Chapter 4 Factors That May Influence Steelhead Distribution and Abundance

This chapter describes the factors that affect steelhead and critical habitat in the action area. A large factor affecting all the listed salmonids is the loss of spawning and rearing habitat upstream of various dams. The limiting factors that affect steelhead survival are high water temperatures, low flows and flow fluctuations, limited spawning and rearing habitat, blocked or delayed passage, and unscreened river diversions. Other factors that may influences steelhead distribution and abundance include: predation and competition; food abundance in the Delta; contaminants, harvest, hatchery operations, and disease.

Water Temperature

Water temperatures that are too low or too high can kill steelhead by impairing metabolic function, or indirectly by increasing the probability of disease, predation, or other secondary mortality factors (Myrick and Cech 2001, Leitritz and Lewis 1980; Reiser and Bjornn 1979, all as cited in McEwan and Jackson 1996). Steelhead temperature tolerances vary among life stages (Bovee 1978; Reiser and Bjornn 1979; Bell 1986, all as cited in McEwan and Jackson 1996) and stocks (Myrick 1998, 2000; Nielsen et al. 1994a) (Table 4-1). In this biological assessment (BA), temperature recommendations of McEwan and Jackson (1996) are used for all life stages except fry and juveniles, which have recently been studied using local stocks in a laboratory situation (Myrick 1998, 2000).

Myrick (1998, 2000) found the preferred temperatures for Mokelumne River Fish Installation, Feather River Hatchery, and naturally spawned Feather River juvenile steelhead placed into thermal gradients were between 62.5 °F and 68°F (17 and 20 degrees Celsius [°C]). Myrick and Cech (2005) also found that Nimbus-strain steelhead had a higher growth rate at 66°F (19°C) than groups of steelhead raised at lower temperatures. This is considerably warmer than the rearing temperature recommended by McEwan and Jackson (1996). Feather River snorkel survey observations and temperature data from summer 1999 also appear to corroborate Myrick’s (1998, 2000) results. Young-of-the-year (YOY) steelhead in the American River have been observed in snorkel surveys, captured by seining, and passive integrated transponder (PIT) tagged in habitats with a daily average temperature of 72 °F and a daily maximum over 74 °F (California Department of Fish and Game [DFG] and the U.S. Bureau of Reclamation [Reclamation] unpublished data).

Table 4-1 Recommended water temperatures (°F) that provide for highest survival for life stages of steelhead in Central Valley streams from McEwan and Jackson (1996), Myrick (1998, 2000), Piper et al 1982, Bell 1991 Myrick and Cech (2001).

Life stage	Temperature recommendation (°F)
Migrating adult	46–52
Holding adult	50-56

Life stage	Temperature recommendation (°F)
Spawning	39–52
Egg incubation	48–52
Juvenile rearing	<65
Smoltification	<57

Flow

Adverse effects to steelhead stocks in the Sacramento and San Joaquin rivers have been mostly attributed to water development (McEwan and Jackson 1996). Specific examples include inadequate instream flows caused by water diversions, rapid flow fluctuations due to water conveyance needs and flood control operations, inadequate coldwater releases from upstream reservoirs, loss of spawning and rearing habitat due to dams, and juvenile entrainment into unscreened or poorly screened water diversions.

Measures to minimize effects on salmon will usually result in concomitant effects on steelhead. However, life history differences between steelhead and Chinook salmon may also lead to different, and potentially conflicting, flow requirements for each species. Although the most important flow needs for steelhead in Central Valley rivers are for cold water during the summer and early fall, increased flows for Chinook salmon are typically scheduled for the spring and mid-fall migration periods. In some cases, such as the temperature criteria for winter-run Chinook from Keswick to Red Bluff Diversion Dam (RBDD), reservoir operations coincide with steelhead requirements. Differences in the timing of flow needed by different species can create difficult management dilemmas, particularly during an extended drought.

In the upper Sacramento River basin, problems of outflow and temperature are closely related (McEwan and Jackson 1996). Low summer and fall outflows can reduce the quality of steelhead rearing habitat because of associated increases in water temperature. In addition, adequate habitat conditions must be maintained all year for steelhead to benefit.

PHABSIM Flow Studies

Sacramento River

The U.S. Fish and Wildlife Service (FWS) (2003) developed spawning flow-habitat relationships for steelhead spawning habitat in the Sacramento River below Keswick Dam using the Physical Habitat Simulation (PHABSIM) component of the Instream Flow Incremental Methodology (IFIM). Relationships were developed by cross section and by stream segments but were not aggregated into riverwide flow-habitat relationships.

Steelhead spawning-weighted-usable-area peaked at river flows of 3,250 cubic feet per second (cfs) in the reach upstream of the Anderson-Cottonwood Irrigation District (ACID) Diversion Dam. This habitat relationship holds regardless of whether the dam boards are in or out. The reach between ACID dam and Cow Creek, spawning usable area also peaked at river flows of

3,250 cfs. In the lower reach, from Cow Creek to Battle Creek, spawning usable area peaked at river flows of about 13,000 cfs, but did not vary significantly in a flow range between about 6,000 and 14,000 cfs.

The minimum required Sacramento River flow is 3,250 cfs. This flow level provides adequate physical habitat to meet the needs of all steelhead life stages in the Sacramento River. Flows during the summer generally well exceed this amount in order to meet temperature requirements for winter-run Chinook salmon. The winter-run temperature requirements result in water temperatures suitable for year-round rearing of steelhead in the upper Sacramento River.

Clear Creek

Denton (1986) used the IFIM to estimate optimal Clear Creek flows for salmon and steelhead. The resultant estimate of optimal Whiskeytown Dam release schedule from the IFIM study is shown in Figure 5–4. Summer-rearing habitat resulting from high water temperatures appeared to be the limiting factor for steelhead. Optimal steelhead flows in the upstream (above the former Saeltzer Dam site) reach were 87 cfs for spawning and 112 cfs for juvenile rearing. Optimum flows for steelhead in the reach below Saeltzer Dam were predicted to be 250 cfs in all months except April when they drop to 225 cfs and May 1 through 15 when they are 150 cfs. Denton (1986) recommended that tributary streamflows occurring below Whiskeytown Dam be included in computing the additional releases required from Whiskeytown Dam to meet the total recommended fishery flow needs.

Feather River

In 2002, DWR conducted an 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]) the Thermalito Afterbay Outlet (TAO) were modeled separately because of their distinct channel morphology and flow regime. The weighted usable (spawning) area (WUA) for steelhead spawning in the LFC had no distinct optimum over the range of flow between 150 and 1,000 cfs. However, in the HFC, a maximum WUA was observed at a flow just under 1,000 cfs. The difference in these results can be attributed to the relative scarcity of suitable steelhead spawning gravels in the LFC segment of the Feather River.

American River

FWS (1997) measured 21 cross sections of the American River in high-density Chinook spawning areas. They estimated the flows at which the greatest usable spawning area would be available to steelhead and Chinook based on measurements of water velocity, water depth, and substrate size from steelhead and Chinook redds in the American River. There was low variability in WUA throughout the range of flows analyzed (1,000-6,000 cfs). Table 4-2 shows the average of the WUA from the 21 cross sections expressed as 1,000 square feet of spawning area per 1,000 feet of stream. The WUA for steelhead peaked at a flow of 2,400 cfs. All flows from 1,000-4,000 cfs provided at least 84 percent of the maximum WUA.

Table 4-2 Average WUA (expressed as 1,000 square feet of spawning area per 1,000 feet of stream) from 21 cross sections measured in 1995 in high-density Chinook spawning areas. Summarized from FWS 1997.

Nimbus Release (cfs)	Steelhead Average WUA	Chinook Average WUA
1,000	31	62
1,200	33	71
1,400	34	78
1,600	35	82
1,800	36	84
2,000	36	83
2,200	36	81
2,400	37	78
2,600	36	74
2,800	36	69
3,000	36	65
3,200	36	60
3,400	35	56
3,600	34	52
3,800	32	48
4,000	31	45
4,200	29	42
4,400	27	38
4,600	26	36
4,800	24	33
5,000	23	31
5,200	22	28
5,400	21	26
5,600	20	25
5,800	19	23
6,000	19	21

Snider et al. (2001) evaluated effects of flow fluctuations in the American River on steelhead and salmon. They defined flow fluctuations as unnatural rapid changes instream flow or stage over short periods resulting from operational activities of dams and diversions. They recommended ramping flows in the American River of 100 cfs/hour or less at flows less than 4,000 cfs to reduce stranding of steelhead caused by rapid dewatering of habitat. They further recommended avoiding flow increases to 4,000 cfs or more during critical rearing periods. These critical rearing periods are January through July for YOY salmon and steelhead, and October through March for yearling steelhead and non-natal rearing winter-run Chinook salmon, unless the higher flows can be maintained throughout the entire period. For the maintenance of sufficient spawning habitat and to keep water flowing through redds, they recommended precluding flow fluctuations that decrease flow below 2,500 cfs during critical spawning periods (December through May).

Ayres Associates (2001) used detailed topography of the river to model sediment mobilization at various flows in the American River. They found that at 115,000 cfs (the highest flow modeled), particles up to 70 millimeters (mm) median diameter would be moved in the high-density spawning areas around Sailor Bar and Sunrise Avenue. Preferred spawning gravel size is 6–125 mm (1/4–5 inches) in diameter.

Snider et al. (2001) produced survival indices for Chinook salmon based on number of redds versus the population estimate of outmigrating juveniles over a period of 7 years of monitoring in the 1990’s. They found that high flows in January had the largest effect on survival according to the following equation: Survival = 11,200*(January maximum flow, cfs)$^{-0.28}$. The higher the flow in January, the lower the survival index, although the confidence bounds in this relationship are large. January is the period with the greatest number of Chinook eggs in the gravel; thus, the high flows are supposedly reducing survival of incubating eggs by scouring or suffocating the eggs and alevins in redds. Because steelhead spawn in similar habitat and require similar incubation conditions, high flows could affect incubating steelhead eggs in a similar manner.

Monitoring has shown that juvenile steelhead numbers in the river decrease throughout the summer such that the available rearing habitat is not fully seeded with fish. Therefore, the rearing population in the river is not likely limited by density-dependent factors. More likely, water temperature and, potentially, predator fish species such as striped bass limit the rearing population of steelhead in the American River. Flows of about 1,500 cfs or greater have sufficient thermal mass to maintain much of the water temperature benefits of cool Folsom releases downstream to Watt Avenue. During years with a low coldwater pool, there may not be enough cold water to provide optimal water temperatures through summer and fall into the peak Chinook spawning period in November. Table 4-3 shows a calculation of estimated fry to smolt survival in the American River.

Table 4-3 Estimates of wild steelhead smolt production and hatchery smolt survival in the American River based on adult hatchery counts, spawner surveys and hatchery yearling releases (Hannon and Deason 2007).

Adult Spawning Year	2007	2006	2005	2004	2003	2002	2001	2000
Year smolts released or outmigrated	2005	2004	2003	2002	2001	2000	1999	1998
Hatchery smolts released in Jan/Feb. of above year[3]	400,000	400,000	419,160	414,819	467,023	402,300	416,060	385,887
In-river spawning adults	504		266	330	343	300		
Total Hatchery Produced Adult Return[1]	3,613	2,660	3,472	2,425	1,386	1,745	3,392	2,057
Unclipped Adults in hatchery	116		118	17	27	69	50	
Percent return of hatchery fish (clipped adult return divided by smolts released two years prior)	0.90%	0.67%	0.83%	0.58%	0.30%	0.43%	0.82%	0.53%
Wild smolts that outmigrated (two years prior)[2]	18,424		17,457	8,552	20,661	22,827	6,132	
Estimate of fry produced based on redd surveys	448,749		220,987	405,445	446,017	333,900		
Fry to smolt survival estimated	available 2010		available 2008	5%		5%		
[1] assumes 20% recreational harvest based on angler surveys in 1999 and 2001								
[2] assumes same smolt to adult survival of wild smolts as for hatchery released smolts and that 10% of in-river spawners are naturally produced fish								
[3] values for 2004 and 2005 are estimates								

Stanislaus River

Aceituno (1993) applied the IFIM to the Stanislaus River between Riverbank and Goodwin Dam (24 river miles) to help to determine instream flow needs for Chinook salmon and steelhead. Table 4-4 gives the resulting instream flow recommendations for rainbow trout and steelhead based on PHABSIM results. Macrohabitat conditions such as water quality, temperature, and the value of outmigration, attraction, and channel maintenance flows were not included in the analysis.

Table 4-4 In-stream flows that would provide the maximum weighted usable area of habitat for rainbow trout and steelhead trout in the Stanislaus River between Goodwin Dam and Riverbank, California (Aceituno 1993).

Life Stage	Instream Flow (cfs)	
	Rainbow Trout	Steelhead
Spawning	100	200
Fry	50	50
Juvenile	150	150
Adult	400	500

Habitat Availability

Large-scale loss of spawning and rearing habitat has been attributed as having the single greatest effect on steelhead distribution and abundance (McEwan and Jackson 1996). Historically, steelhead spawned and reared primarily in mid- to high-elevation streams where water temperatures remained suitable all year. Yoshiyama et al. (1996) estimated that 82 percent of the historical Chinook salmon spawning and rearing habitat has been lost. The percentage of habitat loss for steelhead is presumably greater, because steelhead were more extensively distributed upstream than Chinook salmon. Steelhead could have used numerous smaller tributaries not used by Chinook salmon due to the steelhead's upstream migration during periods of higher flow, superior leaping ability, ability to use a wider variety of spawning gravels, and ability to pass through shallower water. The estimated number of historical, pre-impassable dam, and post-impassable dam river miles available to steelhead in the Sacramento, Feather, American, and Stanislaus rivers and Clear Creek is provided in Table 4-5. Potential migration barriers also occur in many other streams (Table 4-6).

Table 4-5 Estimated number of historical, pre-dam, and post-dam river miles available to steelhead (includes mainstem migratory, spawning, and rearing habitat). The extent of historical habitat is based on Chinook salmon distribution and should be considered minimum estimates for steelhead.
Source: Yoshiyama et al. (1996).

	Historical	Pre-dam	Post-dam	Lower Dam Completed
Clear Creek	25	25	16	1963
Sacramento River	493	493	286	1945
Feather River	211	<211	67	1968
American River	161	27	23	1955
Stanislaus River	113	113	58	1912

Table 4-6 Summary of potential salmonid migration barriers on Central Valley streams. Adapted from Yoshiyama et al. (1996).

Stream[a] and Passable Structures	Notes	First Impassable Barrier	Operator
Sacramento River			
Red Bluff Diversion Dam	FB, SC, FLD	Keswick Dam	Reclamation
Anderson-Cottonwood Irrigation District Diversion Dam	FB, SC, FLD		ACID
Clear Creek			
		Whiskeytown Dam	Reclamation
Battle Creek			
Coleman National Fish Hatchery Weir and various Pacific Gas & Electric (PG&E) dams (e.g. Wildcat)	FLD[b]	Coleman South Fork Diversion Dam; Eagle Canyon Dam (being laddered as part of restoration program)	PG&E
Antelope Creek	DW	Mouth	Edwards Ranch; Los Molinos Mutual Water Co.
Mill Creek			
Ward Diversion Dam	SC, SL, FLD	Morgan Hot Spring	Los Molinos Mutual Water Co.

Stream[a] and Passable Structures	Notes	First Impassable Barrier	Operator
Clough Diversion Dam	BR		
Upper Diversion Dam	SC, SL, FLD		Los Molinos Mutual Water Co.
Deer Creek			
Stanford-Vina Diversion Dam	SC, FLD	Upper Deer Creek Falls	Stanford-Vina Irrigation Co.
Cone-Kimball Diversion Dam	SC, SO		Stanford-Vina Irrigation Co.
Deer Creek Irrigation Co. Diversion	SC, SO		Deer Creek Irrigation Co.
Lower and Upper Deer Creek Falls	FLD		
Butte Creek			
Parrott-Phelan Diversion Dam	SC, FLD	Centerville Head Dam or Quartz Bowl Barrier (barrier most years)	M&T Ranch
Durham-Mutual Diversion Dam	SC, FLD		Durham-Mutual Water Co.
Gorrill Diversion Dam	SC, FLD		Gorrill Ranch
Adams Diversion Dam	SC, FLD		Rancho Esquon Investment Co.
Butte Slough Outfall Gates			
Sanborn Slough	FLD		FWS/RD1004
East-West Weir	FLD		Butte Slough Irrigation District
Weir 2	FLD		DWR
Weir 5	FLD, SC		Butte Slough Irrigation District
Weir 3	FLD		Butte Slough Irrigation District
Weir 1	FLD		FWS
Stony Creek			
Glenn-Colusa Irrigation District (GCID) Canal (Formerly a gravel berm was used, but water canal is now piped under river.)	BR	Black Butte Dam	U.S. Army Corps of Engineers (Corps)
Tehama Colusa Canal Authority (TCCA) rediversion berm (Absent during adult migration)	UN		
Orland North Canal Diversion	FB, UN		
Yuba River			
Daguerre Point Dam	UN, FLD	Englebright Dam	Corps and Yuba County Water Agency
Feather River		Feather River Fish Barrier Dam	DFG
American River		Nimbus Dam	Reclamation
Putah Creek		Putah Diversion Dam	Solano County Water Agency
Yolo Bypass		Fremont Weir	DWR
Mokelumne River			

Stream[a] and Passable Structures	Notes	First Impassable Barrier	Operator
Woodbridge (Lodi Lake) Dam	FLD, FB	Camanche Dam	East Bay Municipal Utility District (EBMUD)
Central Valley Project (CVP)- and State Water Project (SWP)-influenced channels			
Calaveras River[d]			
Bellota Dam	UN with FB	New Hogan Dam	USACE
Stanislaus River		Goodwin Dam	Reclamation
Tuolumne River		La Grange Dam	Tulare Irrigation District
Merced River			
		Crocker-Hoffman Dam	Maxwell Irrigation District
San Joaquin River			
Hill's Ferry Fish Barrier	10/1 - 12/31	Alaskan Weir	DFG

[a] Only streams with barriers are listed.

[b] Not currently operational.

[c] Harrell and Sommer, In press.

[d] Tetra Tech (2001).

BR = breached
DW = dewatered at some point throughout the year
FB = flashboards removed during winter
FLD = fish ladder
SC = screened diversion
SL = sloped dam
SO = salmon can swim over dam
UN = unscreened diversion

Habitat Suitability

Fish Passage, Diversion, and Entrainment

As described above, upstream passage of steelhead has been most severely affected by large dams blocking access to headwaters of the Sacramento and San Joaquin rivers on most major tributaries (McEwan and Jackson 1996). The remaining areas below major dams may not have optimal habitat characteristics. For example, lower elevation rivers have substantially different flow, substrate, cover, nutrient availability, and temperature regimes than headwater streams. In addition, small dams and weirs may impede upstream migrating adults, depending on the effectiveness of fish ladders at various flows or whether the boards are removed from the weirs during the migration period. Salmonids are able to pass some of these dams and weirs under certain conditions, but studies have not been conducted to fully evaluate fish passage at all structures at all flows. In particular, there is concern that high flows over small dams and weirs may obscure the attraction flows at the mouths of the ladders, effectively blocking upstream migration (CALFED 1998).

Sacramento River

Until recently, three large-scale, upper Sacramento River diversions (RBDD, ACID, and GCID) have been of particular concern as potential passage or entrainment problems for steelhead (McEwan and Jackson 1996). The GCID diversion is now screened using large flat-plate screens. Operational controls in effect to protect winter-run Chinook (a reduction in diversion rate to reduce approach velocities to 0.33 ft/s) are likely to provide protection to steelhead as well. In addition, construction to double the screen area, increase the number of bypass structures, and provide a new downstream control structure was completed in 2001. A gradient control structure in the mainstem of the river at mile 206 was completed in 2001 to provide suitable flow conditions through the side channel for operation of the diversion.

In the past, the ACID diversion dam created fish passage problems. However, new fish ladders and fish screens were installed around the diversion and were operated starting in the summer 2001 diversion period. Prior to the 1990s, the dam required a temporary but substantial reduction in Keswick Reservoir releases to manually adjust the dam flashboards, which resulted in dewatered redds, stranded juveniles, and high water temperatures. Reclamation helped modify the flashboards in the 1990s to facilitate adjustment at higher flows, reducing the risk of dewatering redds.

Salmonid passage problems at RBDD have been well-documented (Vogel and Smith 1986; Hallock 1989; FWS 1987, 1989, 1990b; Vogel et al. 1988, all as cited in DFG 1998). Vogel (1989, as cited in DFG 1998) estimated the entrainment of young salmon from 1982 through 1987 averaged approximately 350,000 fish per year. The fish louver and bypass system originally constructed at RBDD was replaced with rotary drum screens and an improved bypass system, which began operation in April 1990. The drum screen facility was monitored to assess juvenile salmon entrainment into the Tehama-Colusa Canal through 1994 (FWS 1998). No fish were collected in monitoring efforts in 1990 to 1992 or 1994. In 1993, 33 salmon were entrained, resulting in an estimated 99.99 percent screening efficiency. The drum screen facility at RBDD is highly efficient at reducing salmonid entrainment.

Facilities improvements have been second only to the implementation of “gates-out” operation of RBDD for improving juvenile salmonid survival (FWS 1996). The RBDD gates were raised during the non-irrigation season beginning in 1986-87 to improve fish passage conditions, especially for winter-run Chinook salmon. The initial gates-out period of 4 months was incrementally increased to 8 months by 1994-95. Run timing past RBDD is shown in Figure 4-1. The initial four month gates out period resulted in a blockage of steelhead during the peak of their upstream migration, forcing them to use the fish ladders to obtain passage. Under these operations only the earliest migrating steelhead arrive at RBDD before the gates are raised.

During the current gates-out operation (September 15 through May 14), fish passage conditions are “run of the river,” and essentially all adverse effects associated with fish passage are eliminated. Water deliveries at RBDD are limited during these 8 months to diversions through a series of screened, temporary pumps and at the RBDD Research Pumping Plant (FWS 1998). Although the historical counts of juvenile steelhead passing RBDD do not differentiate steelhead from resident rainbow trout, approximately 95 percent of steelhead/rainbow trout juvenile emigrants pass during the gates-out period based on historical emigration patterns at RBDD (DFG 1993, as summarized in FWS 1998).

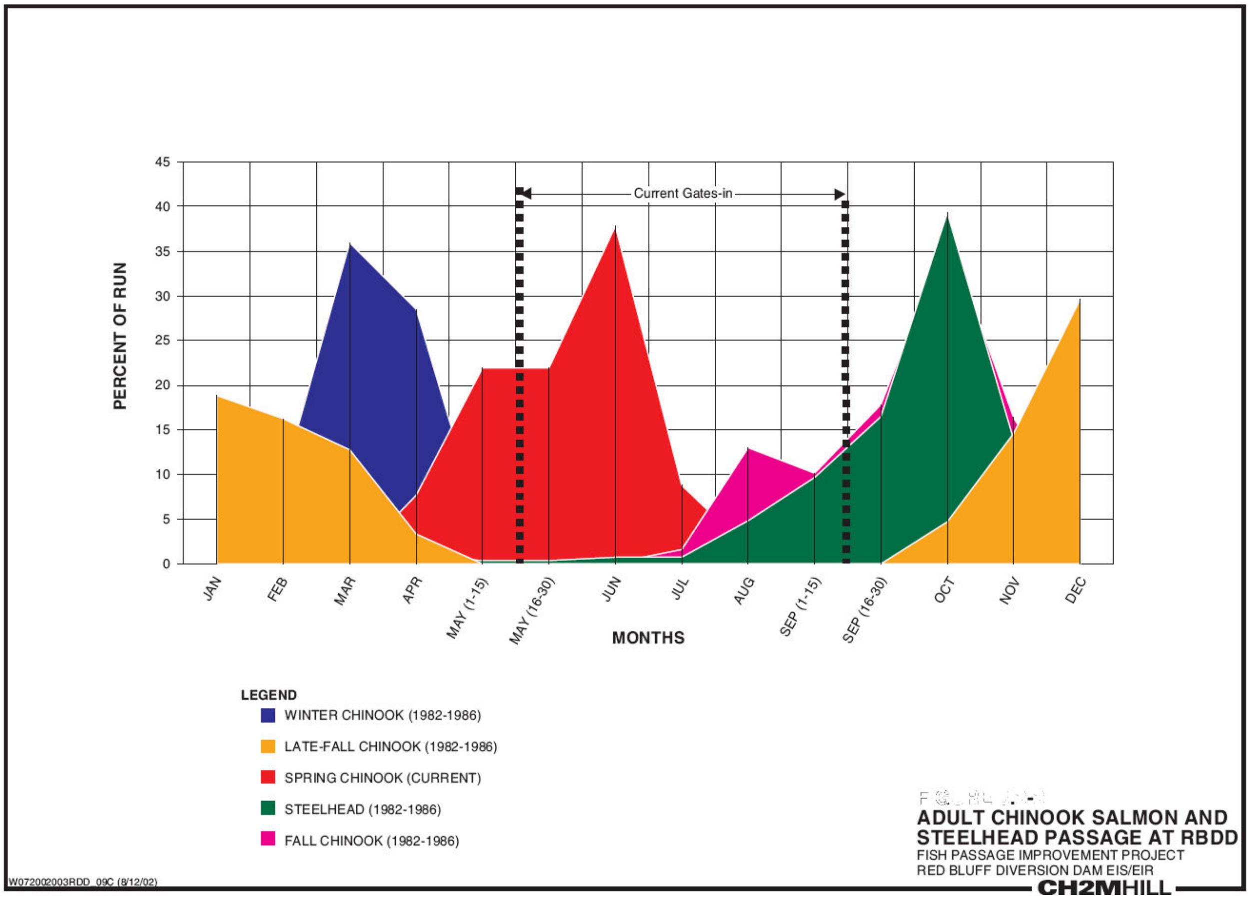

Figure 4-1 Run timing of adult steelhead and Chinook salmon past RBDD (from TCCA and Reclamation 2002).

Immigrating adult steelhead must also negotiate RBDD to gain access to natal streams, including the upper Sacramento River, Clear Creek, and Battle Creek. Approximately 84 percent of adult steelhead immigrants pass RBDD during the gates-out period based on average run timing at RBDD. Therefore, most steelhead have had unimpeded passage past RBDD since 1994-95 (FWS 1998; TCCA and Reclamation 2002). During the late summer and fall months, the steelhead immigration season, delays were typically less than four days for fall-run Chinook salmon (Vogel et al 1988).

In addition to the problems created by large canal diversions, there are an estimated 300 smaller unscreened diversions on the Sacramento River between Keswick Dam and the Delta (McEwan and Jackson 1996) and another 2,000 or so in the Delta itself (DFG diversion database). Operation of these diversions likely entrain juvenile steelhead. However, no steelhead were observed during several years of sampling agricultural diversions in the Delta (Cook and Buffaloe 1998), and only one steelhead was collected during a 2-year study of the large Roaring River Diversion in Suisun Marsh before it was screened (Pickard et al. 1982b).

The diversions at RBDD during the gates-out period are supplemented by rediversions of CVP water stored in Black Butte Reservoir through the Constant Head Orifice (CHO) on the Tehama-Colusa Canal. This rediversion requires the use of a temporary berm across Stony Creek that potentially blocks upstream passage and impedes downstream passage of salmonids and creates an entrainment hazard for downstream migrating juveniles. Over 90 percent of the flow is into the CHO at peak diversions during late May. Although few salmonids are present above the CHO, it creates a significant hazard for those that are present. Recent monitoring data, following installation of the GCID siphon downstream of the CHO, caught few salmonids, suggesting this rediversion hazard poses little risk to salmonids. Although the data are limited, it appears the salmonids move downstream to the mouth of the creek before rediversions begin, which generally coincides with the rise of temperature above 56°F (Reclamation 1998, 2002, and 2003).

The Sacramento-San Joaquin Delta

The Delta serves as a migration corridor to the upper Sacramento and San Joaquin River basins for adult and juvenile steelhead. It also serves as a rearing habitat for juveniles that move into the Delta before they enter saltwater. Presumably, one of the anthropogenic factors that might influence steelhead abundance and distribution in the Delta is CVP and SWP operations. Little data are available to determine the extent to which CVP and SWP Delta operations affect steelhead population abundance.

DWR and Reclamation (1999) reported that significant linear relationships exist between total monthly export (January through May) and monthly steelhead salvage at both Delta fish facilities. The months included in the analysis were based on months that steelhead consistently appeared at the salvage facilities between 1992 and 1998. Scatterplots of 1993 through 2006 CVP and SWP steelhead salvage versus exports are shown in Figure 4-2 and Figure 4-3, respectively.

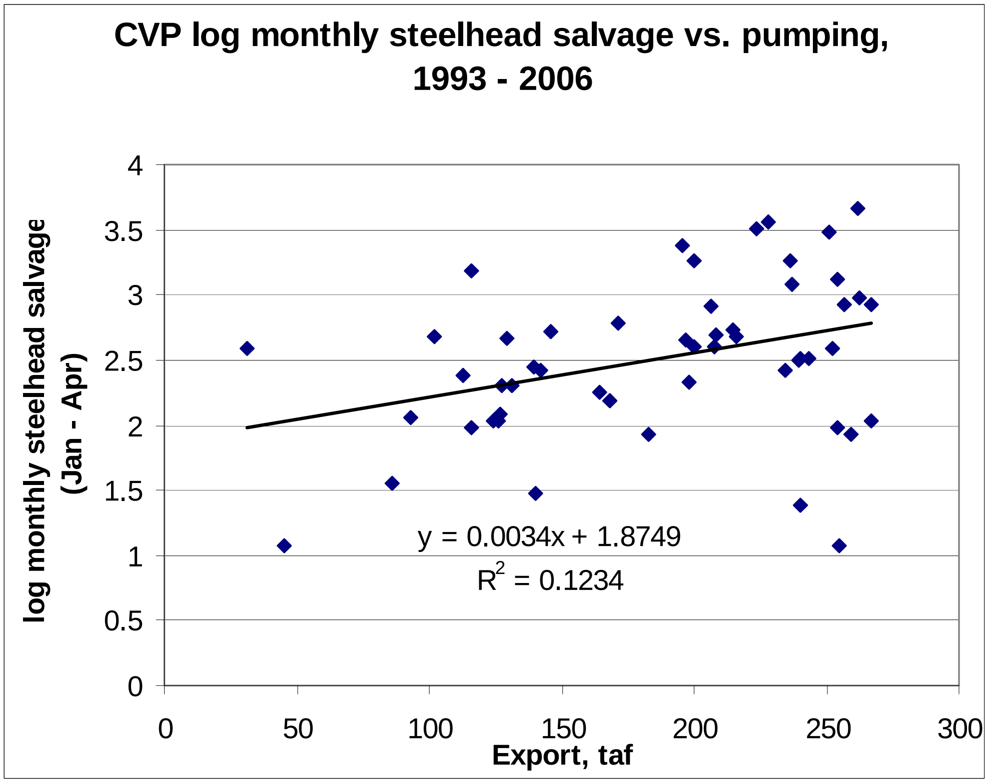

Figure 4-2 Scatterplot of total monthly CVP export in acre feet vs. $\log_{10}$ total monthly CVP steelhead salvage, 1993-2006.

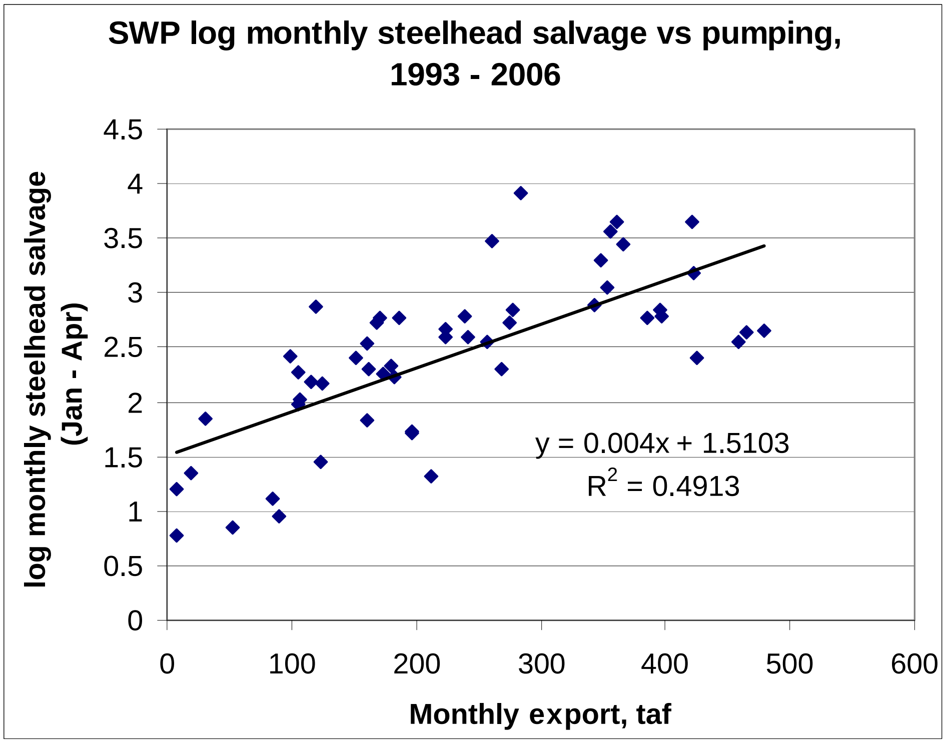

Figure 4-3 Scatterplot of total monthly SWP export in acre-feet vs. $\log_{10}$ total monthly SWP steelhead salvage, 1993-2006.

Figure 4-4 shows steelhead salvage since 1992 (Figure 4-4). Implementation of the Bay-Delta Accord likely helped to reduce steelhead entrainment that otherwise would have occurred. Steelhead presence in the south delta is likely related to yearly population flucuations and water flows from upstream tributaries. Returns to Nimbus and Feather River Hatcheries since 1992 are not correllated (Figure 3-10). These hatcheries release relatively equal numbers of steelhead smolts each year. The lack of correlation in returns to Nimbus and Feather River Hatcheries indicates that factors associated with steelhead survival are complex.

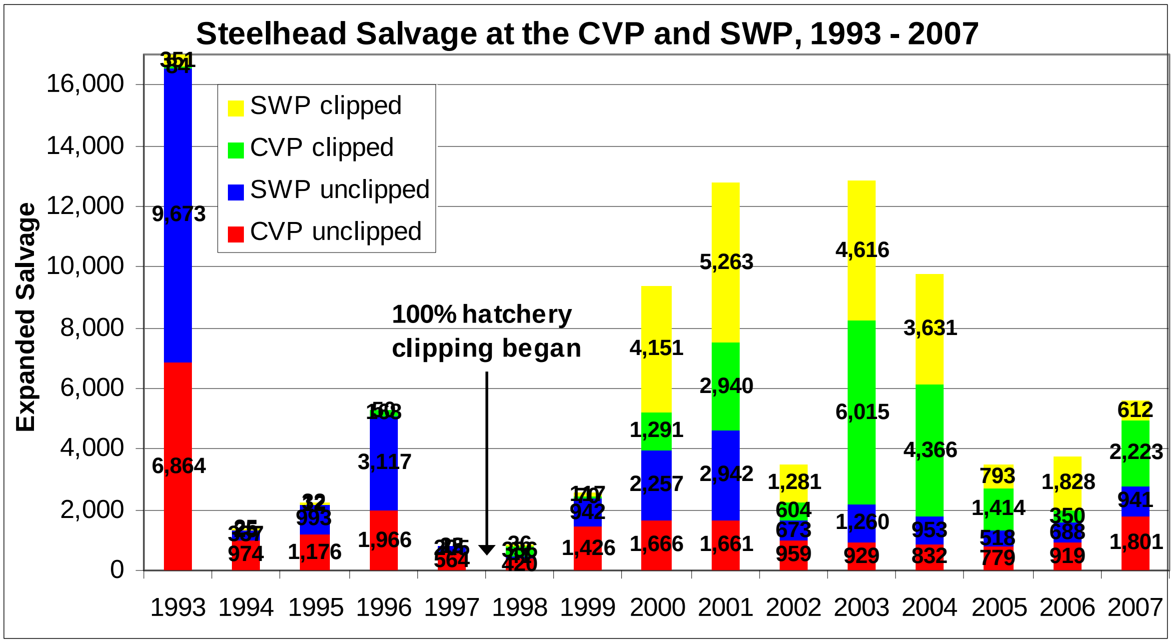

Figure 4-4 Steelhead salvage, 1993 – 2007 by adipose clip status and facility.

In addition to being correlated to amount of water exported, steelhead salvage is positively correlated to December through June catch per unit effort (CPUE) of steelhead in the FWS Chipps Island Trawl (Spearman *R* = 0.89, *P* = 0.02; Figure 4-5), which is considered the best available estimate of juvenile steelhead year-class strength. In other words, the Delta facilities take more steelhead when there are more steelhead. This suggests steelhead salvage at the facilities is an indicator of juvenile year-class strength. Steelhead that are captured at Chipps Island Trawl (Figure 4-6) do not appear to have decreased since 1998 when hatcheries began clipping all steelhead they released. Prior to 1998 abundances may have been higher but there is no way to know if the higher numbers were hatchery or wild fish.

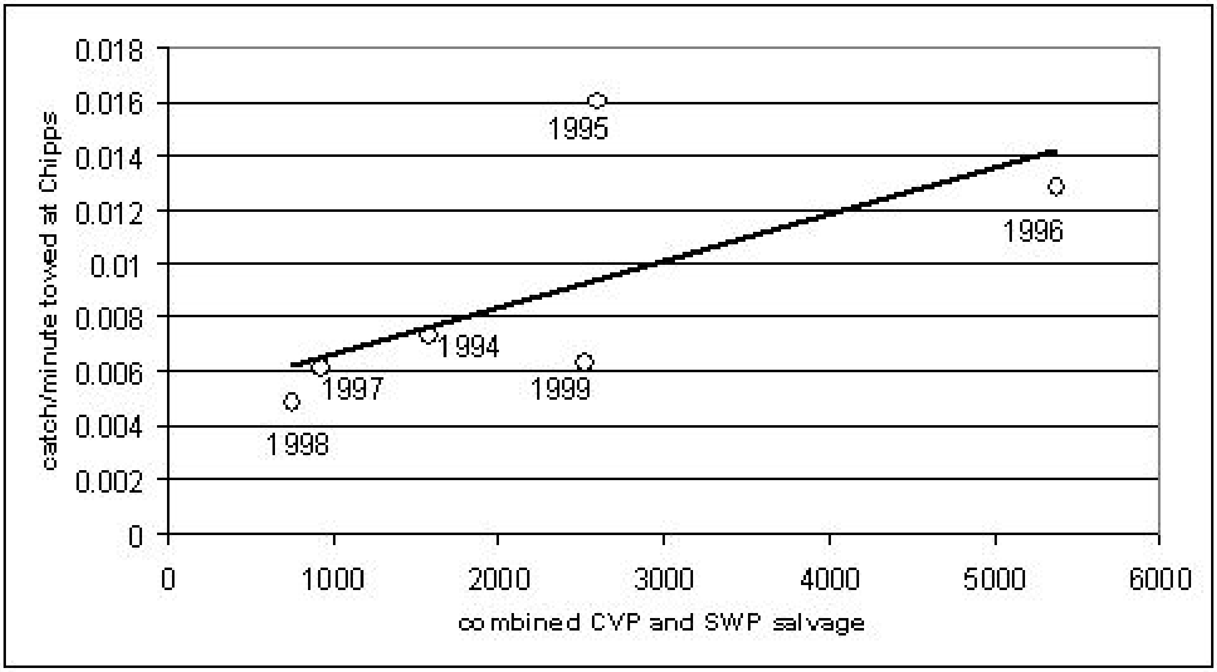

Figure 4-5 Relationship between total combined CVP and SWP steelhead salvage December through June, and December through June steelhead catch per minute trawled at Chipps Island, December 1993 through June 1999.

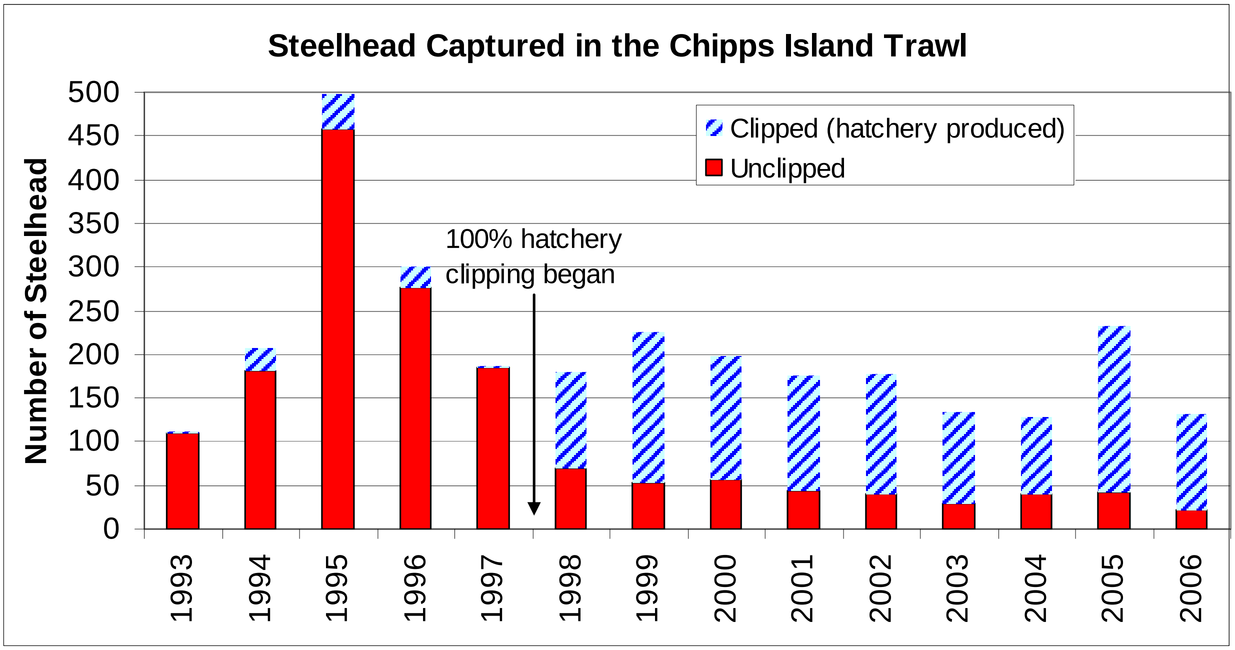

Figure 4-6 Steelhead captured in the Chipps Island Trawl, 1993 – 2006 (data from BDAT) note: 100% hatchery steelhead clipping began in 1998.

The currently available data suggest salvage represents small percentages of hatchery and wild steelhead smolts. The estimated percentages of hatchery smolts in combined (SWP and CVP) salvage ranged from 0.01 to 0.4 percent of the number released from 1998 through 2000. The estimated percentages of the wild steelhead smolt populations salvaged were higher, but were still less than 1 percent each year and ranged from 0.06 percent to 0.9 percent (Nobriga and Cadrett 2001). For salmonids, typically 1-2 percent of smolts survive to return as adults. At a 2 percent smolt-to-adult survival, each steelhead smolt lost represents 0.02 adult or one potential adult for each 50 smolts lost at the pumps. A high percentage of the unclipped steelhead captured at the CVP salvage facility in 2003 had fin erosion, indicating they were likely hatchery fish that missed getting clipped. These fish are currently counted as unclipped and assumed to be wild. Lloyd Hess (personal communication 2003) recommended updating the data sheet for salvage monitoring to include unclipped steelhead that display physical characteristics of hatchery reared steelhead.

The assessment of effects of operations of the CVP and SWP on the Central Valley steelhead DPS is 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 an estimate of the proportion of naturally spawned steelhead smolts emigrating through the Delta. The proportions of adipose fin-clipped steelhead are shown in Figure 4-7. This figure shows that wild (unclipped) steelhead are larger on average than hatchery (clipped) fish.

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.

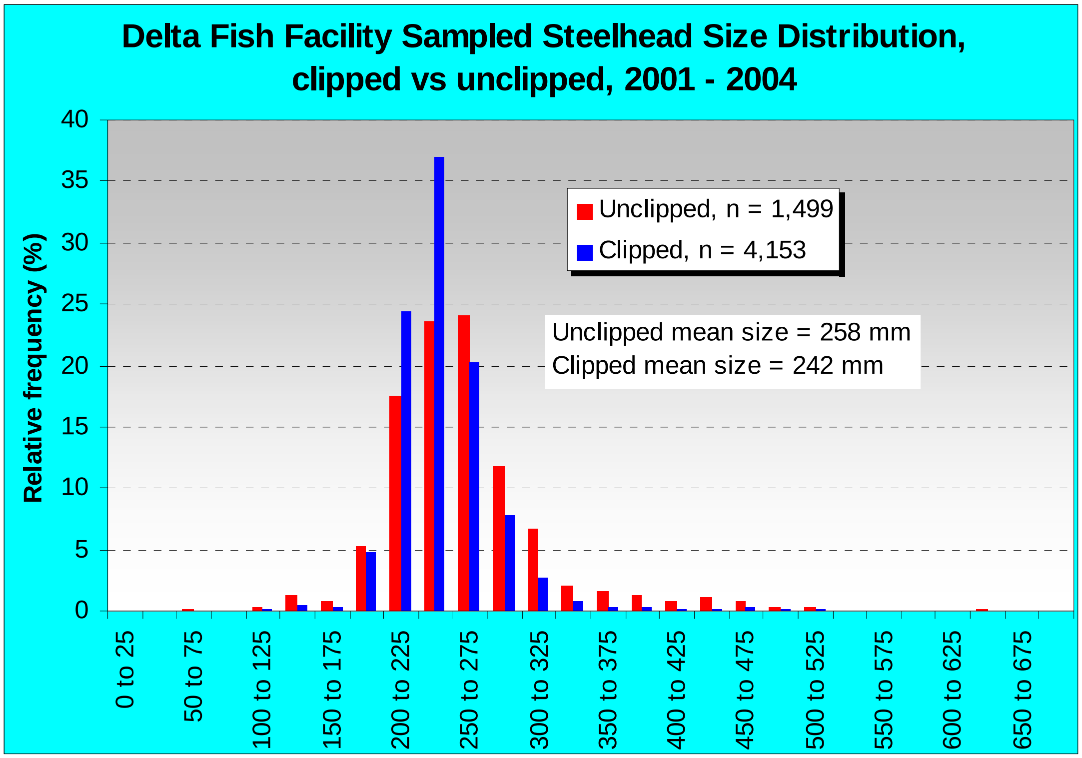

Figure 4-7 Steelhead length frequency, 2001 - 2004. Unclipped fish were significantly larger than clipped fish (t=9.7, P<0.001).

Steelhead salvage and loss density at the SWP and CVP fish salvage facilities are shown in Figure 4-8 through Figure 4-11. Steelhead loss was calculated using a simplified salmon loss equation (at the SWP: LOSS = SALVAGE x 4.34 and at the CVP: LOSS = SALVAGE x 0.579). These densities are indicative of the density of fish in the water in the vicinity of the water intakes for each month.

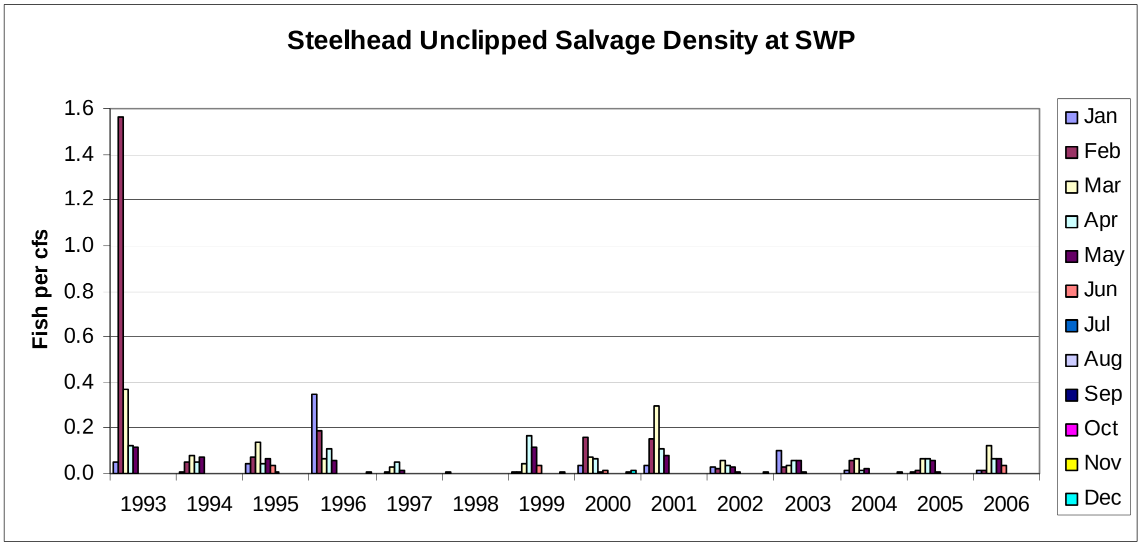

Figure 4-8 Unclipped steelhead salvage density at the SWP, 1993 – 2006.

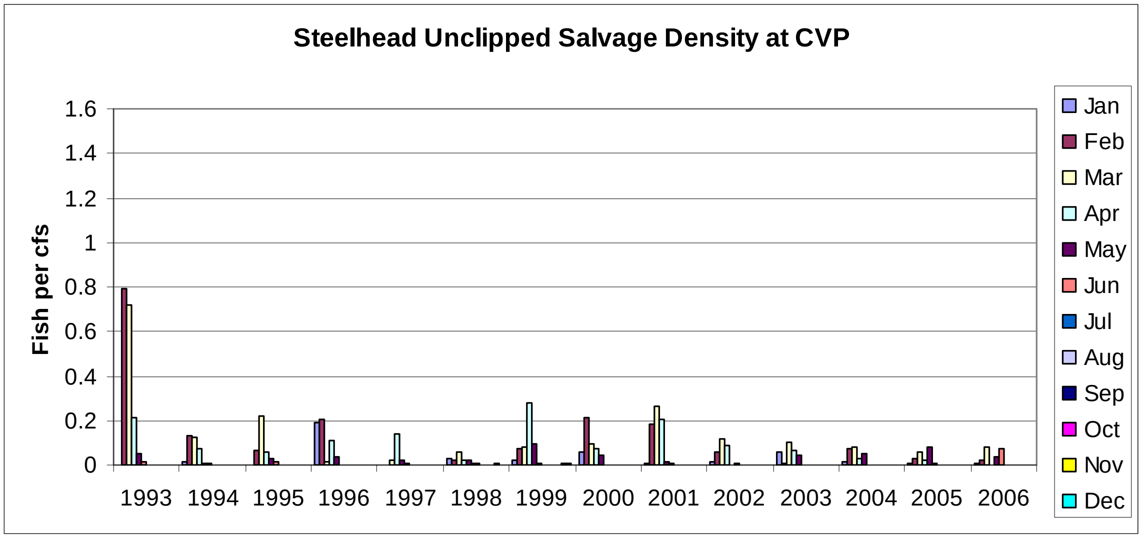

Figure 4-9 Unclipped steelhead salvage density at the CVP, 1996 – 2006.

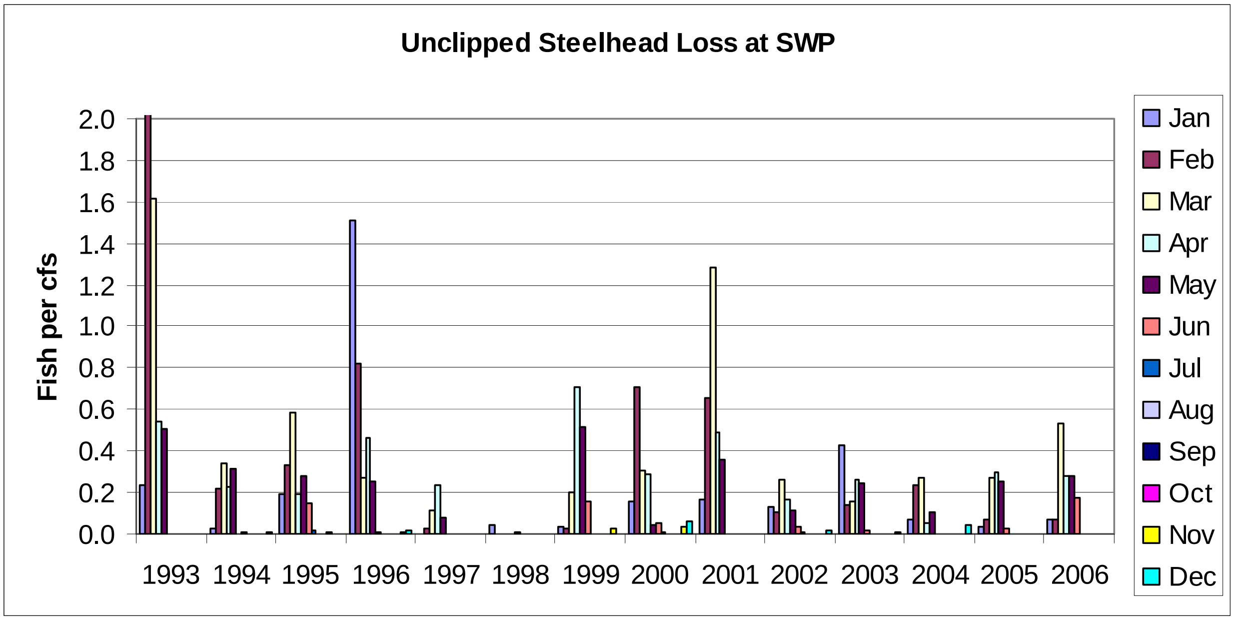

Figure 4-10 Unclipped steelhead loss density at the SWP, 1993 – 2006.

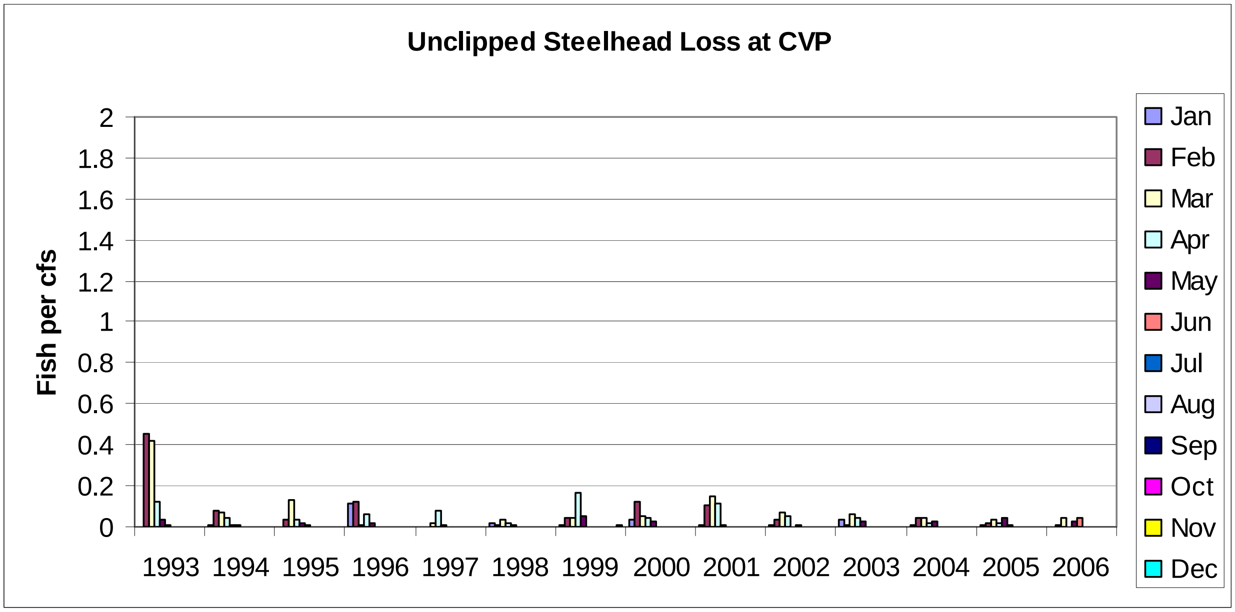

Figure 4-11 Unclipped steelhead loss density at the CVP, 1993 – 2006.

Yolo Bypass

The Yolo Bypass is the primary floodplain of the Sacramento River basin. It is a 59,000-acre leveed basin that 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 the Yolo

Bypass via the Fremont Weir when Sacramento River 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 2003). 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.

Adult Passage during Low-flow Periods

Fyke trap monitoring by DWR from 2000 – 2002 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 2003). The Toe Drain does not extend all the way to Fremont Weir because the channel is blocked by roads or other higher ground at several locations. 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 farther 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 into the bypass 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 2003). At all but the highest flows (for example, 100,000 cfs), 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; 4 in 1999) (DWR unpublished data). Twenty-four (38.7 percent) were adipose fin-clipped; 54 (87 percent) of the steelhead were captured in a rotary screw fish trap (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 4-12. 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 sampling outside the scour ponds mentioned above. Although 50-foot beach seines are inefficient at sampling large fish, it is not believed that 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 the 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.

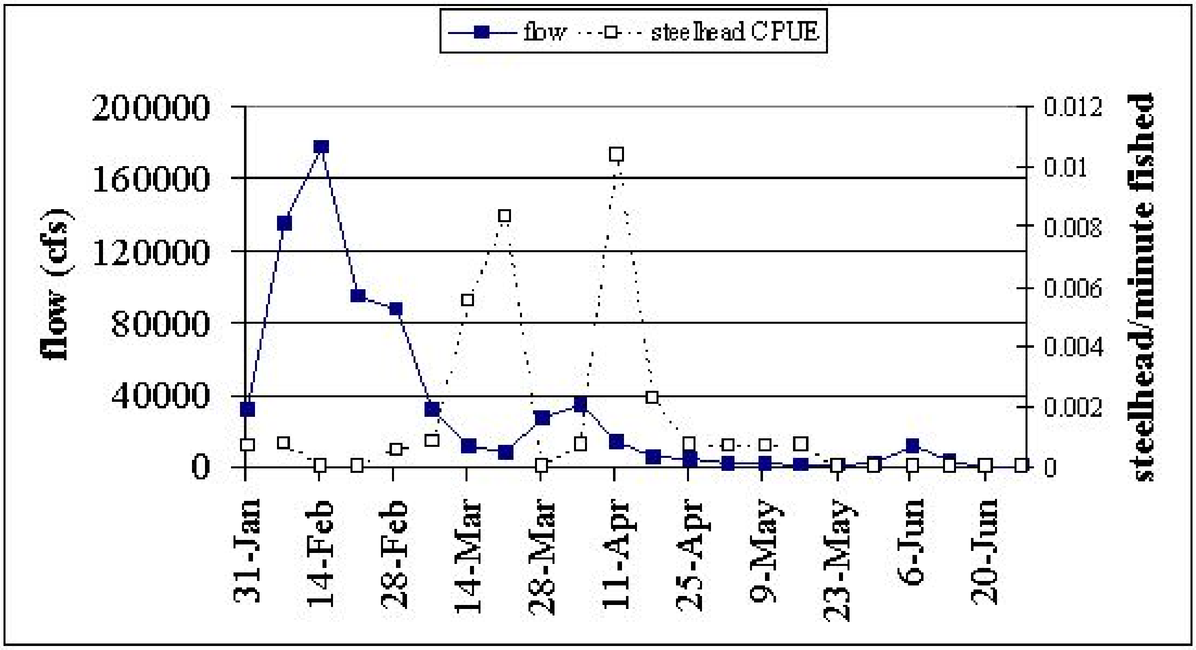

Figure 4-12 Steelhead catch per minute from the Yolo Bypass Toe Drain RST and total Yolo Bypass flow, 1998.

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 4-7). 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 because they were feeding as they emigrated.

Table 4-7 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 FLD); 1 pikeminnow (50 mm FLD); 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 FLD); 2 inland silversides (70 mm FLD)
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.

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 indicated that the modified flashboards were not successful in improving salmonid immigration. Following the evaluation, the regular flashboards are re-installed 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 the gate is operational. The effort to minimize the adverse effects of the SMSCG on salmonid immigration through Montezuma Slough is ongoing. Because 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 mainstem 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 mainstem rivers than headwater streams. Thus, predation loss is probably greater in mainstem rivers than in the historical spawning areas (CALFED 1998). However, essentially very little 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. 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 constructed structures like diversion dams increase resting and feeding habitat for predatory fish. As an example, RBDD formerly impeded upstream passage, or provided a predator refuge and feeding area, for 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). Furthermore, 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 upon 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, it is expected that 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 Interagency Ecological Program (IEP) funded study (#2000-083 Predator-Prey Dynamics in Shallow Water Habitats of the Sacramento-San Joaquin Delta) investigated the feeding ecology of piscivorous fishes in nearshore habitats of the Delta during 2001 and 2003. No steelhead were found in any of the 570 striped bass stomachs, 320 largemouth bass stomachs, or 282 Sacramento pikeminnow foreguts examined (Nobriga and Feyrer 2007).

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 Niño years when warm water off the California coast increases the metabolic demands of predators and attracts additional piscivorous species such as the Pacific mackerel.

Competition for spawning space among steelhead, resident rainbow trout, and Chinook salmon can be a source of egg mortality in mainstem 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 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 and/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 drain water, 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 (no adipose fish clip) 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 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 result in minimum escapements to spawning grounds may exacerbate stream nutrient deficiencies (Gresh et al. 2000). Hatcheries currently remove the carcasses of spawned Chinook salmon and excess Chinook that ascend the hatchery ladders. The fish are used in food programs and not returned to the rivers. Approximately 20% of the marine derived nutrients may be removed from the Central Valley watershed by the current hatchery practices.

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 4-8).

Table 4-8 Production and release data for hatchery steelhead.[a]

Hatchery	River	Yearly production goal	Number released in 1999	Release location
Coleman	Battle Creek	600,000 smolts	496,525	Battle Creek and Balls Ferry
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 [b]	102,440	Lower Mokelumne R.

[a] Source: DFG and National Marine Fisheries Service 2001.

[b] From American or Feather reared at Mokelumne.

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; NMFS 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 the 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, NMFS Fisheries (1998) concluded the Feather River Hatchery steelhead were part of the Central Valley ESU despite an egg importation history similar to the Nimbus Hatchery stock, which NMFS 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).

Hatcheries have come under scrutiny for their potential effects on wild salmonid populations (Bisson et al. 2002, Araki it al. 2007). 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 (Araki et al. 2007).

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 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 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.

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. Estimates of clipped and unclipped steelhead proportions are very difficult to obtain during adult steelhead spawning surveys (Hannon and Deason 2007).

Hatchery and Genetic Management Plans (HGMP) are under development for Nimbus, Feather River, Coleman, and Trinity River hatcheries. These are intended as a mechanism for addressing take of ESA-listed species that may occur as a result of artificial propagation activities and are occurring under separate ESA consultations for each hatchery.

Disease and Parasites

Steelhead are presumed to be susceptible to the same diseases as Chinook salmon (Dennis McEwan, personal communication, 1998). Loss of heterogeneity in hatchery fish can affect resistance to diseases (Arkush et al. 2002). 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.