelhead harvested and the incidence and effects of hooking mortality are unknown. Most of the steelhead sports fishing effort occurs in the American and Feather Rivers. Regulations in place since 1999 prohibit the harvest of naturally produced steelhead greater than 16 inches long.

There is no longer a commercial ocean fishery for steelhead (McEwan and Jackson 1996). However, steelhead may be caught in either unauthorized drift net fisheries, or as bycatch in other authorized fisheries such as salmon troll fisheries. Based on very limited data collected when drift net fishing was legal, the combined mortality estimates for these fisheries were between 5 percent and 30 percent. Steelhead are routinely captured and often retained for personal consumption in salmon seine fisheries in Alaska and British Columbia. McEwan and Jackson (1996) did not think these mortality estimates were high enough to explain the steelhead decline, but they could have been a contributing factor. As mentioned above, the substantial declines in marine-derived nutrients to streams due to overall salmonid declines may also affect growth and survival of juvenile salmonids (Bilby et al. 1996, 1998). Levels of ocean harvest that attempt to maximize production from a minimum of adults may exacerbate stream nutrient deficiencies (Gresh et al. 2000).

Hatcheries

Four Central Valley steelhead hatcheries (Mokelumne River, Feather River, Coleman and Nimbus Hatcheries) collectively produce approximately 1.5 million steelhead yearlings annually when all four hatcheries reach production goals (CMARP 1998). The hatchery steelhead programs originated as mitigation for the habitat lost by construction of dams. Steelhead are released at downstream locations in January and February at about four fish per pound, generally the time period that the peak of outmigration is believed to begin (Table 4–10).

Table 4–10 Production and release data for hatchery steelhead[10].

Hatchery	*River*	*Yearly production goal*	*Number released in 1999*	*Release location*
Coleman	Battle Creek	600,000 smolts	496,525	Battle Creek and Balls Ferry

10 Source: DFG and NOAA Fisheries 2001.

Hatchery	*River*	*Yearly production goal*	*Number released in 1999*	*Release location*
Feather R.	Feather	450,000 yearlings	345,810	Gridley
Nimbus	American	430,000 yearlings	400,060	Sacramento R. below American R.
Mokelumne R.	Mokelumne	100,000 yearlings[11]	102,440	Lower Mokelumne R.

The hatchery runs in the American and Mokelumne Rivers are probably highly introgressed mixtures of many exotic stocks introduced in the early days of the hatcheries (McEwan and Jackson 1996; NOAA Fisheries 1997b, 1998). Beginning in 1962, steelhead eggs were imported into Nimbus Hatchery from the Eel, Mad, upper Sacramento, and Russian Rivers and from the Washougal and Siletz Rivers in Washington and Oregon, respectively (McEwan and Nelson 1991, as cited in McEwan and Jackson 1996). Egg importation has also occurred at other Central Valley hatcheries (McEwan and Jackson 1996).

Stock introductions began at Feather River Hatchery in 1967 when steelhead eggs were imported from Nimbus Hatchery to raise as broodstock. In 1971 the first release of Nimbus-origin fish occurred. From 1975 to 1982, steelhead eggs or juveniles were imported from the American, Mad, and Klamath Rivers and the Washougal River in Washington. The last year that Nimbus-origin fish were released into the Feather River was 1988. Based on preliminary genetic assessments of Central Valley steelhead, NOAA Fisheries (1998) concluded Feather River Hatchery steelhead were part of the Central Valley ESU despite an egg importation history similar to the Nimbus Hatchery stock, which NOAA Fisheries did not consider part of the Central Valley ESU. It is possible the Feather River Hatchery stock maintained substantial genetic affinity to other Central Valley stocks because it was not completely extirpated before the construction of Feather River Hatchery, as the American River stock possibly was (Dennis McEwan, personal communication, 1999).

The concern with hatchery operations is two-fold. First, they may result in unintentional, but maladaptive genetic changes in wild steelhead stocks (McEwan and Jackson 1996). DFG believes its hatcheries take eggs and sperm from enough individuals to avoid loss of genetic diversity through inbreeding depression and genetic drift. However, artificial selection for traits that improve hatchery success (fast growth, tolerance of crowding) are not avoidable and may reduce genetic diversity and population fitness.

The second concern with hatchery operations revolves around the potential for undesirable competitive interactions between hatchery and wild stocks. Intraspecific competition between wild and artificially produced stocks can result in wild fish declines (McMichael et al. 1997, 1999). Although wild fish are presumably more adept at foraging for natural foods than hatchery reared fish, this advantage can be negated by density-dependent effects resulting from large

11 From American or Feather reared at Mokelumne.

numbers of hatchery fish released at a specific locale, as well as the larger size and more aggressive behavior of the hatchery fish.

Hallock et al. (1961, as cited in McEwan and Jackson 1996) reported that the composition of naturally produced steelhead in the population estimates for the 1953-54 through 1958-59 seasons ranged from 82 percent to 97 percent and averaged 88 percent. This probably does not reflect the present composition in the Central Valley due to continued loss of spawning and rearing habitat and increased hatchery production. During the latter 1950s, only Coleman and Nimbus Hatcheries were in operation. Today, four Central Valley steelhead hatcheries (Mokelumne River, Feather River, Coleman, and Nimbus Hatcheries) collectively produce approximately 1.5 million steelhead yearlings annually (CMARP 1998).

Current data are not available to estimate the relative abundance of naturally spawned and hatchery produced steelhead adults in the Central Valley. Since 1998 however, Central Valley hatcheries have attempted to clip the adipose fins of all hatchery-produced steelhead. This provides an opportunity to estimate the proportion of naturally spawned steelhead smolts emigrating through the Delta. Data from the FWS Chipps Island Trawl indicate the proportion of juvenile steelhead that are adipose-clipped is between 60 percent and 80 percent.

Disease and Parasites

Steelhead are presumed to be susceptible to the same diseases as Chinook salmon (Dennis McEwan, personal communication, 1998). Disease problems are often amplified under crowded hatchery conditions and by warm water. See DFG (1998) for a detailed discussion of Central Valley salmonid diseases.

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

Status

NOAA Fisheries listed winter-run Chinook as threatened under emergency provisions of the ESA on August 4, 1989 (54 FR 32085), and formally listed the species on November 5, 1990 (55 FR 46515). The State of California listed winter-run Chinook as endangered in 1989 under the CESA. On January 4, 1994, NOAA Fisheries 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 Endangered Species Acts. The State and Federal listing decisions were finalized in February 1999 and September 1999, respectively. The fall/late fall runs of Chinook salmon are proposed for listing but have not been listed. They are included in this consultation to cover Essential Fish Habitat 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 (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 lbs.), 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 1976). 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 SacramentoSan Joaquin system.

Central Valley Chinook Salmon

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 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 construction success. Roni and Quinn (1995) reported that under high density conditions on the spawning ground, natural selection may produce stocks with exceptionally large-sized returning adults.

Among Chinook salmon, two distinct types have evolved. One type, described as a “stream-type” Chinook, 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 obtain a larger size prior to smolting. At the time of saltwater entry, stream-type (yearling) smolts are much larger, averaging 73 to 134 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).

The second type is called the “ocean-type” Chinook, which is commonly found in coastal streams in North America. Ocean-type Chinook typically migrate to sea within the first three 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 utilize 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 impact 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.

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 Chinook salmon). NOAA F (1999) determined the four Central Valley Chinook races comprise only three distinct ESUs, the fall/late fall-run ESU, the spring-run ESU and the winter-run ESU. NOAA Fisheries (1999) determined 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 which 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 (NOAA Fisheries 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; 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 been broken down, resulting in intermixed life history traits in many remaining habitats. The genetic characteristics of the Feather River spring-run are discussed in a later section.

Spawning

Spawning occurs in gravel beds that are often located at the tails of the holding pools (FWS 1995a, as cited in DFG 1998). Adults have been observed spawning in water 0.8 feet 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 <0.3 inches in diameter) (Platts et al. 1979; Reiser and Bjornn 1979 both as cited in DFG 1998).

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). 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 used 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 (NOAA Fisheries 1998).

The most complete historical record of spring-run 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 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 5–1). 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 1888–1901.

Table 5–1 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 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, and oxygenated to allow over-summer survival. Adults tend to hold in pools in close proximity to quality spawning gravel. DFG (1998) characterized these holding pools as having moderate water velocities (0.5-1.3 feet per second) and cover such as bubble curtains.

Spawning

Spawning occurs in gravel beds that are often located at the tails of the holding pools (FWS 1995a, as cited in DFG 1998). Adult Chinook have been observed spawning in water >0.8 feet 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 <0.3 inches in diameter) (Platts et al. 1979; Reiser and Bjornn 1979 both as cited in DFG 1998).

Currently, adult Chinook that DFG considers spring-run, spawn from mid- to late August through early October, with peak spawning times varying among locations (Figure 5–1). 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).

Sex and Age Structure

Fisher (1994) reported 87 percent of spring-run adults are three-year-olds based on observations of adult Chinook salmon trapped and examined at RBDD between 1985-1991. Studies of coded wire tagged Feather River Hatchery spring-run recovered in the ocean fishery indicated harvest rates average 18 percent to 22 percent for age-three fish, 57 percent to 85 percent for age-four fish, and 97 percent to 100 percent for age-five fish (DFG 1998). These data are consistent with Fisher's (1994) finding that most of the spawning population is three-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. These values are very similar to the fecundity of spring-run estimated for the Baird Hatchery in the latter 19th 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 between 1877 and 1901.

Egg and Larval Incubation

Egg survival rates are dependent on water temperature. Chinook salmon eggs had highest survival in the American River when water temperatures were 53° F to 54° 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). 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 one 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 main stem, non-natal tributaries to the Sacramento River, and the Delta (DFG 1998). Emigration timing is highly variable (Figure 5–1). 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).

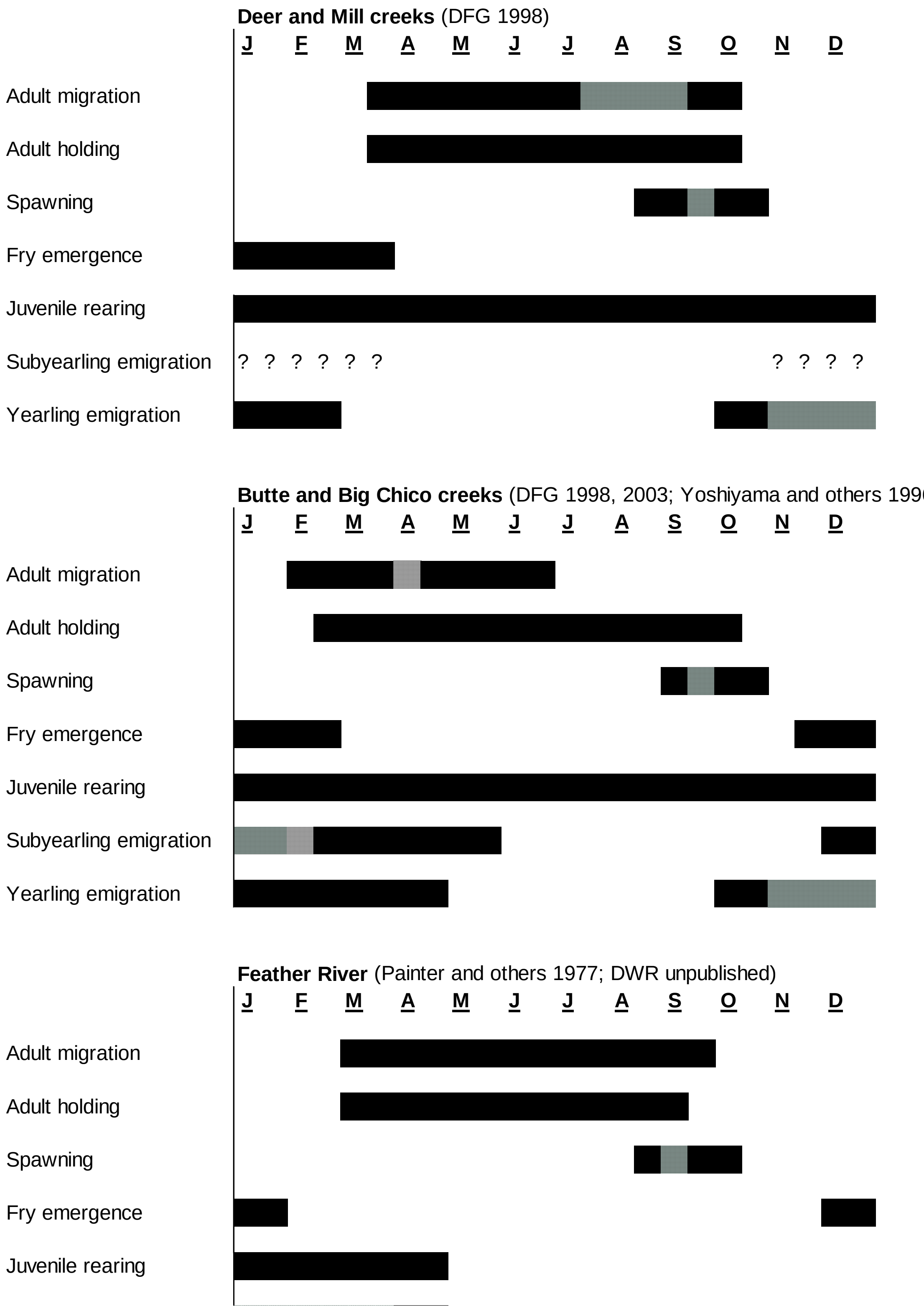

Figure 5–1 Spring-run Chinook salmon life cycle for various Central Valley streams. Cross hatching indicates period of peak occurrence.

Table 5–6 Sacramento River winter–run and spring–run redd distribution 2001 through 2003.

	Winter redds	Percent	Spring redds	Percent
Keswick to A.C.I.D. Dam.	1359	47.1%	9	5.8%
A.C.I.D. Dam to Highway 44 Bridge	500	17.3%	26	16.7%
Highway 44 Br. to Airport Rd. Br.	935	32.4%	33	21.2%
Airport Rd. Br. to Balls Ferry Br.	65	2.3%	35	22.4%
Balls Ferry Br. to Battle Creek.	5	0.2%	19	12.2%
Battle Creek to Jellys Ferry Br.	2	0.1%	30	19.2%
Jellys Ferry Br. to Bend Bridge	8	0.3%	3	1.9%
Bend Bridge to Red Bluff Diversion Dam	0	0.0%	0	0.0%
Red Bluff Diversion Dam to Tehama Br.	10	0.3%	1	0.6%
Tehama Br. To Woodson Bridge	0	0.0%	0	0.0%
Woodson Bridge to Hamilton City Br.	0	0.0%	0	0.0%
Hamilton City Bridge to Ord Ferry Br.	0	0.0%	0	0.0%
Ord Ferry Br. To Princeton Ferry.	0	0.0%	0	0.0%
	2884	100.0%	156	100.0%

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 NOAA Fisheries (1998) indicated spring-run may actually have been the most abundant run in the Central Valley during the 19th 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 20th 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 even 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/or gradual habitat degredation 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 main stem 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 2/3 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 NOAA Fisheries (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 tribs other than Mill Creek. Snorkel surveys are good for identifying population trends. They usually underestimate the actual number of fish present. Recent comparison during 2001 and 2002 on Butte Creek of the snorkel survey with a rigorous Schaefer carcass survey suggest that the snorkel survey is an underestimate by as much as 50% (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 re-appeared in the lower reaches of Clear Creek in 1999. Historic accounts of spring-run Chinook in Clear Creek are sparse and population estimates are non-existent. 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 they likely held over and spawned in cooler water present in the upper watershed upstream of Whiskeytown Dam. A falls at French Gulch restricted upstream migration to periods of high runoff in the spring.

Attempts to re-establish the spring-run 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. As stated above, 30 potential spring-run were observed in Clear Creek in 1999. During surveys in 2000 nineteen possible spring-run were counted during snorkel surveys. During the decline in numbers of Chinook in September the remains of five Chinook were found, potentially poached (DFG 2001a). During 2001 surveys, nine spring-run were counted from April to July. The monthly survey counts in 2001, however probably included multiple observations of the same fish. The first redd was observed on September 13 in the lowermost reach (DFG 2002).

Results of adult spring–run counts in 2002 are not yet available but at least one fresh adult was observed in Clear Creek below the former Saeltzer dam in mid-May of 2002.

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 based on length criteria developed for the upper Sacramento River. In late 2000, 41 spring Chinook juveniles were collected in the trap. 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. 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).

Denton (1986) used the IFIM 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 cfs would 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 salmon (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, while the Clear Creek Road Bridge to Whiskeytown Dam reach is the section of creek more suitable for spring-run Chinook because temperatures are better in that upstream 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.

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

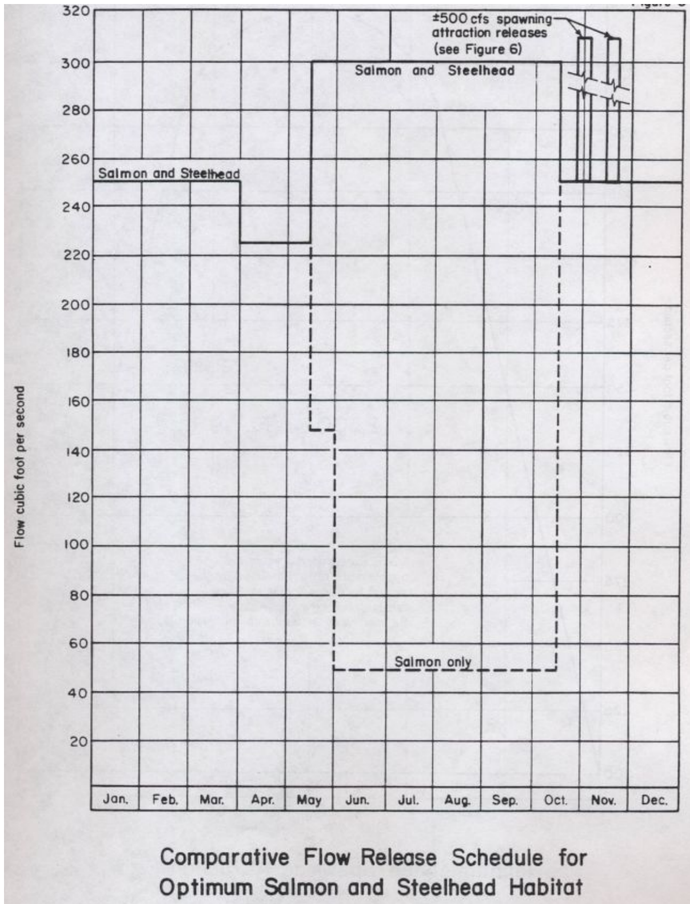

Figure 5–4 Clear Creek flows for optimum salmon and steelhead habitat.

Recent flows in Clear Creek likely resulted from a general flow schedule developed for maintenance of salmon and steelhead. 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.

Sacramento River Main stem

Some spring-run Chinook may spawn in the Sacramento River between RBDD and Keswick Dam. Sacramento main stem spring-run abundance reported in counts has declined sharply since the mid-1980s (Figure 5–5). The criteria for run classification at RBDD has 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 five-year geometric mean abundance reported by NOAA Fisheries (1998) was 435 fish. There is evidence 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. Since spring-run and fall-run Chinook now use the same spawning riffles, fall-run spawners may displace the spring-run redds during nest construction. This redd displacement is called superimposition. The criteria used to distinguish spring from fall-run from 1970 – 1988 probably resulted in many fish being classified as spring-run in August and September that were really fall–run (DFG 2003) so the increasing overlap may be simply an artifact of the variable run classification.

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. Due to the varied methods used over the years to estimate population abundance in each tributary, there were 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 BY data are lacking altogether on rates of grilse (two-year old) returns, age structure, and sex ratio of returning adults. In estimating CRR, DFG (1998) assumed the following: (1) spawning adults return as three-year-olds (a justification for this was presented above); (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 three 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 1947-64 period was about 1,900 fish (geometric mean = 1,717).

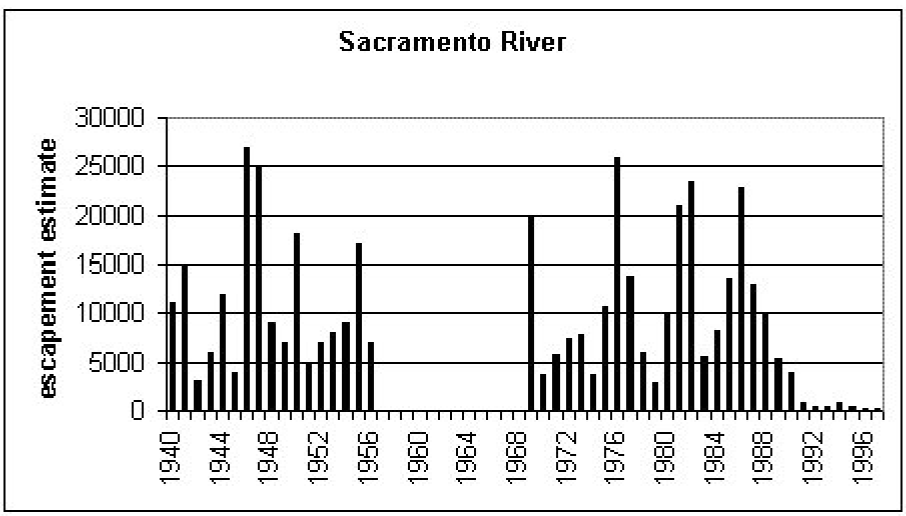

Figure 5–5 Estimated adult spring-run Chinook salmon population abundance in the upper Sacramento River.

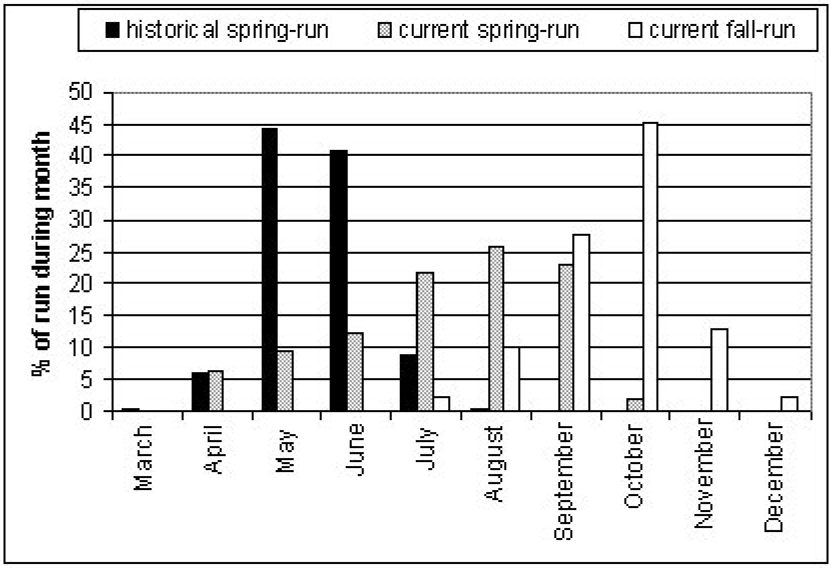

Figure 5–6 Migration timing of spring-run and fall-run Chinook salmon.

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.

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 5–7). However, the more conservative geometric mean CRR was only 1.05, suggesting the population was merely replacing itself. This agrees with the 1990-99 three-year running average escapement, which shows no consistent trend of either increase or decrease (Figure 5–8).

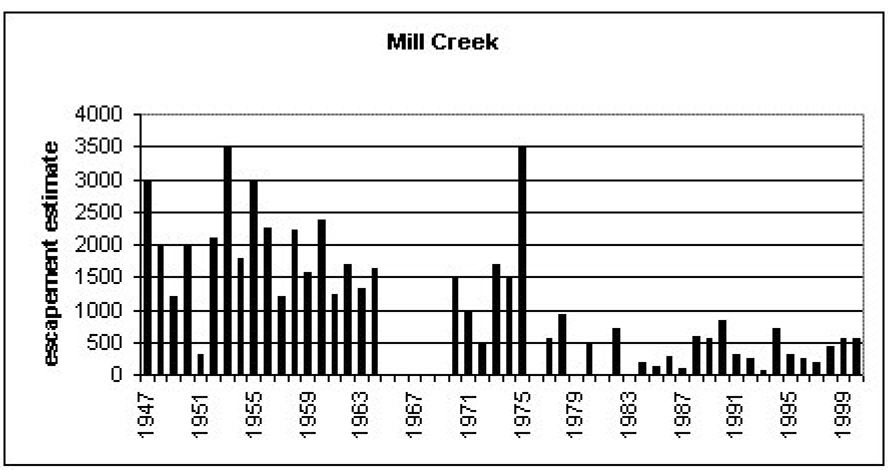

Figure 5–7 Adult spring-run Chinook counts in Mill Creek.

Table 5–7 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	1104/424 = 2.6

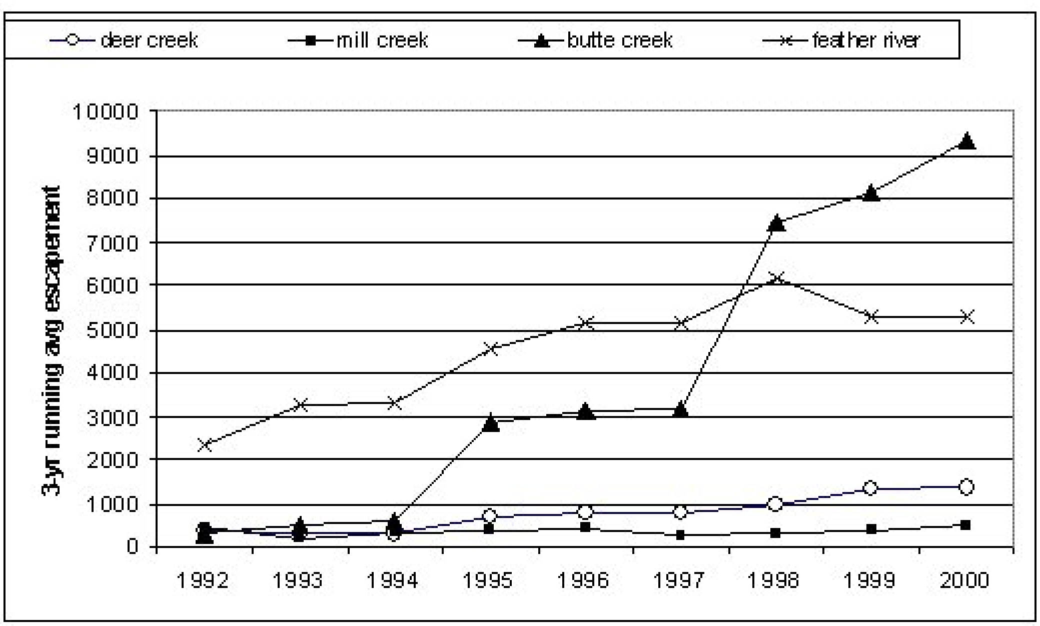

Figure 5–8 Three-year running average abundance of returning adult spring-run Chinook salmon in selected Central Valley streams.

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 six 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 six-mile extension. A fish ladder constructed around Upper Deer Creek Falls is managed to allow steelhead passage, but not spring-run passage. Spring-run are excluded because the reach lacks 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 1940-64 period was about 2,200 fish (geometric mean = 2,290). Again, as in Mill Creek, recent counts are lower (Figure 5–9), with a geometric mean escapement of 599 for the 1990 through 1999 period.

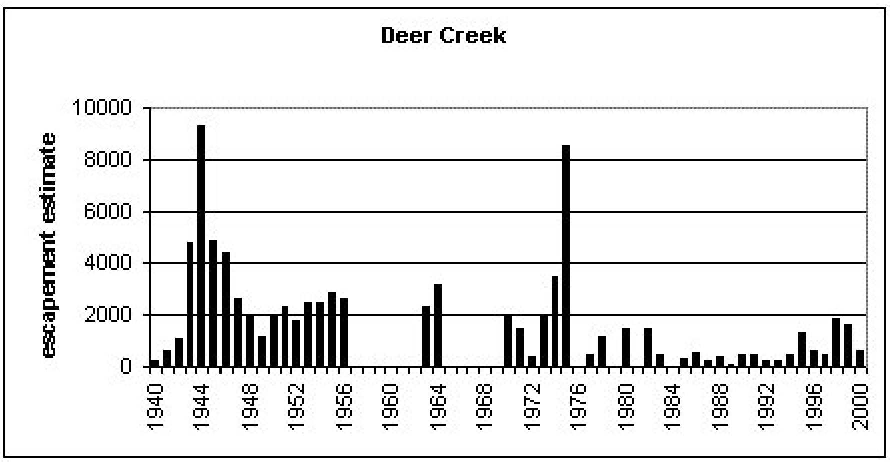

Figure 5–9 Estimated adult spring-run Chinook salmon population abundance in Deer Creek.

The mean Deer Creek CRR has been 2.1 during 1990-99, suggesting that like Mill Creek, the population may be rebounding slightly (Table 5–8). In addition, the geometric mean CRR (1.7), and the 1990-99 three-year running average escapement (Figure 5–8) also suggest a slight population increase during the 1990s.

Table 5–8 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
1	1993	259/458 = 0.6
2	1994	485/448 = 1.1

Cohort	*BY*	*CRR*
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

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 historic limit of travel for spring-run salmon and steelhead during most years was a natural barrier (Quartz Bowl Barrier) one mile below the PG&E Centerville Head Dam. Recent DFG surveys have only found fish above the Quartz Bowl barrier during 1998, 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 to 27, 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 (Figure 5–10).

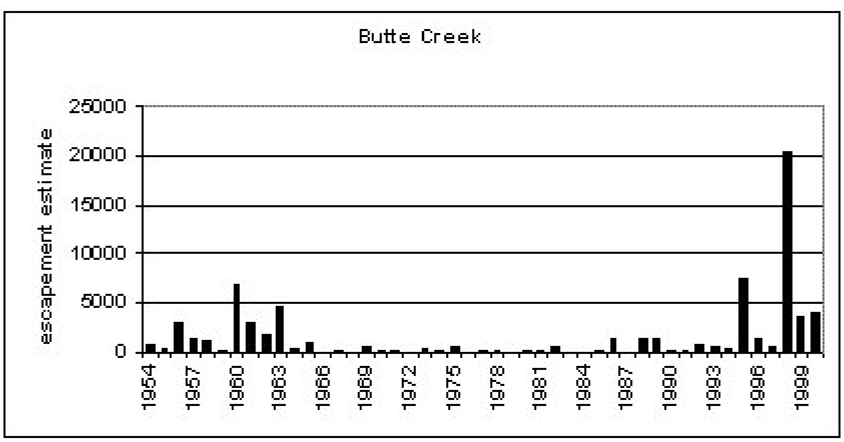

Figure 5–10 Estimated adult spring-run Chinook salmon population abundance in Butte Creek.

The Butte Creek spring-run increased dramatically during the last decade. CRR have been highly variable, but always greater than 1.0 during the last seven years (1993-99), ranging from 1.3 to

10.3, with a mean of 4.3 and a geometric mean of 3.5 (Table 5–9). The three-year running average escapement for 1990-99 suggests a comparatively rapid abundance increase as well (Figure 5–8).

Table 5–9 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

Feather River

Historically, the Feather River spring-run population was similar in magnitude to the size of the present hatchery run (Figure 5–11). 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 impacted 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.

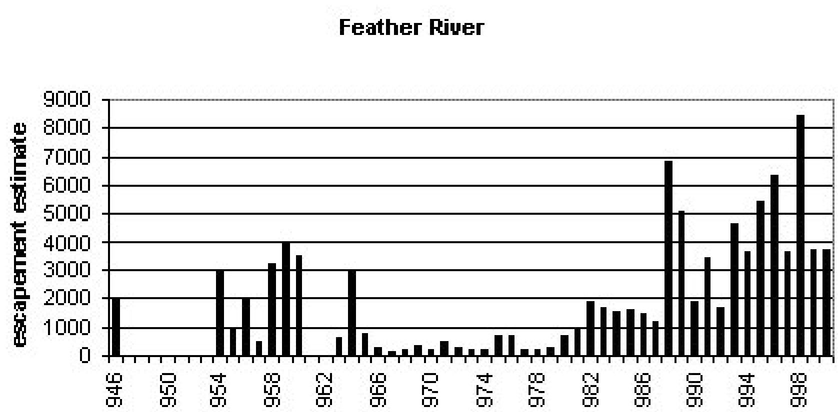

Figure 5–11 Estimated adult spring-run Chinook salmon population abundance in Feather River.

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. All post-Oroville spring-run population estimates are based on counts of salmon entering FRH.

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 (Figure 5–7). The three-year running average escapement suggests the same (Figure 5–8).

Table 5–10 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

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 worsened (Figure 5–12 and Figure 5–13). 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 fall and spring-run (Dr. Dennis Hedgecock, presentation at the 1999 Salmon Symposium in Bodega Bay).

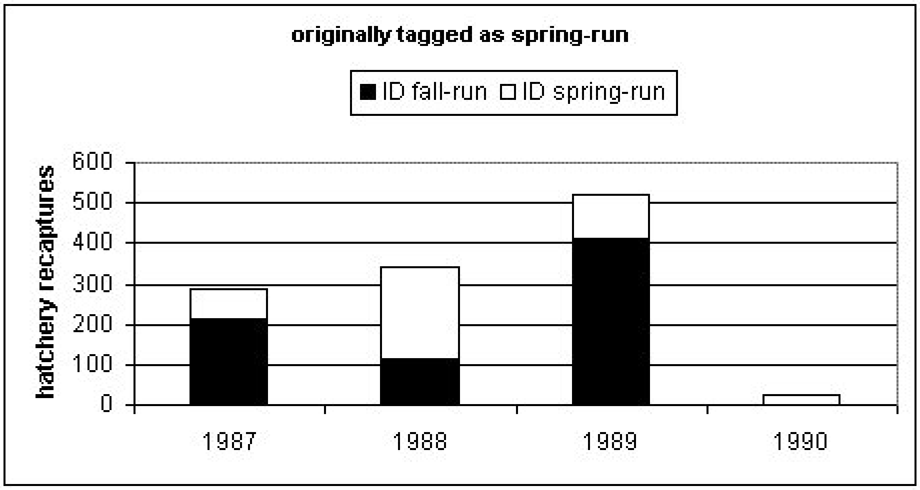

Figure 5–12 The disposition of Chinook salmon spawned, tagged, and released as spring-run from FRH.

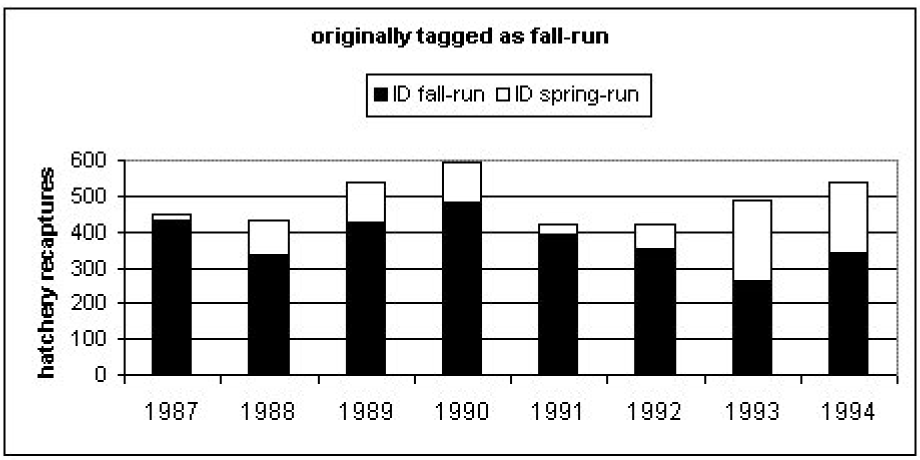

Figure 5–13 The disposition of Chinook salmon spawned, tagged, and released as fall-run from FRH.

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 Endangered Species Act on June 5, 1997. 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 three year life cycle in the Trinity River and are dependent on freshwater habitat conditions year round due to a full year of freshwater residency. 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 for 35 to over 100 days depending on water temperature and emerge from the gravel two weeks to seven 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 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 main stem 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 many northerly populations spending two full years 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 16-18 months in the ocean before returning to their natal streams to spawn as three or four year olds, age 1.2 or 2.2. Southerly populations are mostly three year olds. Some precocious males, called “jacks”, return to spawn after only six 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 comprised of naturally produced coho from 1991-95 at a point in the river near Willow Creek (FWS 1998). This in part prompted the threatened status listing in 1997. Mark recapture estimates of coho salmon run size conducted since 1977 had a mean run size of 15,959 coho from 1977 through 1999 (DFG 2003). These estimates included a combination of hatchery produced and wild coho.

Chapter 6 Factors That May Influence Abundance and Distribution of Winter-run and Spring-run Chinook Salmon and Coho Salmon

Water Temperature

Water temperatures that are too low or too high can kill Chinook salmon directly by impairing metabolic function or indirectly by increasing the probability of disease, predation, or other secondary mortality factors (Boles et al. 1988). Chinook salmon temperature tolerances vary by life stage, and may also vary among stocks, but the latter is not well studied. The recommendations included in this BA were developed by Boles et al. (1988) based on previous temperature studies of Chinook salmon and other salmonids. An overview of temperature effects on Chinook salmon follows.

Table 6–1 Recommended water temperatures (°F) for all life stages of Chinook salmon in Central Valley streams as presented in Boles et al. (1988).[a]

Life stage	*Temperature recommendation (°F)*
Migrating adult	<65
Holding adult	<60
Spawning	53 to 57.5[b]
Egg incubation	<55
Juvenile rearing	53 to 57.5[c]
Smoltification	54[d]

[a] The lower thermal limit for most life stages was about 38° F.
[b] Can have high survival when spawned at up to 60° F, provided temperatures drop quickly to <55° F.
[c] Temperature range for maximum growth rate based on Brett (1952, as cited in Boles et al. 1988).
[d] No results for Chinook salmon. Estimate based on studies of steelhead and Coho salmon (Boles et al. 1988).

The temperature recommendation for migrating adults was based on Hallock et al. (1970, as cited in Boles et al. 1988) who found Chinook immigration into the San Joaquin River was impeded by temperatures of 70° F, but resumed when the temperature fell to 65° F.

The temperature recommendations for adult holding and spawning, and for egg incubation were based on laboratory studies of Sacramento River Chinook egg survival (Seymour 1956, as cited in Boles et al. 1988). Egg mortality was high at constant temperature of 60° F, but was considerably reduced at temperatures between 55° F and 57.5° F. However, sac-fry mortality remained very high (greater than 50 percent) at temperatures above 56° F, presumably due to "aberrations in sequential physiological development." Table 6–2 shows the relationship between water temperature and mortality of Chinook eggs and pre-emergent fry compiled from a variety of studies.

Table 6–2 Relationship between water temperature and mortality of Chinook salmon eggs and pre-emergent fry.

Water Temperature (EF)[a]	Egg Mortality[b]	Instantaneous Daily Mortality Rate (%)	Pre-Emergent Fry Mortality[b]	Instantaneous Daily Mortality Rate (%)
41-56	Thermal optimum	0	Thermal optimum	0
57	8% @ 24d	0.35	Thermal optimum	0
58	15% @ 22d	0.74	Thermal optimum	0
59	25% @ 20d	1.40	10% @ 14d	0.75
60	50% @ 12d	5.80	25% @ 14d	2.05
61	80% @ 15d	10.70	50% @ 14d	4.95
62	100% @12d	38.40	75% @ 14d	9.90
63	100% @11d	41.90	100% @ 14d	32.89
64	100% @ 7d	65.80	100% @10d[c]	46.05

[a]This mortality schedule was compiled from a variety of studies each using different levels of precision in temperature measurement the lowest of which was whole degrees Fahrenheit (±0.5°F). Therefore, the level of precision for temperature inputs to this model is limited to whole degrees Fahrenheit.

[b]These mortality schedules were developed by the FWS and DFG for use in evaluation of Shasta Dam temperature control alternatives in June 1990.[12]

[c]This value was estimated similarly to the preceding values but was not included in the biological assumptions for Shasta outflow temperature control FES (Reclamation, 1991b).

Reclamation installed a temperature control device on Shasta Dam in 1997 to allow cool water releases to be made through the power penstocks, avoiding power bypasses. Release temperatures from Shasta Dam from 1994 to 2001 are shown in Figure 6–1.

Yearly water temperatures downstream at Bend Bridge, a temperature compliance point, are shown in Figure 6–2. Temperature compliance points (Bend Bridge and Jelly's Ferry) vary by water year type and date between April 15 and October 31 for winter–run spawning, incubation, and rearing. The objective is to meet a daily average temperature of 56° F for incubation 60° F

[12]Richardson, T. H., and P. Harrison. 1990. Fish and Wildlife Impacts of Shasta Dam Water Temperature Control Alternatives. Prepared for Reclamation, Sacramento, California. FWS--Fish and Wildlife Enhancement, Sacramento, California.

for rearing. After October 31 natural cooling generally provides suitable water temperatures for all Chinook life cycles.

Rearing juvenile Chinook salmon can tolerate warmer water than earlier life stages. Nimbus Hatchery fall-run were able to feed and grow at temperatures up to at least 66° F (Cech and Myrick 1999), but this is not reflected in the Boles et al. (1988) temperature recommendation for juveniles. The relationship between temperature and growth rate seen in Cech and Myrick's (1999) data parallels that observed in northern salmon that exhibit maximum growth at 66° F when fed satiation rations. Nimbus Chinook had maximum growth rates at 66 F and lower rates at 59 and 52° F (Myrick and Cech 2001). The theoretical upper lethal temperature that Sacramento River Chinook salmon can tolerate has been reported as 78.5° F (Orsi 1971, as cited in Boles et al. 1988). However, this result must be interpreted with several things in mind.

First, the theoretical maximum corresponds to the most temperature tolerant individuals. It is not a generality that can be applied to an entire stock. Second, it is only a 48-hour LT-50. This means it is a temperature that can only be tolerated for a short period of time. It does not indicate a temperature at which a Chinook could feed and grow. Third, indirect mortality factors (for example, disease and predation) would likely lead to increases in total mortality at temperatures well below this theoretical laboratory-derived maximum. For example, Banks et al. (1971, as cited in Boles et al. 1988) found Chinook growth rates were not much higher at 65° F than at 60° F, but the fish had higher susceptibility to disease at 65° F.

The Boles et al. (1988) temperature recommendation for Chinook salmon smoltification is 54° F. This recommendation was based on studies of steelhead and Coho salmon in the Pacific Northwest and is therefore questionably applicable to Chinook stocks at the southern limit of the species' range. This is probably not an important issue for winter-run or spring-run yearlings since they tend to emigrate during the cool November through March period when temperatures are below 55° F in most areas. More recent studies show that Chinook salmon that complete juvenile and smolt phases in the 50° F to 62° F range are optimally prepared for saltwater survival (Myrick and Cech 2001).

Newman (2000) modeled the effect of temperature on coded wire tagged fall-run smolt survival from FWS paired Delta release experiments. Newman's analysis indicated smolt survival would decrease by 40 percent as temperature rose from 58° F to 76° F. We infer from this result that water temperature would be unlikely to affect spring-run smolt survival until it exceeded 58° F. On average, Delta temperatures have exceeded 58° F during April or May (Figure 6–3), when subyearling spring-run are emigrating. However, water project operations cannot efficiently control water temperatures in the Delta.

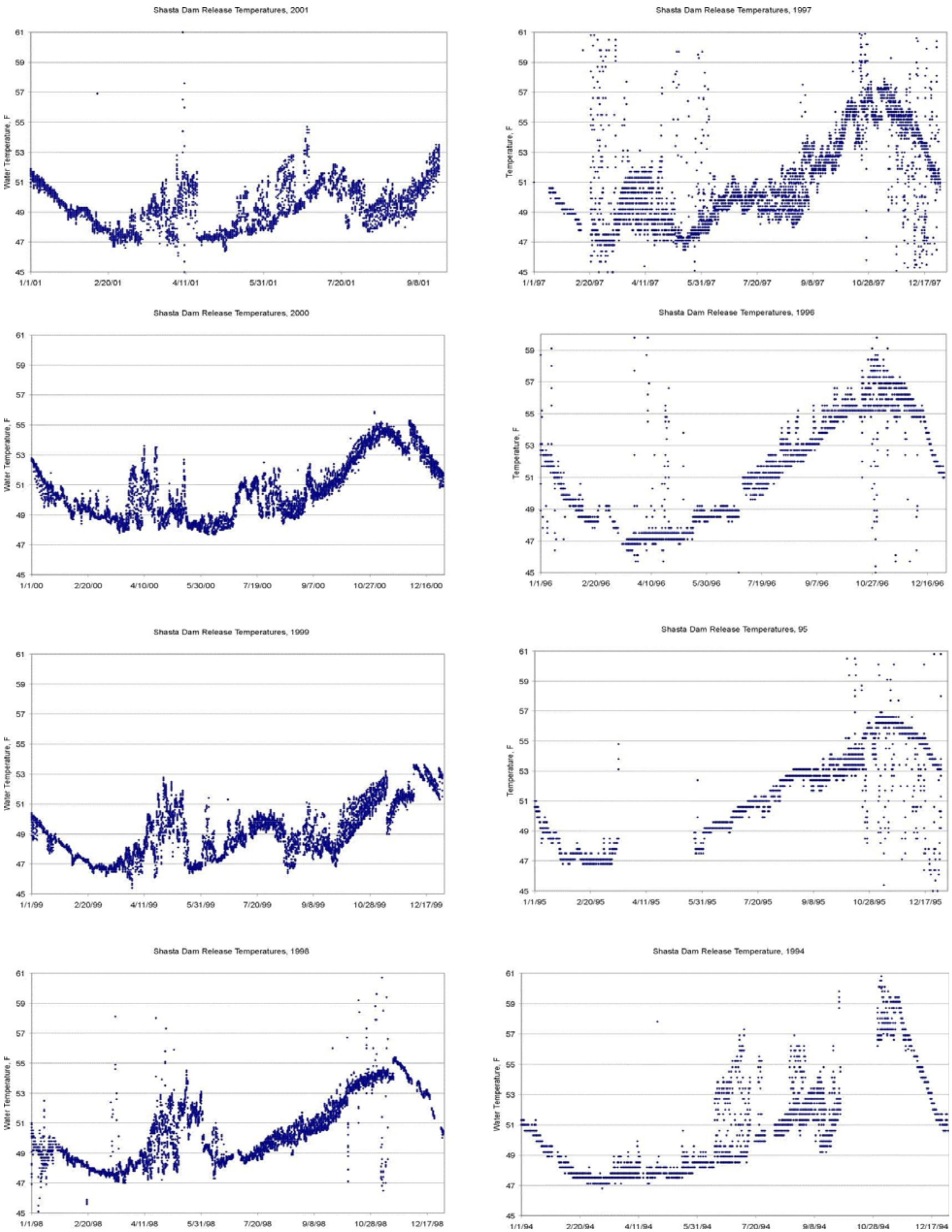

Figure 6–1 Shasta Dam Release Temperatures 1994–2001.

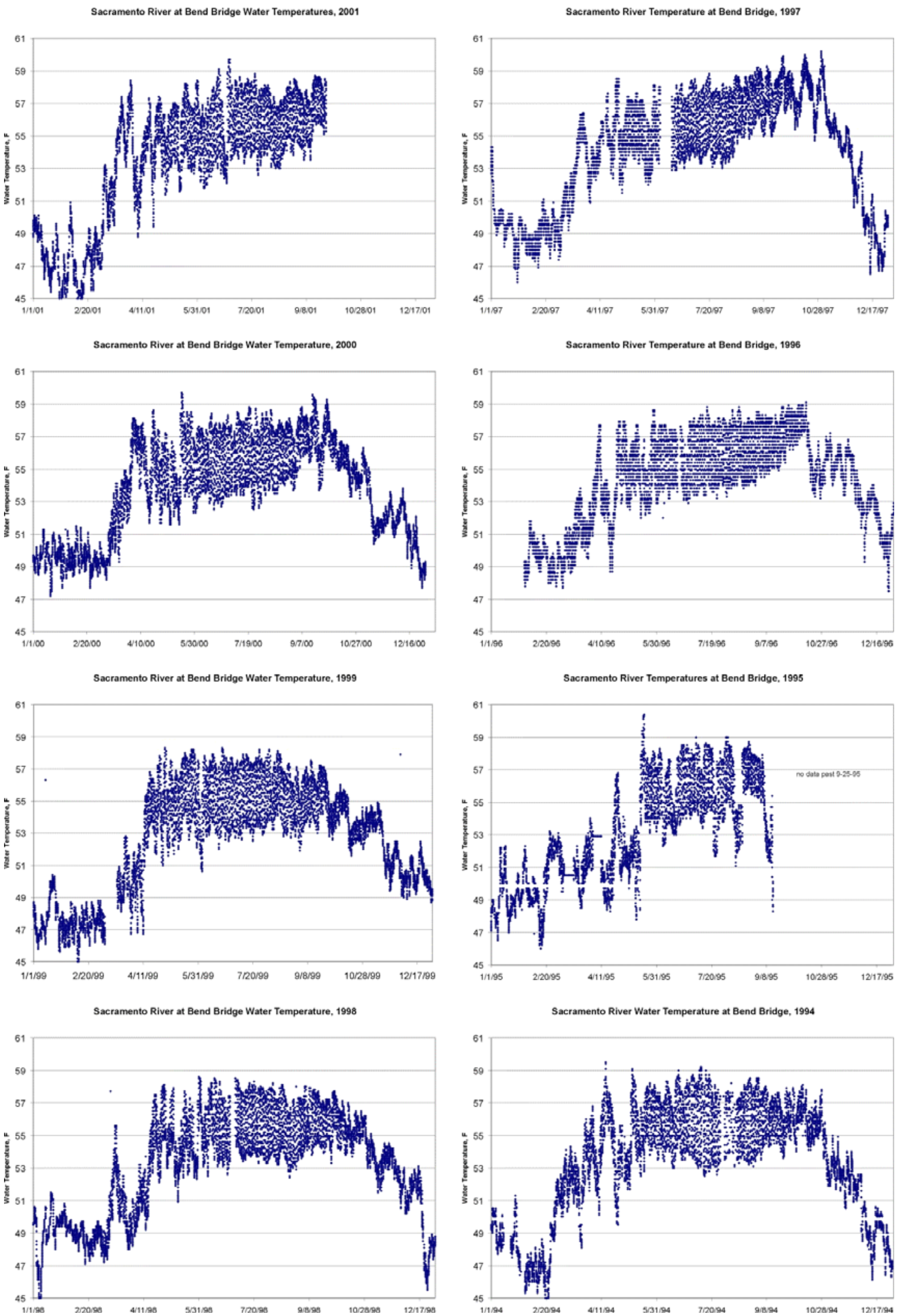

Figure 6–2 Sacramento River at Bend Bridge Water Temperatures 1994–2001.

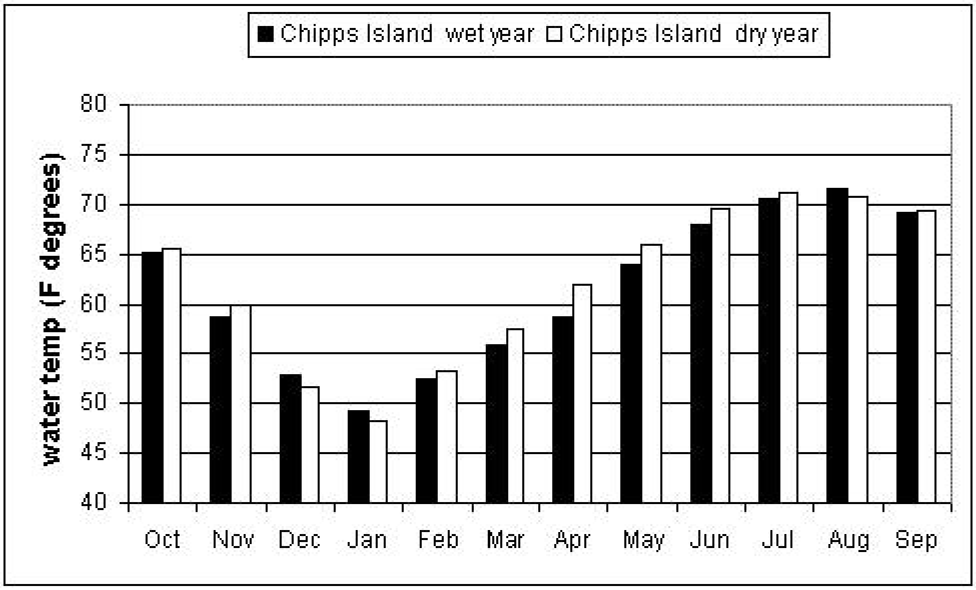

Figure 6–3 Monthly mean water temperatures for the Sacramento River at Chipps Island for water years 1975–1995.

Flow and Spawning

In stream flow recommendations have been developed for Chinook salmon for most major Central Valley streams. Many of the recommendations are intended to optimize habitat area for salmon spawning and egg incubation. High flows can affect redds by scouring the gravel away down to the depth of the eggs and washing the eggs out or by piling more gravel and fines on top of redds so that alevins are unable to emerge or are suffocated. Lowering flows to below the depth of the egg pockets following spawning can kill incubating eggs and alevins.

In stream flow studies

Sacramento River

U.S. Fish and Wildlife Service (2003) developed spawning flow-habitat relationships for winter, fall, and late fall Chinook salmon and steelhead spawning habitat in the Sacramento River below Keswick Dam using the Physical Habitat Simulation (PHABSIM) component of the in stream flow incremental methodology (IFIM). Relationships were developed by cross section and by stream segments but were not aggregated into river-wide flow-habitat relationships.

Winter–run Chinook salmon spawning usable area peaked at around 10,000 cfs in the upstream reach above ACID Dam when the dam boards are in; with the boards out the peak was around 4,000 – 5,000 cfs. In the next reach downstream (ACID Dam to Cow Creek) habitat peaked at 8,000 – 9,000 cfs. In the lower reach (Cow Creek to Battle Creek) spawning habitat peaked at around 4,000 cfs but had low variability in wetted usable spawning habitat area in the flow range analyzed (3,250 – 30,000 cfs). The highest density redd counts for winter-run occur in the upper and middle reach, although since the ACID fish ladder was built there has been a substantial increase in spawning upstream of the dam (Killam 2002). ACID puts the boards in during early April and they stay in until fall, so the flows dictated by water use would be compatible with maximization of habitat area during that time.

Fall-run and late-fall–run had different wetted usable spawning area values but the flow v. habitat relationship was about the same for the two runs. Upstream of the ACID Dam, spawning habitat peaked at 3,250 cfs with the dam boards out and at about 6,000 cfs with the boards in. Between ACID and Cow Creek spawning habitat peaked at around 4,000 cfs. Between Cow Creek and Battle Creek habitat peaked at about 3,500 cfs. The highest density redd counts for fall and late fall-run occur in the middle reach.

Feather River

Chinook salmon spawning distribution in the Feather River has been studied in detail by Sommer et al. (2001a), although the data are not specific for spring–run. Approximately three-quarters of spawning occurs in the low flow channel, where the heaviest activity is concentrated in the upper three miles. By contrast, spawning activity below Thermalito Afterbay Outlet is fairly evenly distributed. The proportion of salmon spawning in the low flow channel has increased significantly since the completion of the Oroville Complex and FRH. The significant shift in the distribution of salmon spawning in the Feather River to the upper reach of the low flow channel is perhaps one of the major factors affecting any in-channel production of spring-run as a result of superimposition mortality. Since they spawn later in the fall, fall-run fish may destroy a significant proportion of the redds of earlier spawning spring–run.

The major factors that had a statistically significant effect on spawning location were flow distribution and escapement (Sommer et al. 2001a). Significantly more salmon spawned in the low flow channel when a higher proportion of flow originated from that reach. Attraction flows are known to change the spawning distribution of salmon in other rivers. Higher escapement levels were also weakly associated with increased spawning below Thermalito Afterbay Outlet. Since salmon are territorial, increasing densities of salmon would be expected to force more fish to spawn downstream. As will be discussed in further detail in the “Hatchery” section of this chapter, Feather River Fish Hatchery operations may also affect salmon spawning location.

In 2002, DWR conducted an in stream flow incremental methodology (IFIM) habitat analysis for the lower Feather River (DWR 2004). This analysis drew on the earlier IFIM work of Sommer et al. (2001), but added an additional 24 transects, and included additional fish observations. The river segments above (the low flow channel, LFC) and below (the high flow channel, HFC) were modeled separately due to their distinct channel morphology and flow regime. The WUA for Chinook salmon spawning in the LFC increased from 150 cfs to a peak at 800 cfs. Beyond the peak, the WUA index falls sharply again. Although the WUA curve peaks at 800 cfs, the current base flow in the LFC (600 cfs) represents 90 percent of the highest habitat index value. In the HFC, the WUA rises from the lowest modeled flow (500 cfs) and peaks near 1,700 cfs, above which it again declines out to 7000 cfs.

Redd Scouring

High flows, such as those released from dams to draw down storage for flood control during heavy runoff periods, have the potential to scour salmon and steelhead redds and injure eggs or sac-fry in the gravel. These same flows are important for maintaining rearing habitat and high quality spawning gravel. River specific geomorphic studies evaluated the bedload mobilization flow for the affected rivers. The future probability of occurrence of flow releases exceeding the bedload mobilization flow is based on the historic hydrograph since the respective dam was constructed. This is because scouring flows are generally a result of flood control operations during high runoff periods, which will not likely change in the near future.

Sacramento River

Buer (1980) conducted bedload movement experiments by burying a 50 gallon drum in a riffle below Redding. Gravel up to 3 inches in diameter began to accumulate in the barrel at about 25,000 cfs, indicating initiation of surface transport. Painted rocks moved 200 to 300 feet down the riffle at 25,000 cfs. Flows of 40,000 to 50,000 cfs would likely be required to move enough bedload to scour redds (Koll Buer, pers. comm 2003.). The coarse riffles (small boulders and large cobbles), are probably armored from release of sediment-free flows from Shasta Dam. These armored riffles appear not to change and thus probably remain immobile even at flows exceeding 100,000 cfs (Calfed 2000). A bed mobility model was applied to four of the Army Corps of Engineers Comprehensive Study cross sections as another bed mobility estimate to compare to the empirical bed mobility observations. The bed mobility model suggests bed mobility thresholds between 15,000 cfs and 25,000 cfs between River Mile 169 and 187 although the model is not considered appropriate for the Sacramento River (Calfed 2000).

Probability of occurrence for a release exceeding 25,000 cfs at Keswick Dam are approximately 50 percent each year and flows in the 40–50,000 cfs range occur in about 30–40 percent of years (Figure 6–4). Therefore in about 30-40 percent of years some redds could potentially be scoured when flows over 50,000 cfs occur when eggs are in the gravel. This would most likely occur during fall and late fall–run incubation. The significance to the population is difficult to determine, but based on the amount of scouring that occurs in unregulated rivers with large salmon runs compared to regulated rivers such as those in the Central Valley long term negative population effects from redd scouring is probably not very significant. On the Sacramento River, the two-year return interval flood has been reduced from 119,000 cfs to 79,000 cfs since construction of Shasta Dam (as measured at Red Bluff, Figure 6–7).

Clear Creek

Sampling was conducted in Clear Creek at the USGS Clear Creek near Igo gauge during high flows in January and February 1998 to estimate a flow threshold that initiated coarse sediment transport (McBain & Trush and Matthews 1999). Sampling bedload movement during a 2,600 cfs flow showed that mainly sand was being transported. During a 3,200 cfs flow medium gravels were being transported. Particles slightly greater than 32 mm were being transported by the 3,200 cfs (D_{84} = 7.5 mm) flow while no particles larger than 11 mm were sampled during the 2,600 cfs flow (D_{84} = 1.8 mm). Their initial estimate for a coarse sediment transport initiation threshold is in the 3,000 to 4,000 cfs range. Marked rock experiments at Reading Bar, the first alluvial reach out of the Clear Creek canyon, suggest that large gravels and cobbles (D_{84}) are not significantly mobilized by a 2,900 cfs flow.

The majority of post Whiskeytown Dam floods are produced from tributaries downstream of Whiskeytown Dam, but floods larger than about 3,000 cfs are caused by uncontrolled spillway releases from Whiskeytown Dam, as happened in WY 1983 (19,200 cfs, the largest post-regulation flood), 1997 (15,900 cfs), and 1998 (12,900 cfs) floods. These flows are the result of heavy runoff from the upper Clear Creek watershed and not affected by Reclamation water release operations. Reclamation does not make releases in Clear Creek that exceed the bedload mobilization point unless recommended by fishery agencies for the benefit of fish. A probability of exceedance plot for Whiskeytown Dam is in Figure 6–6. Instantaneous flows of 3,000 cfs occur on average about once every two years and flows of 4,000 cfs occur about once every three years (Figure 6–5). One day average flows of 3,000 cfs occur about once every five years.

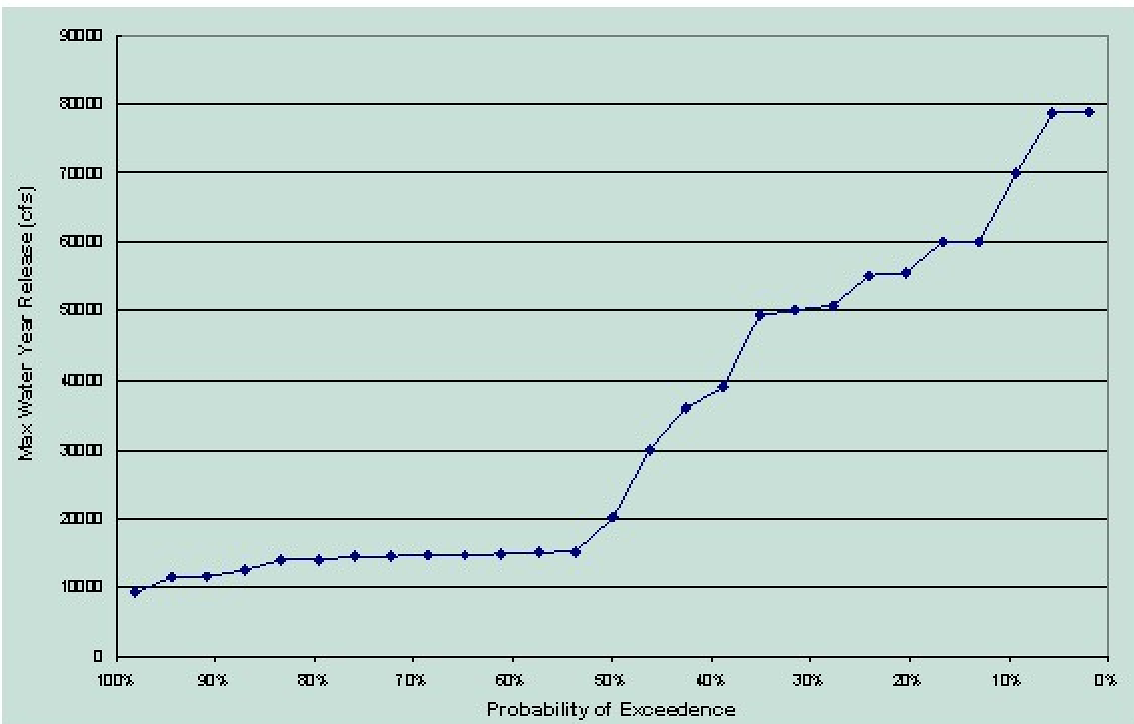

Figure 6–4 Yearly probability of exceedance for releases from Keswick Dam on the Sacramento River.

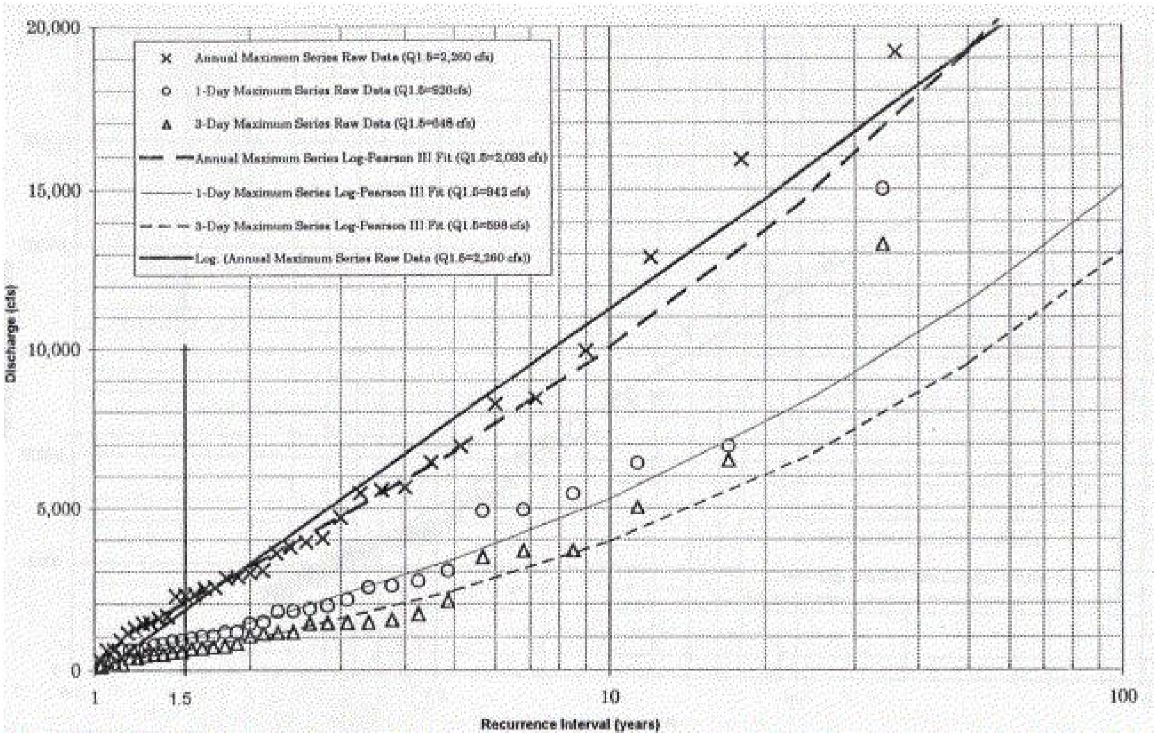

Figure 6–5 Clear Creek near Igo (Station 11-372000) flood frequency analysis of annual maximum, one-day average, and three-day average flood series for post-dam (1964–97) data.

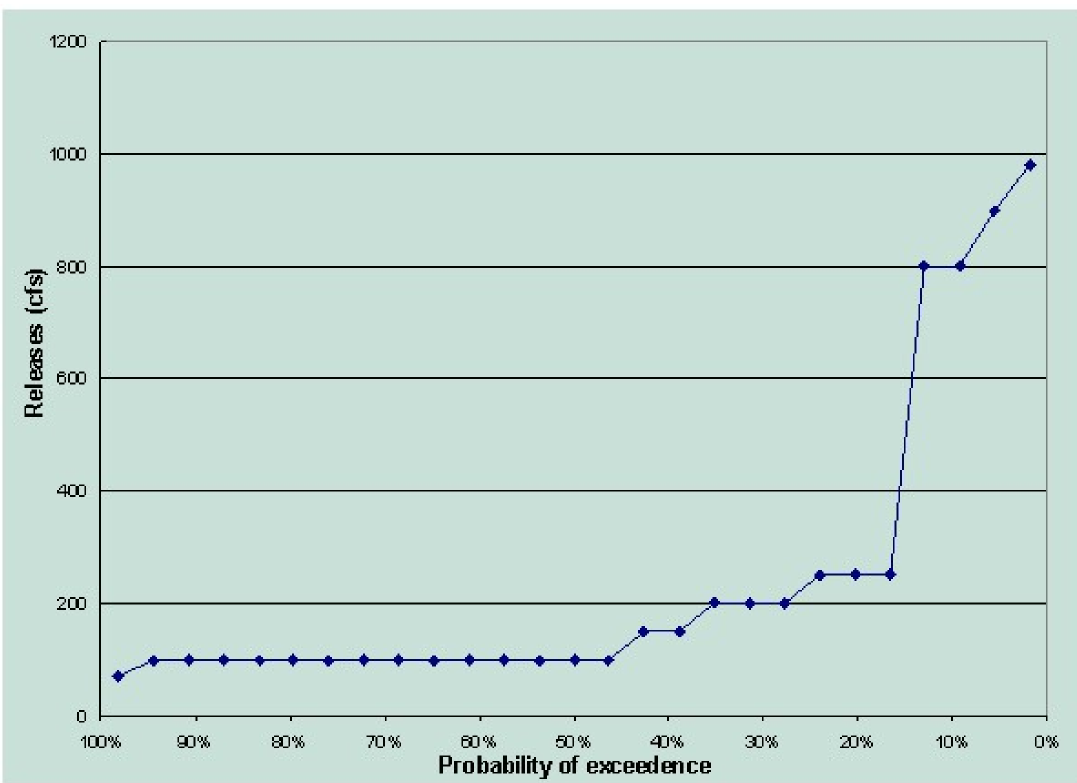

Figure 6–6 Yearly probability of exceedance for releases from Whiskeytown Dam on Clear Creek.

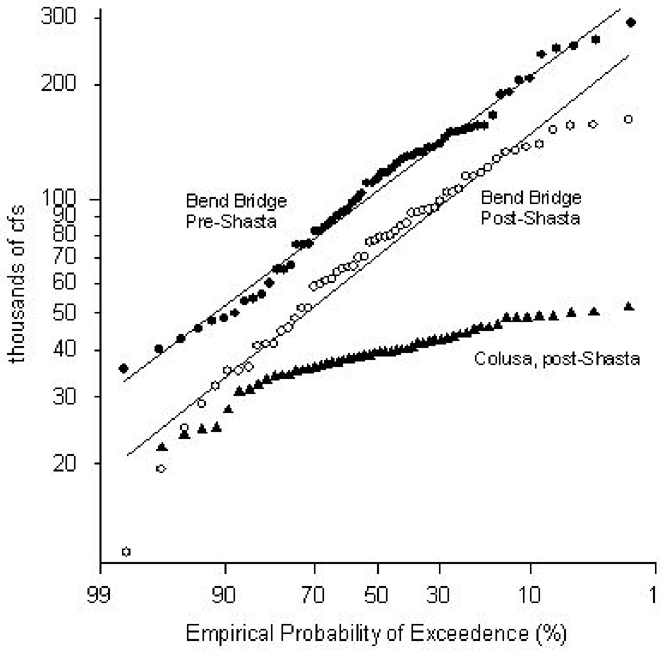

Figure 6–7 Empirical flood frequency plots for the Sacramento River at Red Bluff (Bend Bridge gauge) for pre- and post-Shasta periods, and downstream at Colusa for the post-Shasta period.

The reduced peak flows at Colusa reflect diversions into the Butte Basin between the two gauges. Data from U.S. Geological Survey internet site (www.usgs.gov), Red Bluff (Bend Bridge) and Colusa gauges. Chart from Calfed (2000).

American River

Ayres Associates (2001) used a two-dimensional model of the lower American River constructed from two foot topography to determine at what flows spawning beds would be mobilized. Their modeling results indicated that the spawning bed materials are moving for flows of 50,000 cfs or greater. There appeared to be minimal movement for flows as low as 30,000 cfs, although some movement may occur for flows between 30,000 and 50,000 cfs. Shear stress conditions tend to be highest upstream of Goethe Park, where the majority of salmon and steelhead spawning occurs.

Flood frequency analysis for the American River at Fair Oaks Gauge shows that on average flows will exceed 30,000 cfs about once every four years and exceed 50,000 cfs about once every five years (Figure 6–8). Fair Oaks gauge flows result almost entirely from Folsom and Nimbus releases.

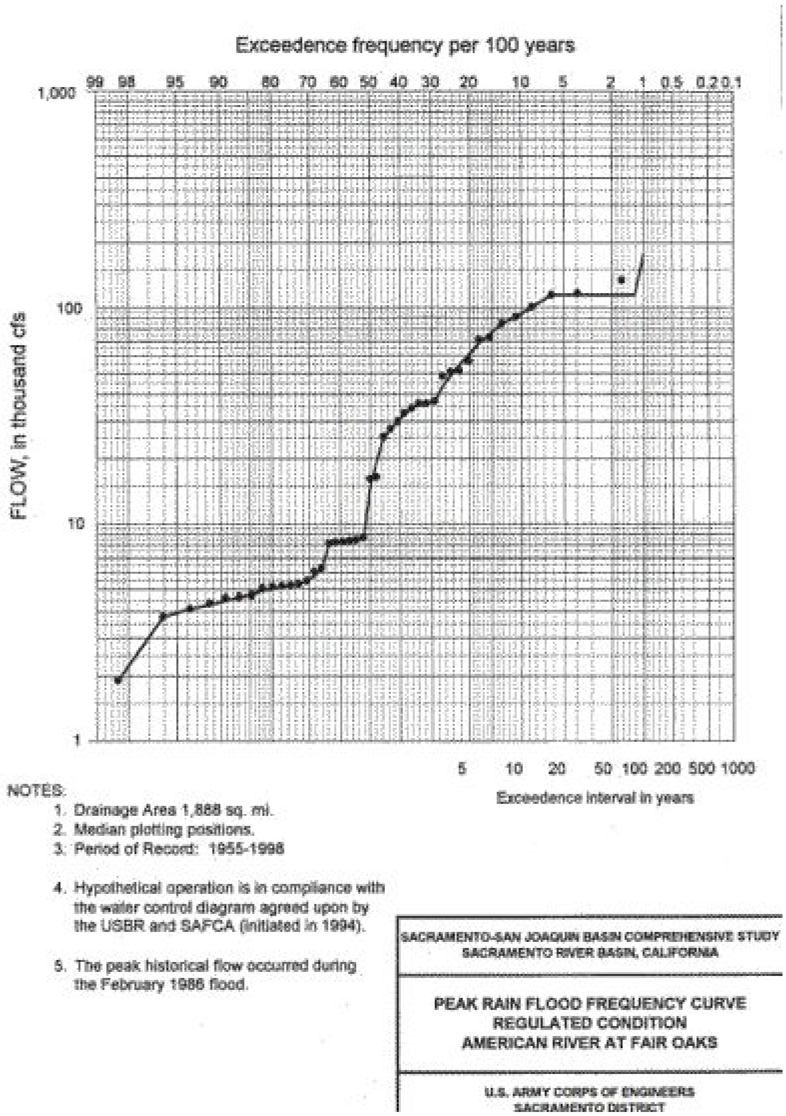

Figure 6–8 Flood frequency analysis for the American River at Fair Oaks Gauge (U.S. Army Corps of Engineers 1999).

Stanislaus River

Kondolf et al. (2001) estimated bedload mobilization flows in the Stanislaus River to be around 5,000 to 8,000 cfs to mobilize the D_{50} of the channel bed material. Flows necessary to mobilize the bed increased downstream from a minimal 280 cfs near Goodwin Dam to about 5,800 cfs at Oakdale Recreation Area.

Before construction of New Melones Dam, a bed mobilizing flow of 5,000 to 8,000 cfs was equivalent to a 1.5 to 1.8 year return interval flow. On the post dam curve, 5000 cfs is approximately a five-year return interval flow, and 8,000 cfs exceeds all flows within the 21 year study period, 1979–99 (max flow = 7,350 cfs on 1/3/97). The probability of occurrence for a daily average flow exceeding 5,330 cfs (the pre-dam bankfull discharge) is 0.01, or one year in a hundred. Figure 6–9 shows the yearly exceedance probability for Goodwin Dam releases.

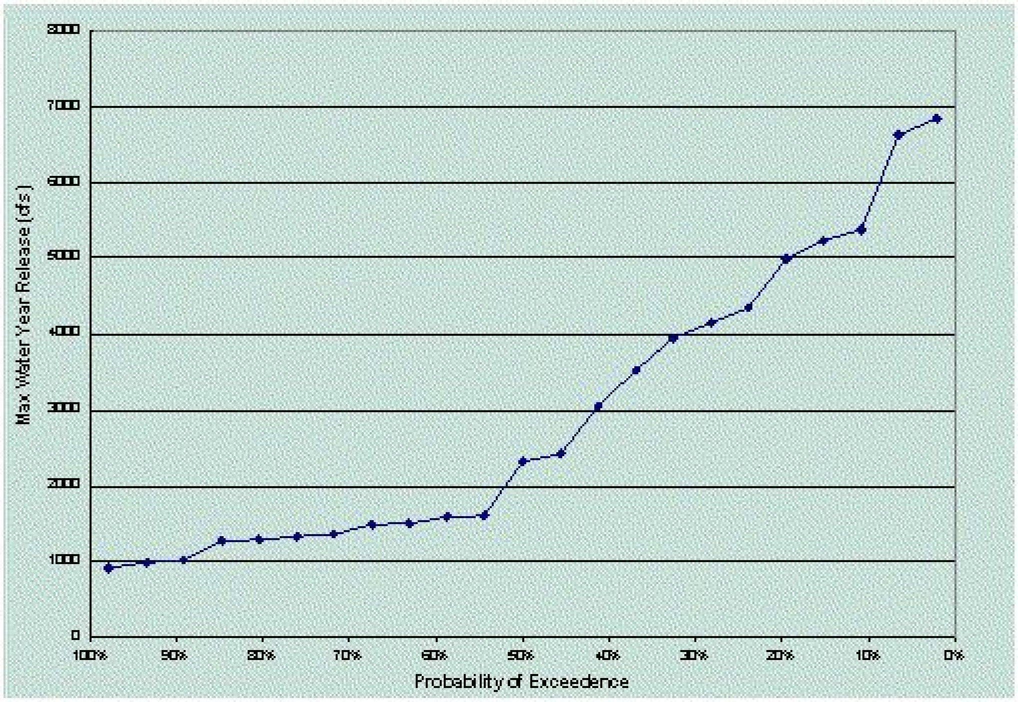

Figure 6–9 Exceedance probability for yearly Goodwin Dam releases.

Flow Fluctuations/Stranding

Flow fluctuations have the potential to dewater salmon and/or steelhead redds or isolate and strand juvenile salmonids below project reservoirs (NOAA fisheries question #3). Depending on the frequency and timing of flow fluctuations within and between years salmon and steelhead populations can be affected.

Clear Creek

Table 6–3 shows the stage discharge relationship in Clear Creek at Igo. If we use the 5 inch redd depth as the threshold for redd dewatering then a flow drop of 100 cfs in the 100 to 300 cfs range could start to dewater the shallowest redds. A flow drop of 150 cfs in the 300 to 800 cfs range could start to dewater redds and a flow drop of 300 cfs between 800 and 1,800 cfs could start to dewater redds. Flows over 500 cfs in Clear Creek are the result of uncontrolled runoff or pulse flows prescribed through collaboration with fishery agencies for the benefit of fish and habitat.

Table 6–3 Stage discharge relationship for the Clear Creek at Igo USGS gauge, Station 11-372000.

STAGE, INCHES	*DISCHARGE, CFS*
33.12	101
38.52	200
42.72	301
46.2	400

STAGE, INCHES	*DISCHARGE, CFS*
49.32	501
52.2	602
54.72	702
57	803
59.16	903
61.08	1000

Sacramento River

Based on the Sacramento River at Bend Bridge gauge, drops in flow of approximately 800 cfs in the low end of the flow range up to about 20,000 cfs have the potential to start to dry up the shallowest redds 5 inches deep (Table 6–4). Areas of the river away from stream gauges where there is not as much confinement and more spawning activity probably experience less change in stage for a given flow change but the data was not available to evaluate other locations.

Table 6–4 Stage discharge relationship in the Sacramento River at Bend Bridge, gauge 11377100.

STAGE, INCHES	*DISCHARGE, CFS*
8	4190
10	4500
12	5020
15	5490
18	5990
21	6490
24	6990
27	7490
31	7990
34	8500
38	9000
41	9510
45	10000
48	10500
52	11000
55	11500
59	12000
62	12500
65	13000

STAGE, INCHES	*DISCHARGE, CFS*
68	13500
71	14000
74	14500
78	15000
81	15500
84	16000
87	16500
90	17000
92	17500
95	18000
98	18500
101	19000
103	19500
106	20000
110	21000
114	22000
118	23000
122	24000
126	25000
129	26000
133	27000
137	28000
140	29000
144	30000

American River

Snider et al. (2001) evaluated flow fluctuations relative to stranding in the American River and made the following recommended for operations of the Folsom project.

Ramping rates should not exceed 100 cfs per hour when flows are $\leq$ 4,000 cfs;

Flow increases to 4,000 cfs or more should be avoided during critical periods (January through July for young of the year salmon and steelhead and October through March for yearling steelhead and non-natal rearing winter-run Chinook salmon) unless they can be maintained throughout the entire period; and

Flow fluctuations that decrease flow below 2,500 cfs during critical spawning periods should be precluded: October – December for Chinook salmon and December – May for steelhead. They define flow fluctuations as unnatural rapid changes in stream flow or stage over short periods resulting from operational activities of dams and diversions.

The shallowest salmon redds observed prior to any flow changes were under 5 inches of water referenced to the original bed surface (Hannon, field observations 2002) and the shallowest steelhead redds observed were over 7 inches deep (Hannon and Healey 2002). Steelhead could likely spawn in water as shallow as Chinook so this analysis is based on water depth reductions of 5 inches that could drop the water level to even with the top of the shallowest redds. Evenson (2001) measured Chinook egg pocket depth in the Trinity River. The shallowest egg depth found was 2.2 inches under the gravel referenced to the original bed surface and the mean depth to the top of the egg pocket was 9 inches. Ninety-three percent of the top of egg pockets were buried at least 5 inches under the gravel. Five inch deep eggs would not become dewatered until water drops at least 10 inches but fry emergence could be prevented if no water is over the surface of the redd. Based on cross sections measured in 1998 by the FWS, flow changes of 100 cfs generally change the water depth by about 1 inch in a flow range of 1,000 to 3,000 cfs and by about 0.5 inch in a flow range from about 3,000 to 11,000 cfs. Therefore, when flows are 3,000 cfs or lower flow drops of 500 cfs or more can begin to dewater redds. When flow is over 4,000 cfs flow drops of 1,000 cfs or more can begin to dewater redds.

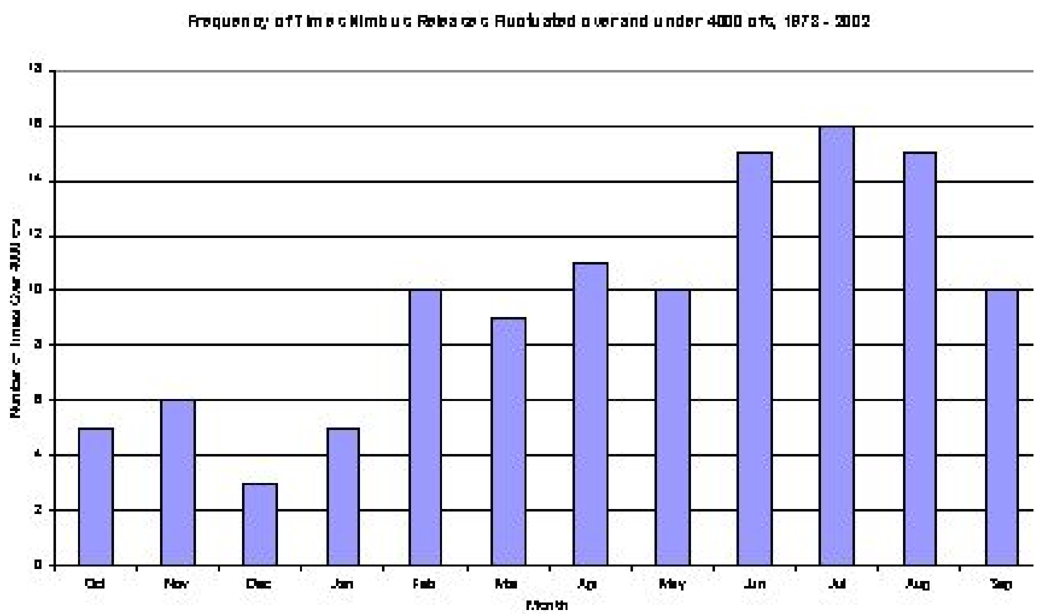

Figure 6–10 Frequency of times Nimbus releases fluctuated over and under 4000 cfs, 1972–2002.

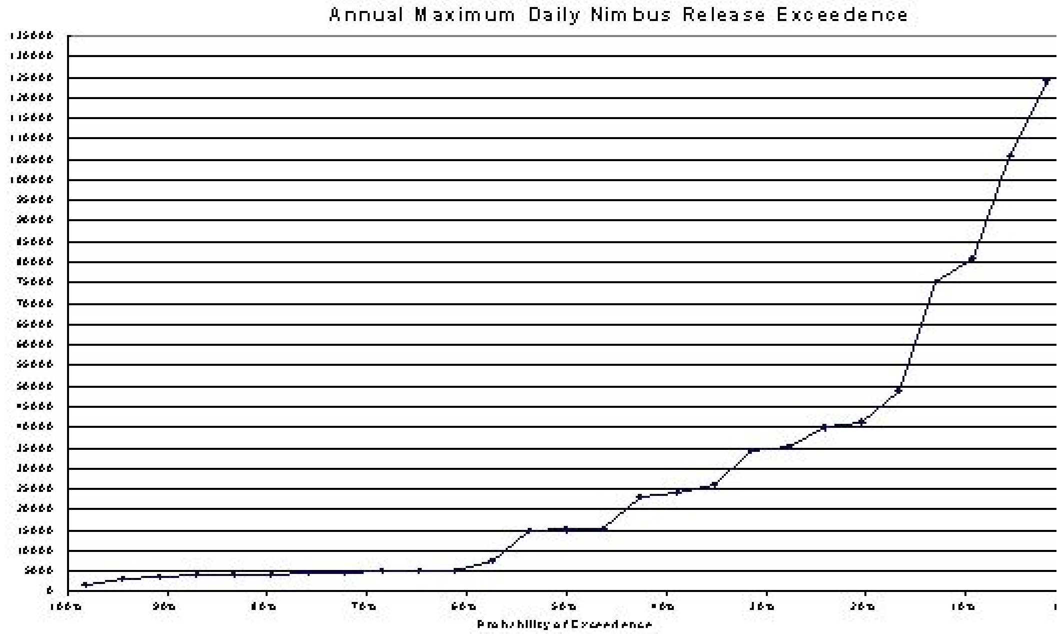

Figure 6–11 Annual Maximum Daily Nimbus Release Exceedance.

Stanislaus River

Based on the Stanislaus River at Ripon gauge, drops in flow of approximately 50 cfs in the flow range of 100 to 300 cfs have the potential to start to dry up the shallowest redds 5 inches deep (Table 6–5). Although the Ripon gauge is downstream of spawning areas, the channel morphology at the gauging station is similar to that through much of the spawning area so the stage discharge relationship should be similar. Drops in flow of 100 cfs in the flow range of about 300 to 1,000 cfs will cause a 5 inch drop in water surface elevation. Drops in flow of about 175 cfs in the flow range of 1,000 to 2000 cfs will cause about a 5 inch drop in water level.

Table 6–5 Stage discharge relationship in the Stanislaus River at Ripon, gauge 11303000.

Stage, inches - 440	*Discharge, cfs*
3	100
5	125
8	150
10	174
13	200
17	251
21	300
24	350
27	400

Stage, inches - 440	*Discharge, cfs*
32	501
37	601
43	700
49	800
54	900
58	1000
67	1200
76	1400
84	1600
92	1800
100	2000
120	2500
139	3000
175	4000
199	5000
215	6000

Flow and Its Importance to Sub-adult Chinook Salmon

Streamflow is important to sub-adult Chinook salmon (Healey 1991). Larger salmon populations tend to occur in larger river systems, suggesting a direct effect of discharge on the amount of suitable habitat area. River flows directly affect through-gravel percolation rates, which are very important to egg survival, and may help disperse swim-up fry to suitable rearing habitats.

Streamflows indirectly affect other environmental conditions, which in turn affect Chinook survival. For instance, flow rates can affect in stream temperatures for a short distance downstream of reservoirs before ambient air temperatures take over. In natural stream systems, flow is correlated with turbidity. Turbidity may be important in juvenile life stages. Juvenile salmon losses to predators may be reduced by at least 45 percent in turbid water stream reaches relative to clear water reaches (Gregory and Levings 1998). Turbid water may also stimulate faster migration rates, which reduces the time young fish are exposed to freshwater mortality risks. The relative survival benefits of longer versus shorter freshwater residence time in juvenile Chinook has not been determined for Central Valley stocks. Pink salmon, the most abundant of the salmon species, emigrate to the ocean immediately upon emergence from the gravel and presumably derive survival benefits from this trait, although pink salmon are generally less abundant in watersheds requiring freshwater migrations over longer distances. High outflows and sediment loads can increase egg mortality through scouring and suffocation (Healey 1991).

In the upper Sacramento Basin, problems of flow and temperature are closely associated during the summer and fall. Low flows make spring-run habitat in tributaries like Clear Creek, Cottonwood Creek, and Antelope Creek marginally usable, or even unusable. Problems with low flow and high temperature may also occur in current spring-run habitat like Butte and Big Chico Creeks. The likelihood that survival will be reduced in low flow years could be greater in unregulated tributaries than in regulated tributaries where stored water can sustain releases longer through dry periods.

Fish Passage

As with steelhead and other salmon races, migration barriers are a problem for winter-run and spring-run Chinook (Table 3-5). Winter-run and Spring-run have been cut off from much of their historical upper basin spawning habitat for decades by large dams. In addition, migration may be slowed or prevented in smaller tributary streams by numerous smaller agricultural diversion facilities.

ACID Diversion Dam

The ACID diversion dam created fish passage problems and can require a substantial reduction in Keswick Reservoir releases to adjust the dam flashboards, which results in dewatered redds, stranded juveniles and higher water temperatures. However, Reclamation assisted in the redesign and renovation of the flashboards and related facilities in the 1990's to reduce the risks of dewatering redds. Fish ladders and fish screens were installed around the diversion and were operated starting with the summer 2001 diversion period. During the spawning runs in 2001 and 2002 there was a substantial increase in spawning upstream of the diversion dam, attributable to the access provided by the fish ladders (Table 4-6 winter–run redd chart).

Red Bluff Diversion Dam

Problems in salmonid passage at RBDD provide a well-documented example of an agricultural facility impairing salmon migration (Vogel and Smith 1984; Hallock 1989; FWS 1987, 1989, 1990a; Vogel et al. 1988, all as cited in DFG 1998). The implementation of gates-out operations and construction of the rotary drum screen facility have substantially improved fish passage conditions at RBDD (see discussion of RBDD in Chapter 3). All spring-run juvenile emigrants pass RBDD during the gates-out period based on historical average run timing at RBDD. However, about 30 percent of adult spring–run immigrants that attempt to pass Red Bluff encounter gates-out conditions based on run timing when gates were lowered year roung (FWS 1998, as cited in DFG 1998). The current gates down operation potentially delays 15 percent of the adult winter–run and 35 percent of the juveniles going downstream in July, August, and September encounter the lowered gates (NOAA Fisheries 2003). Based on winter–run population increases that have occurred since the current gate operations were initiated, the population seems capable of increasing under current operations.

Aerial redd surveys conducted for winter–run and spring–run spawning since 1987 by DFG show that since the gates out period was moved to September 15 – May 15 in 1993, few winter–run have spawned below RBDD (Table 6–6). During 1994 and 1995 higher percentages of spring–run spawned below RBDD than in other years. The majority of spring–run production in recent years has continued to occur in Sacramento River tributaries downstream of RBDD (Mill Creek, Deer Creek, Big Chico Creek, Butte Creek, and Feather River) despite the partial elimination of migration delays. Not counting Feather River spring–run which are primarily considered to be of hatchery origin, 92 percent of spring–run since 1992 occurred in the tributaries downstream of RBDD. The proportion of spring–run using these tributaries was not affected by migratory delays at RBDD. The 8 percent of spring–run in the Sacramento River and tributaries upstream of RBDD were potentially affected by migratory delays at RBDD.

Table 6–6 Percent of winter run and spring–run redds counted below Red Bluff Diversion Dam, 1987 – 2003. data from Killam (2002).

Year	***Winter–run % Spawning Below RBDD***	***Spring–run % Spawning Below RBDD***	***Months RBDD Gates Raised***
1987	5	no survey	December - March
1988	25	3	December - mid-February
1989	2	0	December - mid-April; gates in 11 days in February
1990	7	0	December - March
1991	0	0	December - April
1992	4	0	December - April
1993	2	0	September 15 - May 15
1994	0	15	September 15 - May 15
1995	1	9	September 15 - May 15
1996	0	0	September 15 - May 15
1997	0	1	September 15 - May 15
1998	3	0	September 15 - May 15
1999	0	no survey	September 15 - May 15
2000	0	0	September 15 - May 15
2001	0.4	3	September 15 - May 15
2002	0.2	0	September 15 - May 15
2003	0.3	0.6	September 15 - May 15

New redds constructed in the Sacramento River during the typical spring-run spawning period (late August and September) since redd surveys began have shown low numbers of new redds relative to new redds counted during winter–run spawning timing and fall–run spawning timing. Peaks in redd count numbers are evident during winter–run spawning and fall–run spawning but not during spring–run spawning. The number of new redds has diminished through July and then increased at the end of September before the large increase that occurs after October 1 when they become classified as fall-run. This suggests that the number of spring-run spawning in the Sacramento River is low (average of 26 redds counted) relative to the average spring-run escapement estimate between 1990 and 2001 in the main stem Sacramento River of 908. The additional fish have not been accounted for in the tributaries upstream of RBDD. The additional fish appear to spawn in October and get counted as fall-run redds.

Additional analysis of effects of RBDD on salmon and steelhead was analyzed in an EIS (CH2M Hill 2002). Reclamation intends to maintain the same May 15 – September 15 gates in period as has been used since the 1993 winter–run biological opinion as stated in chapter 2.

Suisun Marsh Salinity Control Gates

The Suisun Marsh Salinity Control Gates (SMSCG) have the potential to affect immigration of all four Chinook races as adults move upstream through Montezuma Slough. Edwards et al. (1996) and Tillman et al. (1996) indicated operation of the SMSCG delays and/or blocks the upstream migration of adult salmon. The studies were unable to provide an accurate estimate of the magnitude of the delay or blockage due to variable results, but a potential minimum delay of about 12 hours per tidal day is possible when the gates are closed. The biological significance of this potential increase in migration time to spring-run populations is unknown since DFG staff estimates it takes a salmon 30 days to reach its spawning area from the bays (DFG 1998). Further, Montezuma Slough is only one path through the estuary, and its relative importance to the overall immigration of adult spring-run has not been studied.

Limited information is available regarding the behavior of adult Chinook in estuaries. Information from the literature indicates that tidal phase, natal origin, water temperature, dissolved oxygen, and changes in flow can all affect upstream immigration. Stein (2003) tracked 480 adult salmon, tagged with ultrasonic transmitters, through the Delta as part of multi-agency Delta Cross Channel studies. Salmon movements were inconsistent between individuals. Many salmon crossed back and forth between different channels for weeks while some moved upstream quickly. Transit times in the Delta ranged from3–48 days.

Generally, adult spring-run may be present in Suisun Marsh from February through June, with peak occurrence in May. The SMSCG are operated only to meet salinity standards. Therefore, avoidance measures (flashboards and gates out of water) are already in place to minimize effects during months when specific conductance is below standards by more than two mS/cm. Measures to improve passage for adult spring-run would be most effective if implemented when adult spring-run are moving upstream in late March through May of dry and critical water years, and mid-April through May in above and below normal water years.

DWR (1997) discussed several specific measures to mitigate gate operation effects on immigrating salmon. The measures examined included: (1) structural modifications to the flashboard section of the control gate facility in the form of openings or passages in individual flashboards; (2) lowering the height of the flashboard structure; and (3) altering the timing of gate closure on flood tides.

The Suisun Marsh Salinity Control Gates Steering Group reviewed the results from the examination of mitigation alternatives and requested an evaluation of the potential effects of structural modifications to the flashboards. Under this evaluation, the flashboard structure was modified by removing one of the four, six-foot tall flashboards and creating two, three-foot horizontal slots at two depths to potentially provide continuous unimpeded passage for adult salmon. To test the effectiveness of this modification, a three-year evaluation was initiated in the fall of 1998 by DFG and DWR to sonic tag adult fall-run Chinook and monitor their movement through the gate structure during threephases of operation: (1) when the gates are open; (2) during full-bore gate operation; and (3) during full-bore gate operation with the modified flashboard structure installed. The evaluation was repeated in two consecutive control seasons with the fish tagging and tracking occurring from approximately September 15 through October 31 of both years. The fish-tagging period was limited to the time when fall-run Chinook were present in Suisun Marsh. The Suisun Marsh Salinity Control Gates Steering Group decided based on preliminary results from the modified SMSCG tests that the slots resulted in less adult passage than the original flashboards. The steering group decided to postpone the third year of the test until September 2001 and to reinstall the original flashboards when gate operation was needed during the 2000–2001 control season. DWR and Reclamation focused on data analysis from August 2000 through February 2001, and conducted the third year of the study during the 2001–02 control season. Based on the these results, another approach to improve passage is being investigated. This modification includes opening the boat lock and using full flashboards when gates are operational. This study will take place over threeyears, from 2001–03. See “Suisun Marsh Salinity Control Gates” in Chapter 10 for more information.

Delta Emigration

The following discussion emphasizes spring-run yearling emigrants, which have been of particular management concern in recent years. This primarily addresses emigration from Mill and Deer Creeks (DFG 1998), which have a higher proportion of spring-run emigrating as yearlings than either Butte Creek (Brown 1995) or the Feather River (DWR 1999a,1999b,1999c). Sub-yearling spring-run emigrate during winter and spring when protections for delta smelt and winter-run Chinook salmon are in place. There is significant uncertainty regarding timing of emigration of yearling spring-run Chinook. Because a relatively small number of yearlings are emigrating, they are difficult to detect in the monitoring programs. Yearlings are relatively large, strong swimmers, so they may also more easily avoid the monitoring gear (McLain 1998). Other juvenile Chinook in the main stem Sacramento River are in the same size range used to define yearling spring-run Chinook, confounding data interpretation.

Marked releases of Coleman Hatchery yearling late fall-run (hereafter Coleman late fall-run Chinook) juveniles have been used as surrogates to estimate the timing of yearling spring-run emigration and take at the Delta export facilities for the Spring-run Protection Plan and the 1992 OCAP. Since 1994, FWS has released approximately 17 percent of the Coleman Hatchery late-fall production in each of November, December, and January to evaluate hatchery operations. The fish were adipose fin-clipped and coded wire tagged before release allowing identification of the members of individual release groups when they are recaptured downstream. The regulatory agencies considered Coleman late-fall Chinook appropriate surrogates for yearling spring-run because they were reared to a similar size as spring-run yearlings and were released in the upper Sacramento River. Because they were large, they were expected to emigrate quickly. They were reared in Sacramento River water, and were therefore expected to quickly habituate to the river conditions. Some patterns have recently been revealed through the Butte Creek coded wire tag program on naturally spawned spring–run. In particular the potential effects of the Sutter Bypass (lower Butte Creek). Residence time for these fish seems to be 60 – 120 days and dependent on water levels in the bypass resulting from Sacramento River flows (DFG 2003).

Coleman late-fall Chinook released in November were captured at Red Bluff and the Glenn-Colusa Irrigation District facility within two or three days of release. However, they were not captured downstream in the lower Sacramento River or the Delta, until about three days after the first significant, precipitation-induced flow event in November or December (Figure 6–12 through Figure 6–20). This suggests Chinook yearlings may use these flow events as migration cues. Based on captures in the FWS Chipps Island midwater trawl and salvage at the CVP's and SWP's Delta export facilities, some individuals may continue to emigrate for up to five months.

The Coleman late-fall Chinook released in December (Figure 6–12 through Figure 6–20) were released after the first significant, precipitation-induced flow event in the fall. However, they were not captured in the Delta until after a second significant precipitation event occurred unless there was significant Sacramento River flow associated with the earlier precipitation-induced events. Since precipitation events occurred sooner after the December releases than the November releases, these fish may have remained in the upper Sacramento River for a relatively short time (several days up to a week), then taken several more days to reach the Delta following a precipitation-induced flow event. Some emigration continued for up to four months.

The emigration of Coleman late-fall Chinook released in January (Figure 6–12 through Figure 6–20) was not as closely related to precipitation-induced flow events as the November or December releases; perhaps because significant precipitation and high flows had generally occurred prior to their release. The relationship between emigration and flow associated with precipitation events is variable, although the 1994 dry water year (Figure 6–12) is an example of January releases emigrating on precipitation-induced flow events throughout the winter and spring. Again, some emigration continued for up to four months.

Since Coleman late-fall and spring-run yearlings are similar in size and rear in the upper Sacramento River, their emigration patterns should be similar. Therefore, Sacramento River flow associated with precipitation events, along with related tributary flow events, probably provides the major cue for yearling spring-run emigration.

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