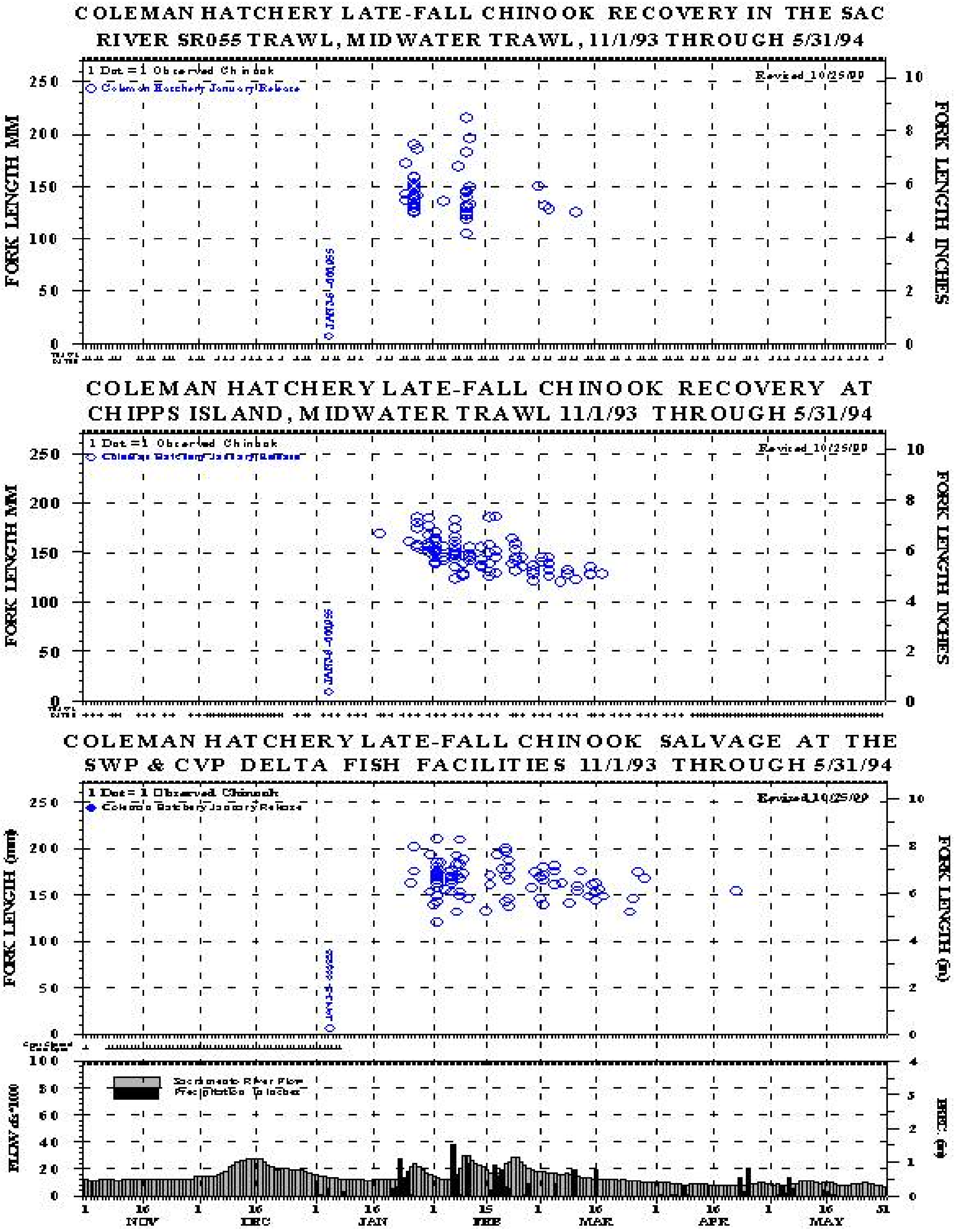


COLEMAN HATCHERY LATE-FALL CHINOOK RECOVERY IN THE SAC RIVER SR055 TRAWL, MIDWATER TRAWL, 11/1/93 THROUGH 5/31/94

COLEMAN HATCHERY LATE-FALL CHINOOK RECOVERY AT CHIPPS ISLAND, MIDWATER TRAWL 11/1/93 THROUGH 5/31/94

COLEMAN HATCHERY LATE-FALL CHINOOK SALVAGE AT THE SWP & CVP DELTA FISH FACILITIES 11/1/93 THROUGH 5/31/94

Figure 6–12 Timing of recoveries of coded-wire-tagged Coleman National Fish Hatchery late fall-run Chinook salmon smolts, Sacramento River flow at Freeport, and precipitation at Red Bluff Airport, winter 1993–1994.

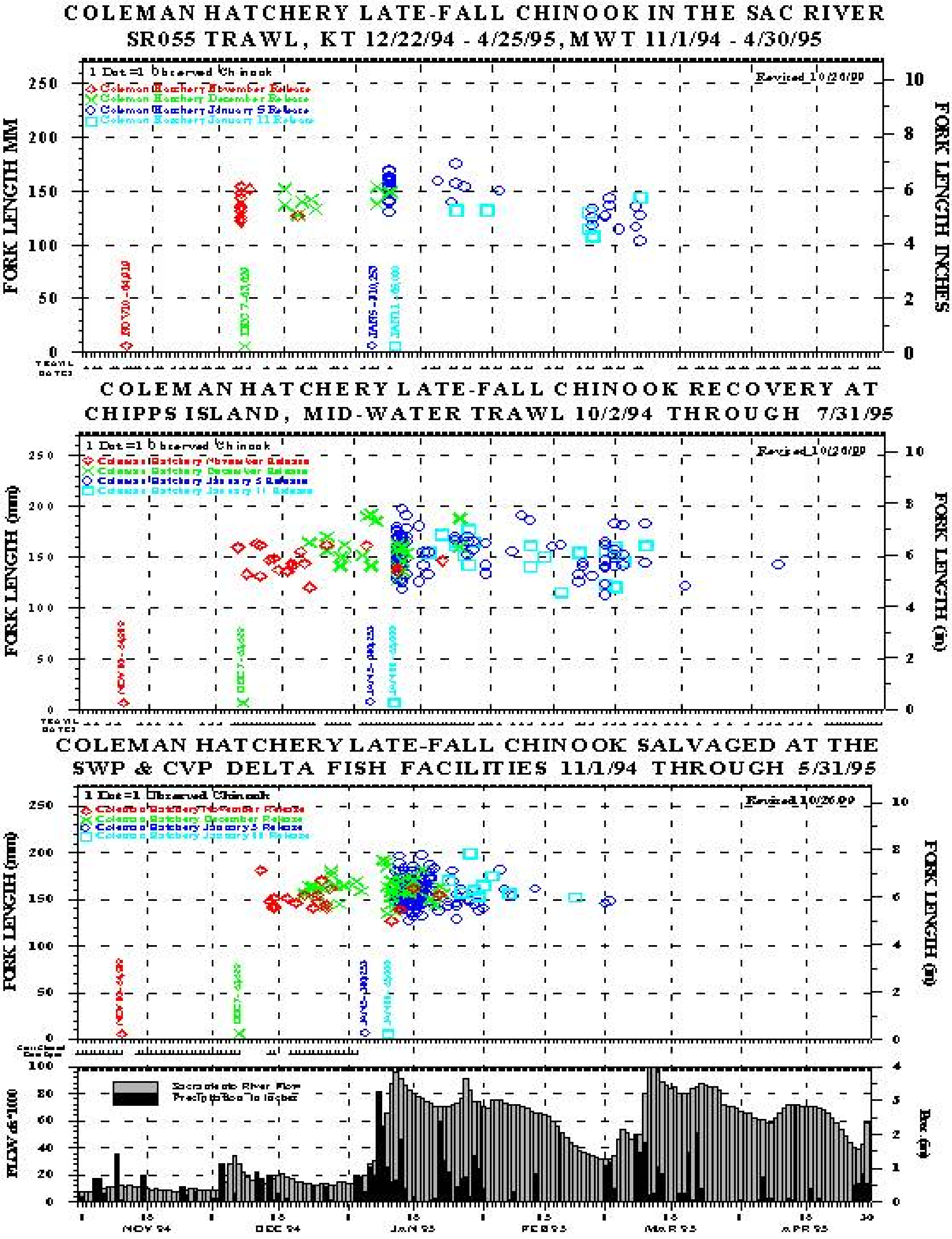


Figure 6–13 Timing of recoveries of coded-wire-tagged Coleman National Fish Hatchery late fall-run Chinook salmon smolts, Sacramento River flow at Freeport, and precipitation at Red Bluff Airport, winter 1994–1995.

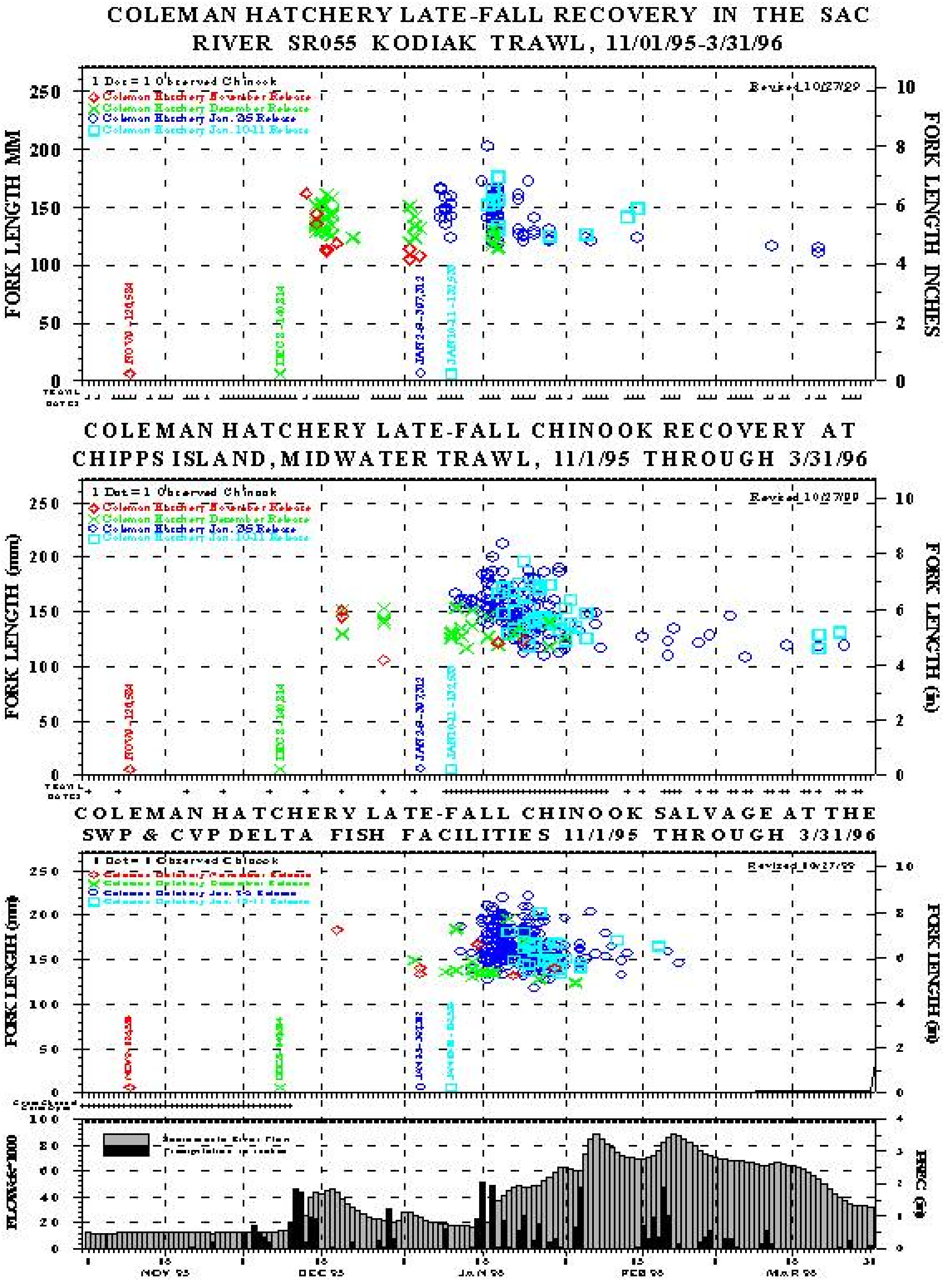
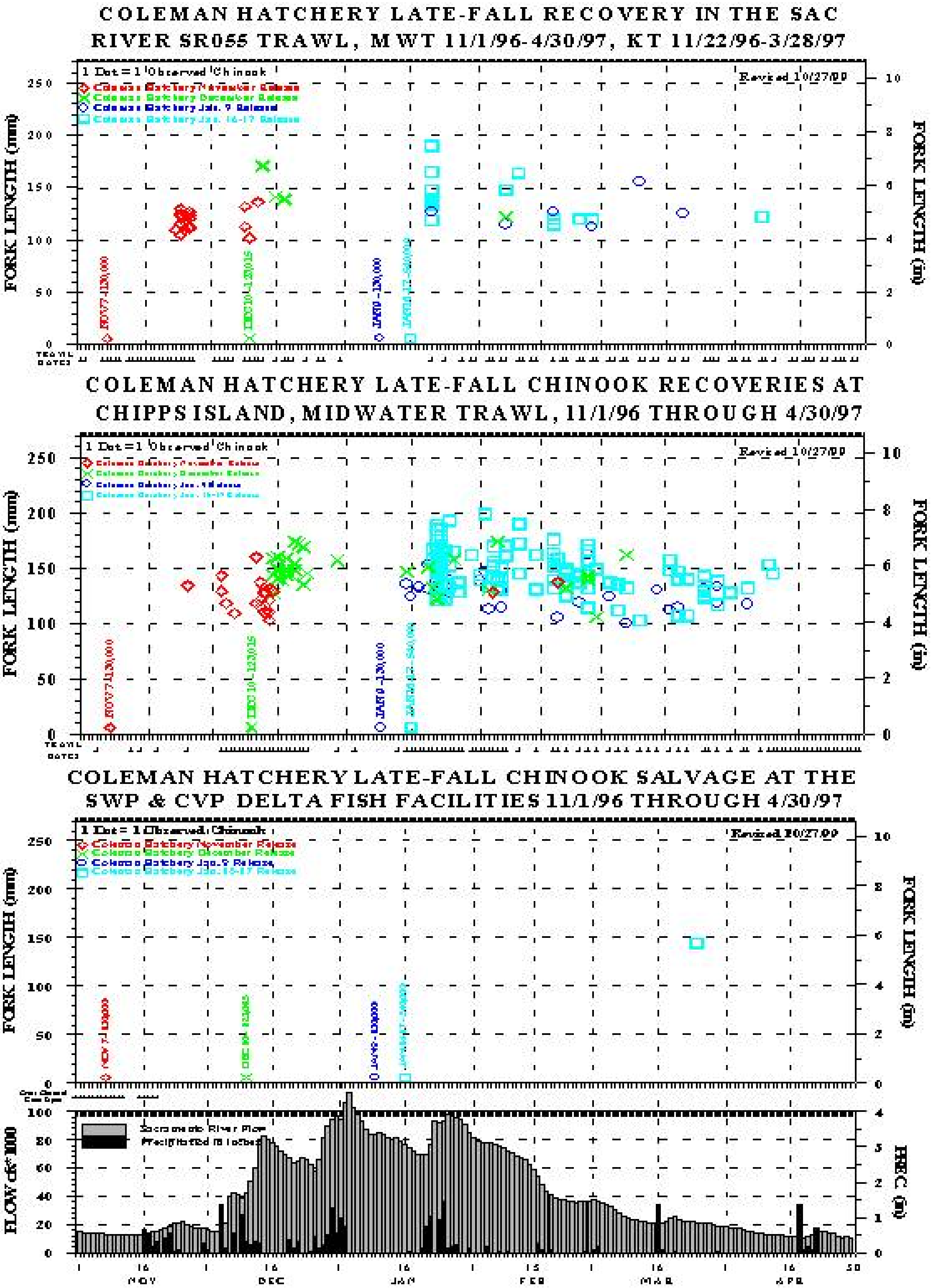


Figure 6–14 Timing of recoveries of coded-wire-tagged Coleman National Fish Hatchery late fall-run Chinook salmon smolts, Sacramento River flow at Freeport, and precipitation at Red Bluff Airport, winter 1995–1996.

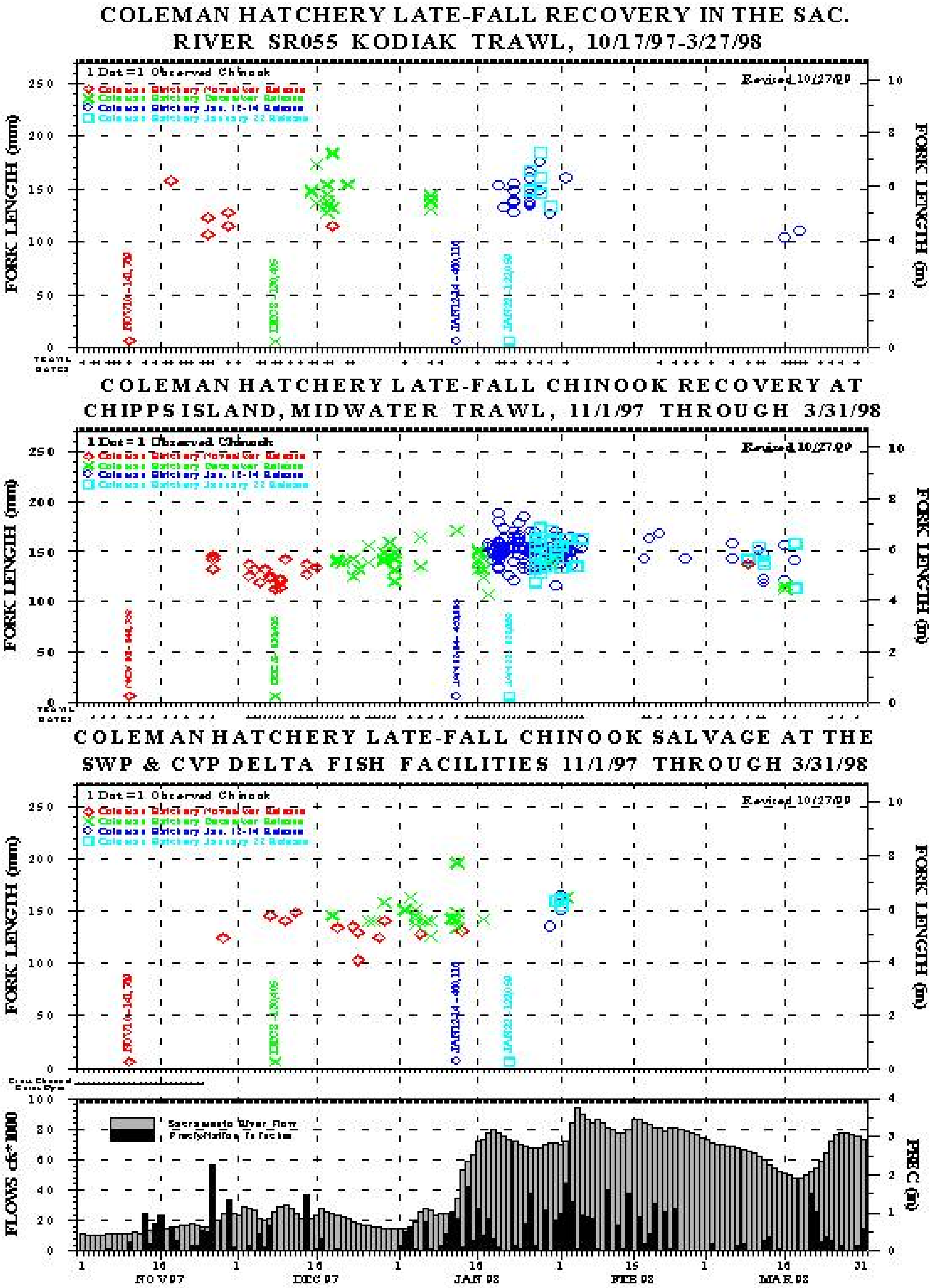


COLEMAN HATCHERY LATE-FALL RECOVERY IN THE SAC RIVER SR055 TRAWL, MWT 11/1/96-4/30/97, KT 11/22/96-3/28/97

COLEMAN HATCHERY LATE-FALL CHINOOK RECOVERIES AT CHIPPS ISLAND, MIDWATER TRAWL, 11/1/96 THROUGH 4/30/97

COLEMAN HATCHERY LATE-FALL CHINOOK SALVAGE AT THE SWP & CVP DELTA FISH FACILITIES 11/1/96 THROUGH 4/30/97

Figure 6–15 Timing of recoveries of coded-wire-tagged Coleman National Fish Hatchery late fall-run Chinook salmon smolts, Sacramento River flow at Freeport, and precipitation at Red Bluff Airport, winter 1996–1997.



COLEMAN HATCHERY LATE-FALL RECOVERY IN THE SAC. RIVER SR055 KODIAK TRAWL, 10/17/97-3/27/98

COLEMAN HATCHERY LATE-FALL CHINOOK RECOVERY AT CHIPPS ISLAND, MIDWATER TRAWL, 11/1/97 THROUGH 3/31/98

COLEMAN HATCHERY LATE-FALL CHINOOK SALVAGE AT THE SWP & CVP DELTA FISH FACILITIES 11/1/97 THROUGH 3/31/98

Figure 6–16 Timing of recoveries of coded-wire-tagged Coleman National Fish Hatchery late fall-run Chinook salmon smolts, Sacramento River flow at Freeport, and precipitation at Red Bluff Airport, winter 1997–1998.

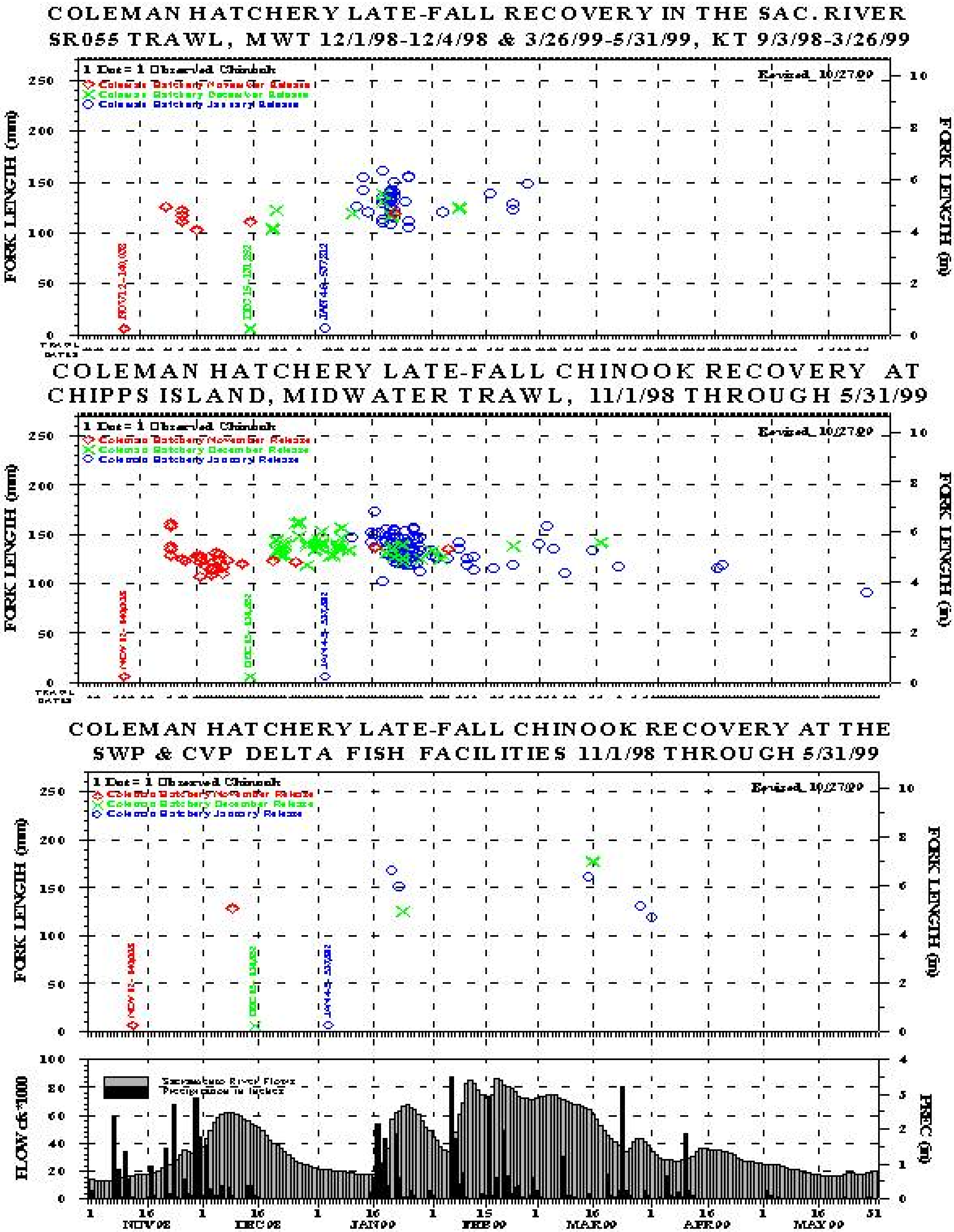


Figure 6–17 Timing of recoveries of coded-wire-tagged Coleman National Fish Hatchery late fall-run Chinook salmon smolts, Sacramento River flow at Freeport, and precipitation at Red Bluff Airport, winter 1998–1999.

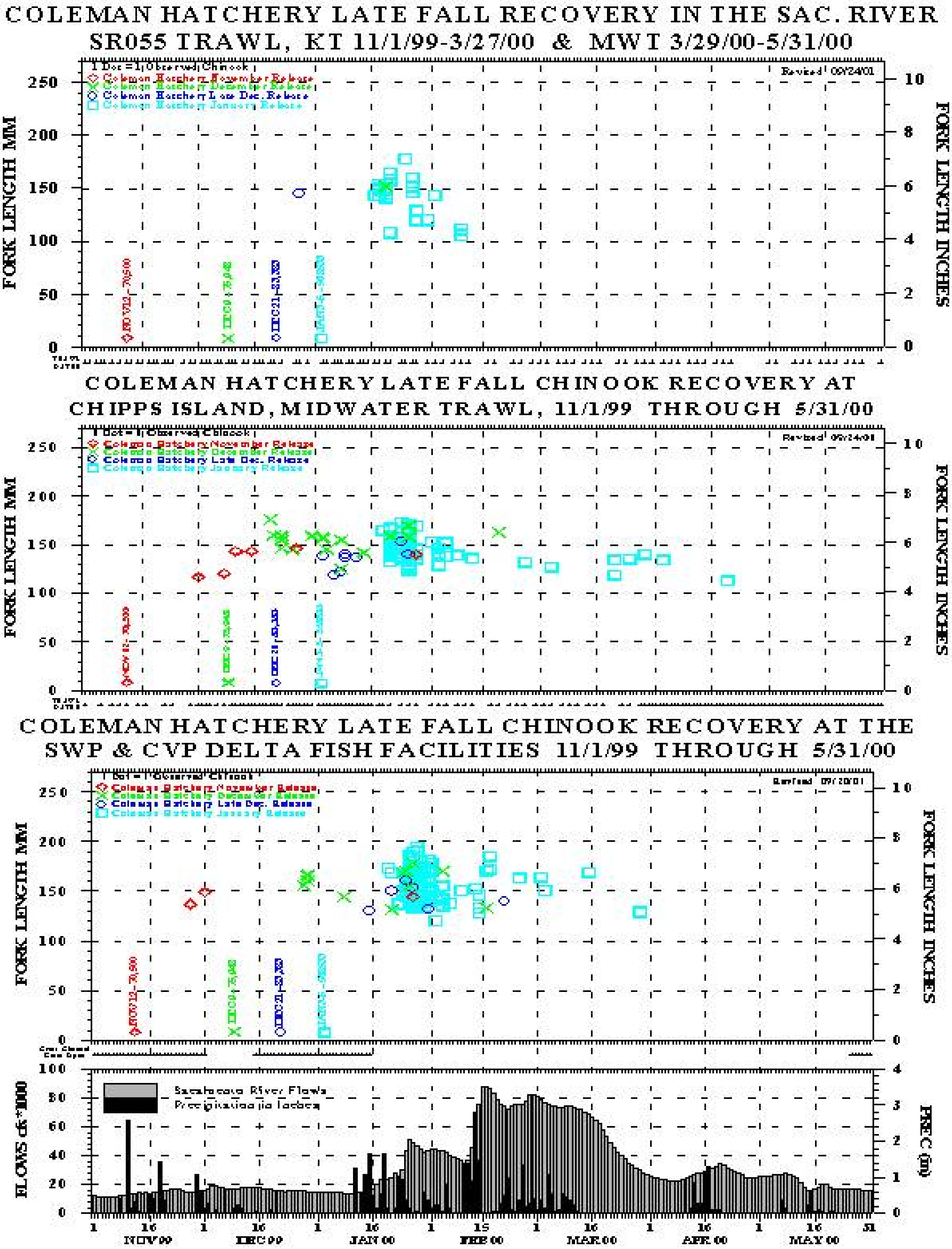
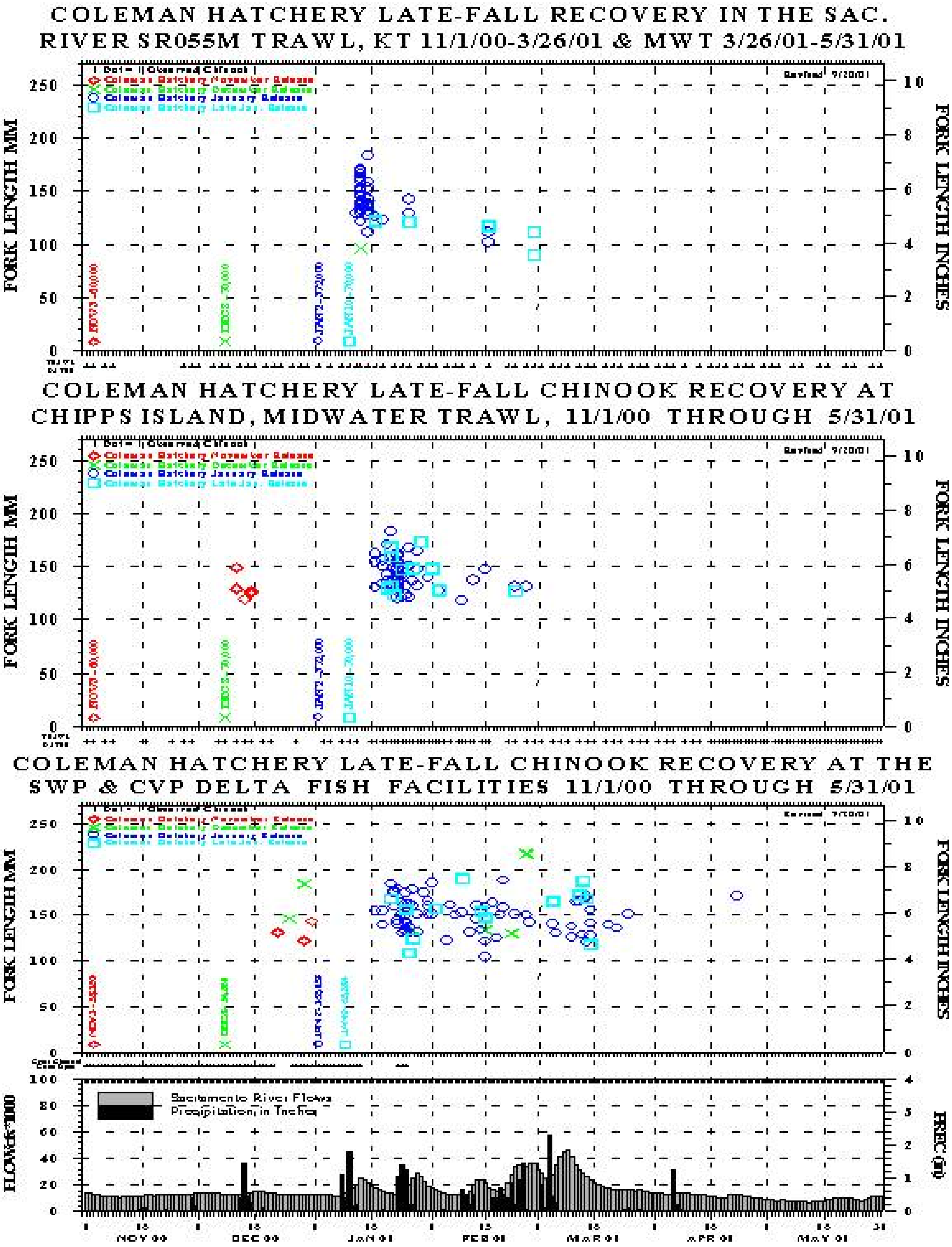


Figure 6–18 Timing of recoveries of coded-wire-tagged Coleman National Fish Hatchery late fall-run Chinook salmon smolts, Sacramento River flow at Freeport, and precipitation at Red Bluff Airport, winter 1999–2000.



COLEMAN HATCHERY LATE-FALL RECOVERY IN THE SAC. RIVER SR055M TRAWL, KT 11/1/00-3/26/01 & MWT 3/26/01-5/31/01

COLEMAN HATCHERY LATE-FALL CHINOOK RECOVERY AT CHIPPS ISLAND, MIDWATER TRAWL, 11/1/00 THROUGH 5/31/01

COLEMAN HATCHERY LATE-FALL CHINOOK RECOVERY AT THE SWP & CVP DELTA FISH FACILITIES 11/1/00 THROUGH 5/31/01

Figure 6–19 Timing of recoveries of coded-wire-tagged Coleman National Fish Hatchery late fall-run Chinook salmon smolts, Sacramento River flow at Freeport, and precipitation at Red Bluff Airport, winter 2000–2001.

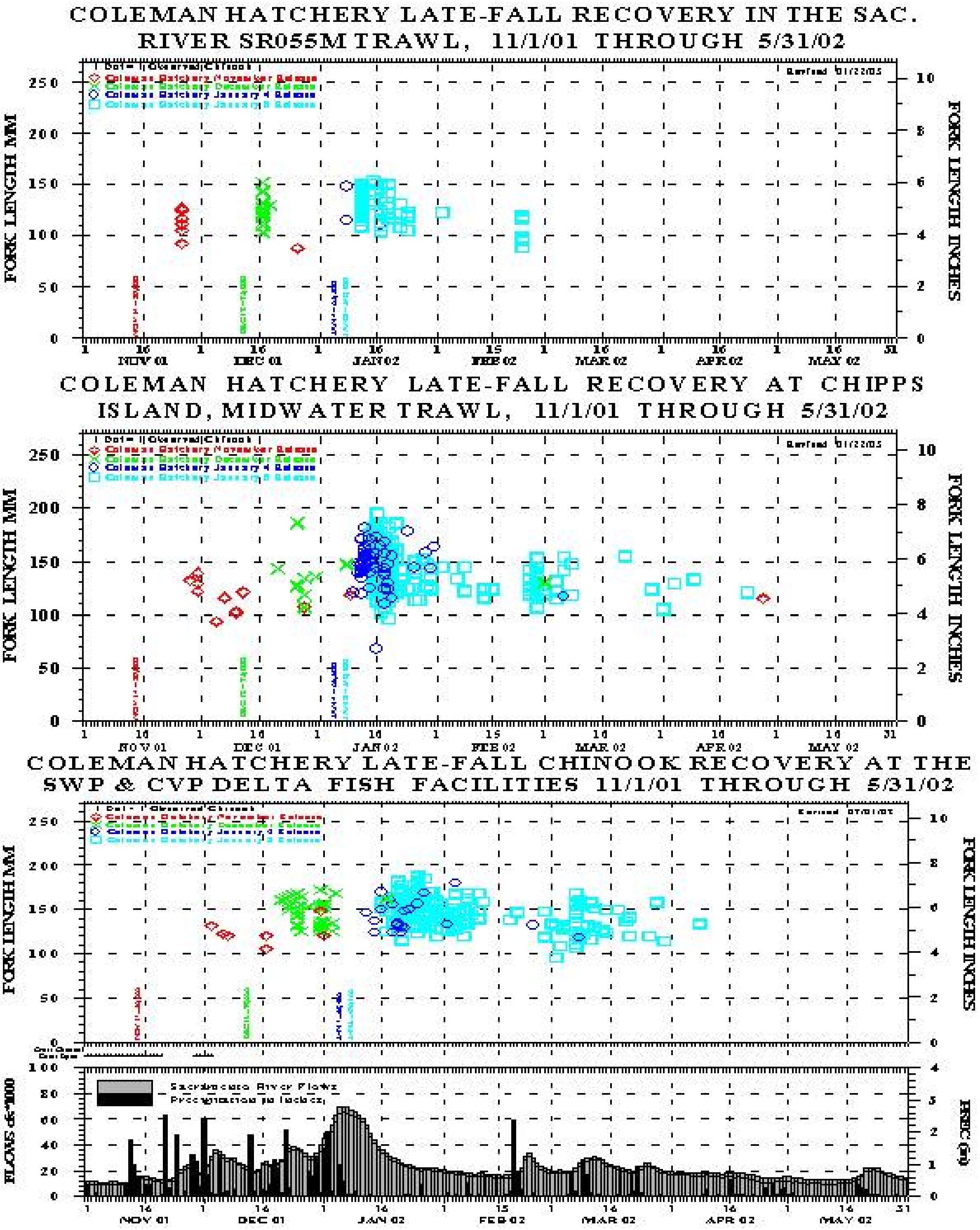


Figure 6–20 Timing of recoveries of coded-wire-tagged Coleman National Fish Hatchery late fall-run Chinook salmon smolts, Sacramento River flow at Freeport, and precipitation at Red Bluff Airport, winter 2001–2002.

Pooling data for all late fall-run yearling releases since November 1993 , the average travel time from Coleman Hatchery to Sacramento has been 19 days, with a standard deviation of 12 days. The average travel time from the hatchery to Chipps Island has been 26 days (standard deviation = 11 days) and the average travel time from the hatchery to the Delta fish facilities has been 33 days (standard deviation = 18 days). The median travel times to Sacramento and the facilities are significantly different; other combinations are not (ANOVA *F* = 4.33; *p* = 0.02, + post hoc multiple comparison tests). Sacramento River flow for 30 days following release from the hatchery explains some of the variability in median travel time to Chipps Island (Figure 6–21)

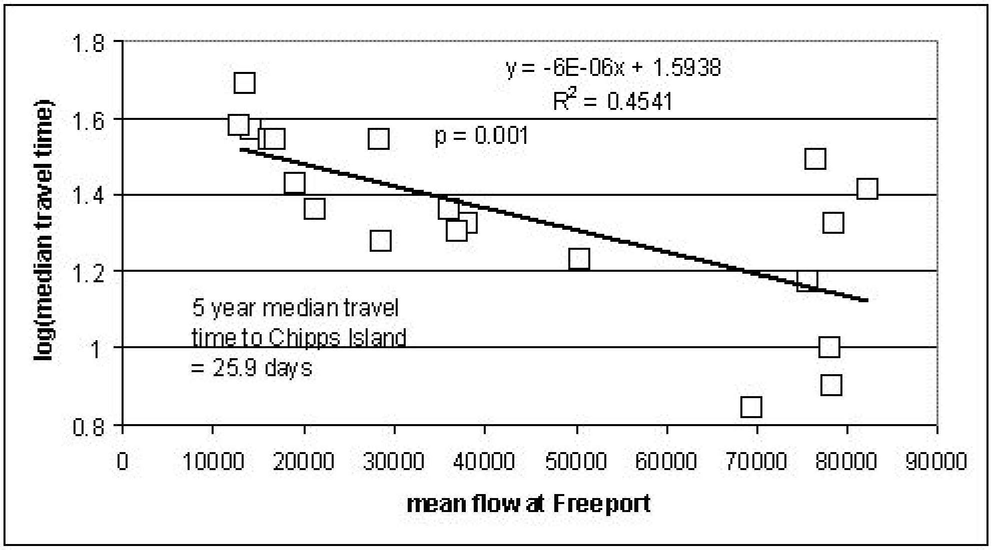


Figure 6–21 Relationship between mean flow (cfs) in the Sacramento River and the log10 time to recapture in the FWS Chipps Island Trawl for Coleman Hatchery late fall-run Chinook salmon smolts. The explanatory variable is mean flow at Freeport for 30 days beginning with the day of release from Coleman Hatchery. The response variable is an average of median days to recapture for November through January releases during winter 1993–94 through 1998–99.

Winter-run migrate through the Delta primarily from December to April. NOAA Fisheries develops an estimate of winter–run juvenile production each year based on the estimated escapement and applying a set of standard survival estimates including pre-spawning mortality, fecundity, egg-to-fry survival, and survival to the Delta (Table 6–7).

Table 6–7 Example of how the winter-run Chinook juvenile production estimate, yellow light and red light levels are calculated using 2001-02 adult escapement data.

2001-2002 Winter-run Chinook Juvenile Production Estimate (JPE)

Total Spawner escapement (Carcass Survey)	**7,572**
Number of females (64.4% Total)	**4,876**
Less 1% pre-spawn mortality	**4,828**
Eggs (4,700 eggs/female)	**22,689,740**
Less 0.5% due to high temp	**113,449**

Viable eggs	**22,576,291**
Survival egg to smolt (14.75%)	**3,330,003**
Survival smolts to Delta (56%)	**1,864,802**
Livingston Stone Hatchery release	**252,684**
Yellow light(1%natural + 0.5 hatchery)	**19,911**
Red Light (2% natural + 1% Hatchery)	**39,823**

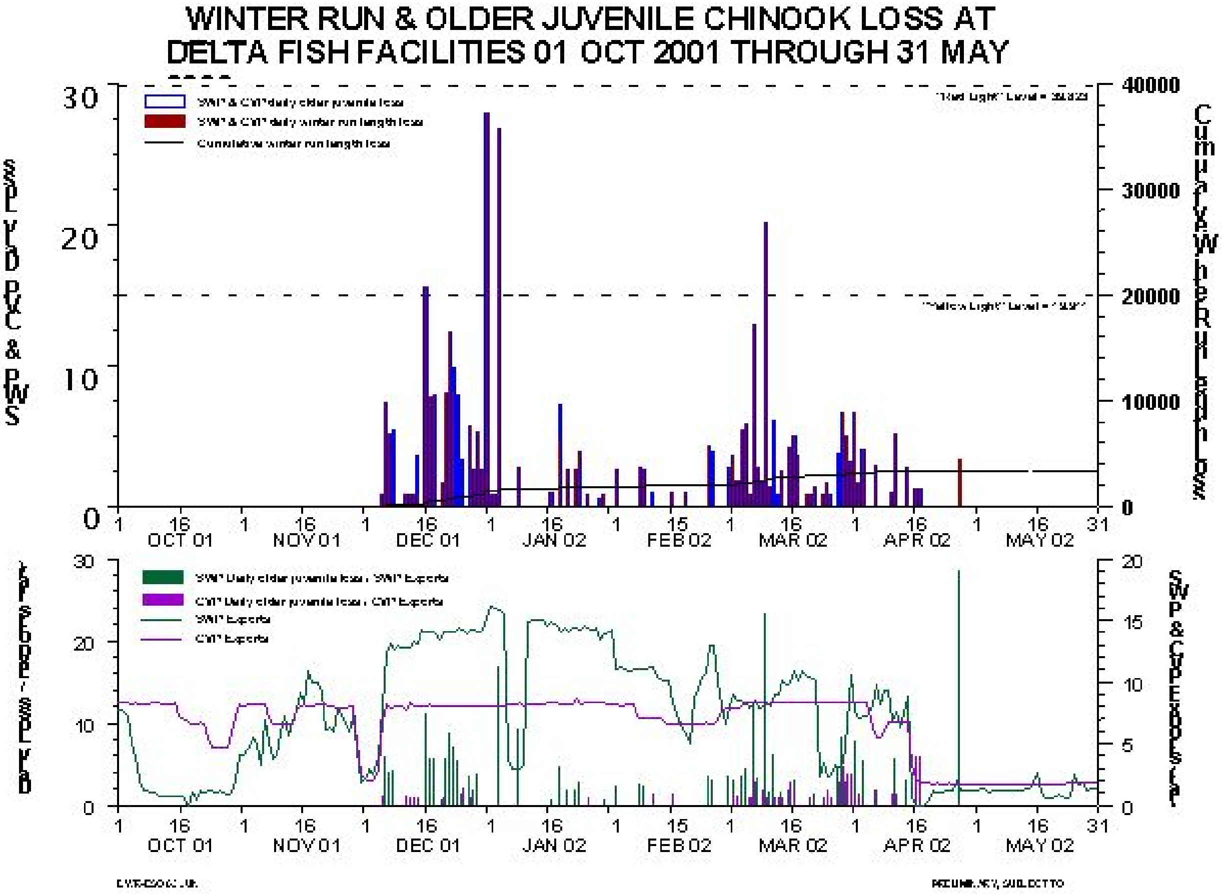


Figure 6–22 Winter–run and older juvenile chinook loss at delta fish facilities, October 2001 – May 2002.

Changes in the Delta Ecosystem and Potential Effects on Winter-run, Spring-run and Fall/Late Fall-run Chinook Salmon

Changes in estuarine hydrodynamics have adversely affected a variety of organisms at all trophic levels, from phytoplankton and zooplankton to the young life stages of many fish species (Jassby et al. 1995; Arthur et al. 1996; Bennett and Moyle 1996). Ecological processes in the Delta have also been affected by interactions among native and introduced species (Bennett and Moyle 1996; Kimmerer and Orsi 1996), the various effects of water management on Delta water quality and quantity (Arthur et al. 1996), and land use practices within the watershed (Simenstad et al. 1999). Cumulatively, these changes may have diminished the suitability of the Delta as juvenile salmon rearing habitat and may have reduced the survival of young salmon migrating through the Delta to the Pacific Ocean. Population level effects of changes in the delta are complex and have not been quantified.

As juvenile salmon from the Sacramento basin migrate through the Delta towards the Pacific Ocean, they encounter numerous junctions in the river and Delta channels. two such junctions are located near Walnut Grove at the DCC (a man-made channel with an operable gate at the entrance) and Georgiana Slough (a natural channel). Both channels carry water from the Sacramento River into the central Delta. The relatively high quality Sacramento River water flows into the central Delta, mixes with water from the east-side tributaries (Mokelumne, Cosumnes and Calaveras Rivers) and the San Joaquin River. This mixture which much of the time is predominantly Sacramento River water is pumped out of the Delta by the SWP and CVP or flows westward through the estuary. The SWP water consists of a higher proportion of Sacramento River water and the CVP consists of more San Joaquin River water (Lloyd Hess personal communication).

Significant amounts of flow and many juvenile salmon from the Sacramento River enter the DCC (when the gates are open) and Georgiana Slough. Mortality of juvenile salmon entering the central Delta is higher than for those continuing downstream in the Sacramento River. This difference in mortality could be due to a combination of factors: the longer route through the central Delta to the western Delta, higher water temperatures, higher predation, more agricultural diversions, and a more complex channel configuration making it more difficult for salmon to find their way to the western Delta and the ocean.

Water is drawn from the central Delta through lower Old River to the export pumps when combined CVP/SWP pumping exceeds the flow of San Joaquin River water down the upper reach of Old River and Middle Rivers. This situation likely increases the risk of juvenile salmon migrating to the south Delta and perhaps being entrained at the SWP and CVP facilities. This condition can be changed either by reducing exports or increasing Delta inflows. Decreasing exports to eliminate net upstream flows (or, if net flows are downstream, cause an increase in positive downstream flows) may reduce the chances of migrating juvenile salmonids moving up lower Old River towards the CVP/SWP diversions. Tidal flows, which are substantially greater than net flows, play a much more important role in salmon migrations than net reverse flow, which can only be calculated and not measured.

Juvenile salmon, steelhead and other species of fish in the south Delta are directly entrained into the SWP and CVP export water diversion facilities (Table 6–8, Figure 6–9, Table 6–10, Figure 6–23, Figure 6–24). Many juvenile salmon die from predation in Clifton Court Forebay before they reach the SWP fish screens to be salvaged (80 percent mortality currently used in loss calculations). Loss at the SWP is thought to vary inversely with the pumping rate because when water is drawn through Clifton Court Forebay faster salmon are not exposed to predation for as long (Buell 2003). At the CVP pumping facilities the survival rate through the facility for

Chinook is about 67 percent. Salmon from the San Joaquin Basin, and those migrating from the Sacramento River or east Delta tributaries through the central Delta are more directly exposed to altered channel flows due to exports and to entrainment because their main migration route to the ocean puts them in proximity to these diversions. Some juvenile salmon migrating down the main stem Sacramento River past Georgiana Slough may travel through Three-mile Slough or around Sherman Island and end up in the southern Delta. There is considerable lack of understanding about how or why salmon and steelhead from the north Delta end up at the diversions in the south Delta, particularly regarding the influence role of the export pumping. Nevertheless it is clear that once juvenile salmon are in the vicinity of the pumps, they are more likely to be drawn into the diversion facilities with the water being diverted. We assume that by reducing the pumping rate, entrainment of fish, and therefore loss or "take" of these fish is reduced. If reservoir releases are not reduced simultaneously, then the net flow patterns in Delta channels are changed, to the benefit of emigrating salmonids and other fish.

Table 6–8 Total Chinook salmon salvage (all sizes combined) by year at the SWP and CVP salvage facilities.

YEAR	SWP	CVP	Total
1981	101,605	74,864	176,469
1982	278,419	220,161	498,580
1983	68,942	212,375	281,317
1984	145,041	202,331	347,372
1985	140,713	137,086	277,799
1986	435,233	752,039	1,187,272
1987	177,880	92,721	270,601
1988	151,908	54,385	206,293
1989	106,259	42,937	149,196
1990	35,296	6,107	41,403
1991	39,170	31,226	70,396
1992	22,193	41,685	63,878
1993	8,647	20,502	29,149
1994	3,478	12,211	15,689
1995	19,164	64,398	83,562
1996	14,728	39,918	54,646
1997	11,853	53,833	65,686
1998	3,956	167,770	171,726
1999	50,811	132,886	183,697
2000	45,613	78,214	123,827
2001	28,327	29,479	57,806
2002	6,348	15,573	21,921
Total	1,895,584	2,482,701	4,378,285

Table 6–9 Average Chinook salmon salvage (all sizes and marks combined) by facility 1981 – 1992.

MONTH	SWP	CVP
Jan	2,889	1,564
Feb	5,989	47,227
Mar	7,679	8,241
Apr	40,552	33,983
May	56,327	55,146
Jun	21,863	15,929
Jul	496	2,105
Aug	232	233
Sep	33	
Oct	1,474	4,814
Nov	2,181	4,133
Dec	9,682	3,365

Table 6–10 Average Chinook salmon salvage (all sizes and marks combined) by facility, 1993 – 2002.

MONTH	SWP	CVP
Jan	1,224	5,933
Feb	1,214	10,978
Mar	1,483	5,199
Apr	7,728	16,485
May	6,082	16,076
Jun	2,001	5,992
Jul	62	220
Aug	34	18
Sep	147	114
Oct	49	56
Nov	39	159
Dec	393	552

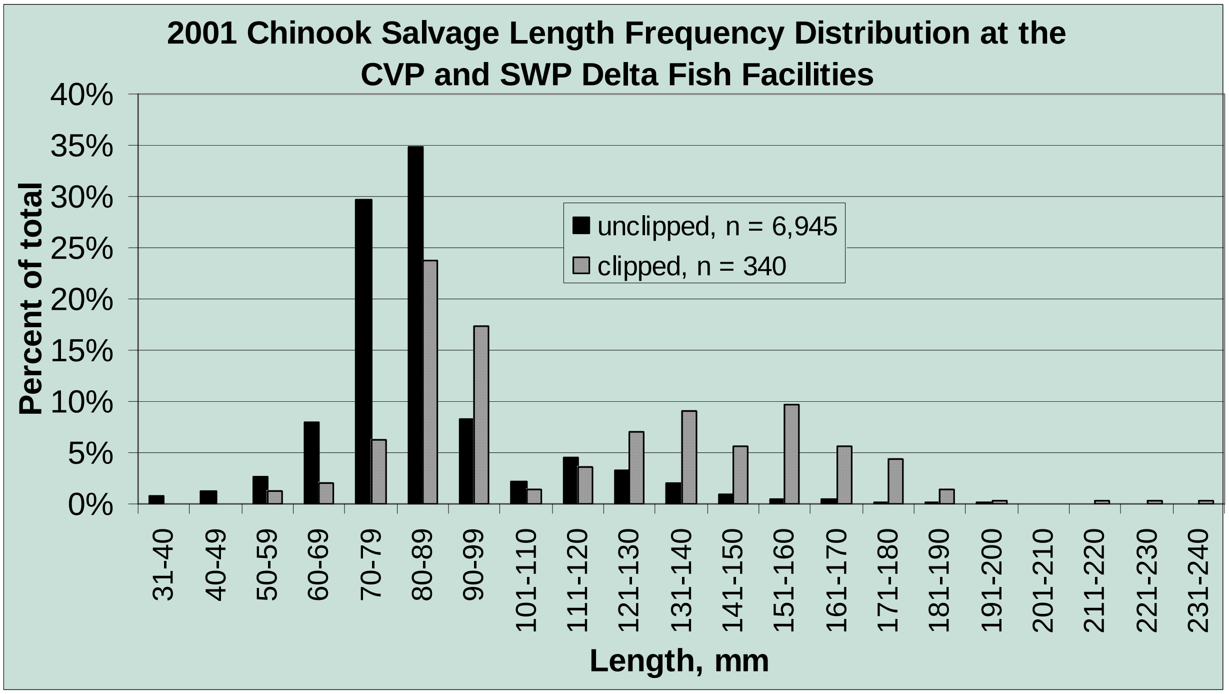


Figure 6–23 Length frequency distribution of Chinook salvaged at the delta fish facilities in 2001.

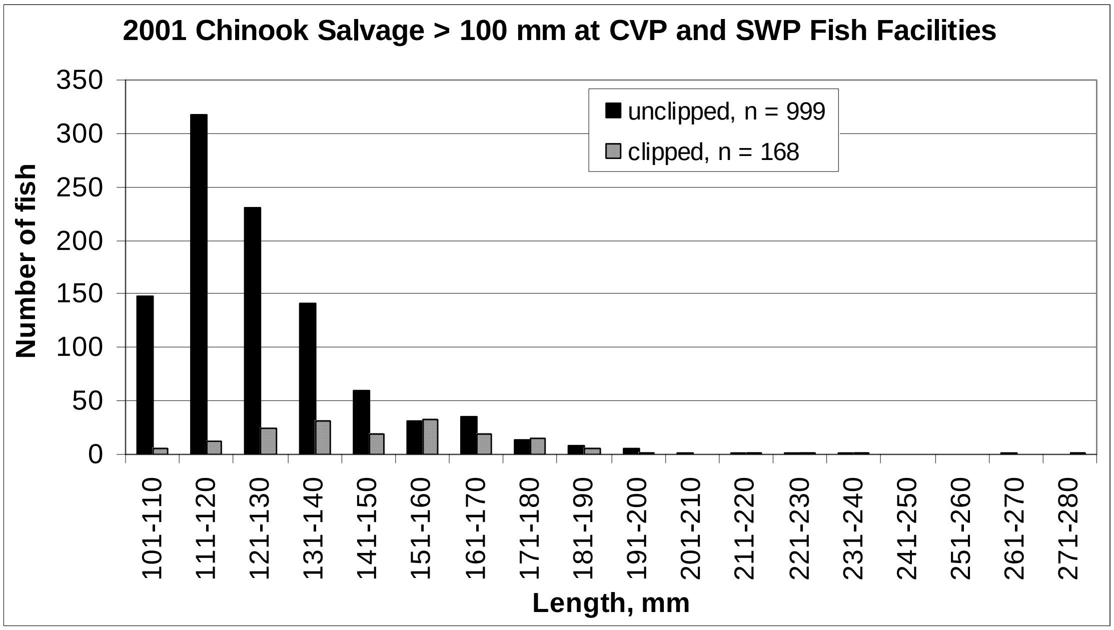


Figure 6–24 Length frequency distribution for Chinook salvaged greater than 100 mm in 2001.

Direct and Indirect Effects of the SWP and CVP Facilities

Delta water project effects on rearing and migrating juvenile Chinook salmon are both direct (based on observations of salvaged fish at the fish salvage facilities) and indirect (mortality in the Delta that is related to export operations). The entrainment rate (direct loss) of juvenile salmon at the facilities is an incomplete measure of water project impact to juvenile salmon, because it doesn't include indirect mortality in the Delta.

FWS CWT studies have been used to assess survival rates of juvenile Chinook migrating through the Delta relative to those remaining in the Sacramento River (Kjelson et al. 1982, Brandes and McLain 2001). Results of these studies suggest survival rates are higher for fish that remain in the Sacramento River, although they do not provide quantitative information regarding what proportion of emigrants remain in the main river, compared to fish that enter the central Delta through the DCC and Georgiana Slough.. Many potential influencing factors have been suggested as indirect effects to salmon survival that may occur when salmon move into the central and/or south Delta from the Sacramento River. Most of these have not been explicitly studied, but the available information is discussed below.

Length of Migration Route and Residence Time in the Delta

The length of time Chinook juvenile salmon spend in the lower rivers and the Delta varies depending on the time of year the salmon emigrate, outflow, and the developmental stage of the fish (Kjelson et al. 1982). Residence times tend to be shorter during periods of high flow relative to periods of low flow, and tend to be longer for fry than for smolts. A proportion of the Chinook salmon production enters the Delta as fry or fingerlings rather than as smolts (DFG 1998). Extending Delta residence time for any juvenile salmon likely increases their susceptibility to the cumulative effects of mortality factors within the Delta but also decreases susceptibility to mortality once they enter the ocean because they are larger.

Much attention has been given to the lower river migration route of salmon produced in the Sacramento watershed (Kjelson et al. 1982; Stevens and Miller 1983; Brandes and McLain 2001). At issue is the migration route via Georgiana Slough (about 37 miles to Chipps Island) compared to that in the Sacramento River from Ryde (27 miles to Chipps Island). Tests completed by FWS found survival is higher for late fall-run Chinook smolts released in the Sacramento River at Ryde vs. Georgiana Slough even though the Georgiana Slough route is only 1.4 times longer. Fish emigrating through Georgiana Slough probably have increased residence time in the Delta due to both the longer travel distance and the generally lower flows in the slough. These factors potentially increase the duration of a migrating salmon's exposure to migration hazards. Delta Cross Channel closures are one of the actions being taken to reduce the likelihood that juvenile Chinook salmon will use an internal Delta route.

The following is an analysis of the relationships between the through-Delta survival of Coleman Hatchery late fall-run Chinook smolts, Delta export losses of these fish in the fall and winter, and Delta hydrologic variables.

FWS has conducted these experiments using late fall-run smolts since 1993. The purpose of the experiments is to determine what factors in the Delta affect yearling Chinook survival. One factor hypothesized to affect survival is emigration route. Based on previous results for fall-run salmon (Brandes and McLain 2001) FWS hypothesized yearlings emigrating through the interior Delta survive at a lower level than juveniles emigrating through the main stem Sacramento River (Brandes and McLain 2001). The juveniles can enter the interior Delta through Georgiana Slough (GS) or the Delta Cross Channel (DCC) when it is open. Since FWS does not have measurements of gear efficiency for its Chipps Island trawl, and gear efficiency is assumed to vary from experiment to experiment, the survival estimates are considered indices of relative survival, not absolute numbers of survivors. To overcome this limitation, FWS uses the ratio of the survival indices of paired releases in the interior Delta and the main stem Sacramento River at Ryde. Evaluating the relative interior Delta survival cancels out differences in gear efficiency.

Models generated using the data from coded wire tagged fish support the conclusion that closure of the DCC gates will improve survival for smolts originating from the Sacramento Basin and emigrating through the Delta. The greatest mortality for smolts between Sacramento and Chipps Island was in the central Delta, and survival could be improved if the gates were closed (Kjelson et al. 1989).

In a generalized linear model that estimates the effects of various parameters on salmon smolt survival through the Delta, Newman and Rice (1997) found that mortality was higher for smolts released in the interior Delta relative to those released on the main stem Sacramento River. They also found lower survival for releases on the Sacramento River associated with the Delta Cross Channel gate being open. Using paired release data, Newman (2000) found that the cross-channel gate being open had a negative effect on the survival of smolts migrating through the Delta and was confirmed using Baysian and GLM modeling (Newman and Remington 2000).

The analyses to date appear to support the conclusion that closing the DCC gates will improve the survival of smolts originating from the Sacramento basin and migrating through the Delta. Even with the DCC gates closed, Sacramento River water still flows into Georgiana Slough and some Sacramento salmon travel that route to the interior of the Delta.

Radio tracking studies of large juvenile salmon in the Delta (Vogel 2003) showed that localized currents created by the DCC operations and flood and ebb tide cycles greatly affected how radio-tagged fish moved into or past the DCC and Georgianna Slough. Fish migration rates were generally slower than the ambient water velocities. Fish were documented moving downstream past the DCC during outgoing tides and then moving back upstream and into the DCC with the incoming tide. When the DCC gates were closed fish movement into Georgianna Slough was unexpectedly high, probably due to fish positions in the water column in combination with physical and hydrodynamic conditions at the flow split. Radio tagged smolts moved large distances (miles) back and forth with the incoming and outgoing tides. Flow conditions at channel splits were a principal factor affecting the routes used by migrating salmon. Hydroacoustic tracking and trawling (Horn 2003 and Herbold 2003) showed that fish in the vicinity of the DCC were most actively moving at night and that they tend to go with the highest velocity flows. Water flow down through the DCC is much greater during the incoming tidal cycles than on the outgoing tides. These results suggest that during periods of high juvenile salmonid abundance in the vicinity of the DCC, closing the gates during the incoming tidal flows at night could reduce juvenile salmon movement into the central Delta through the DCC but may also increase movement into Georgianna Slough.

The survival indices and estimated losses at the Delta fish facilities for all GS and Ryde releases since 1993 are illustrated in Figure 6–25. A unique symbol is used to highlight each paired experiment. In every paired experiment, the survival index of the Ryde release was higher than the GS release. Additionally, the estimated loss of the GS release was higher than the Ryde release in every paired experiment. Evaluating the GS and Ryde data separately, the GS releases all have low survival over a wide range of losses, and the Ryde releases all have low losses over a wide range of survival indices. Survival indices and losses for each of the GS and Ryde releases are not well related.

Delta hydrology is another factor hypothesized to affect Chinook survival, although hydrology should not be viewed independently from effects due to migration route. The relative interior Delta survival of Coleman late-fall juveniles was plotted against Delta exports, Sacramento River flow, QWEST, and export to inflow ratio. The explanatory (hydrologic) variables are average conditions for 17 days from the day of release. This value was selected by FWS based on previously collected data on the average travel time from the release sites to Chipps Island. The combined CVP and SWP losses from each of the GS and Ryde releases are also plotted against the same four hydrologic variables. A simple linear regression was done for each.

Regression and correlation analyses of these data (1993–98) indicate that the survival of smolts released into Georgiana Slough is increased as exports are reduced, relative to the survival of salmon released simultaneously at Ryde (Figure 6–26). These findings are the basis for reducing exports to further protect juvenile salmon migrating through the Delta. There was also a trend of increased loss of GS releases with increased exports, but it was not significant either (Figure 6–27).

Relationships between relative survival (Figure 6–28) or late-fall salvage at the Delta export facilities (Figure 6–29) and Sacramento River flow were not statistically significant. QWEST was also a poor predictor of both relative survival (Figure 6–30) and losses to the export facilities (Figure 6–31).

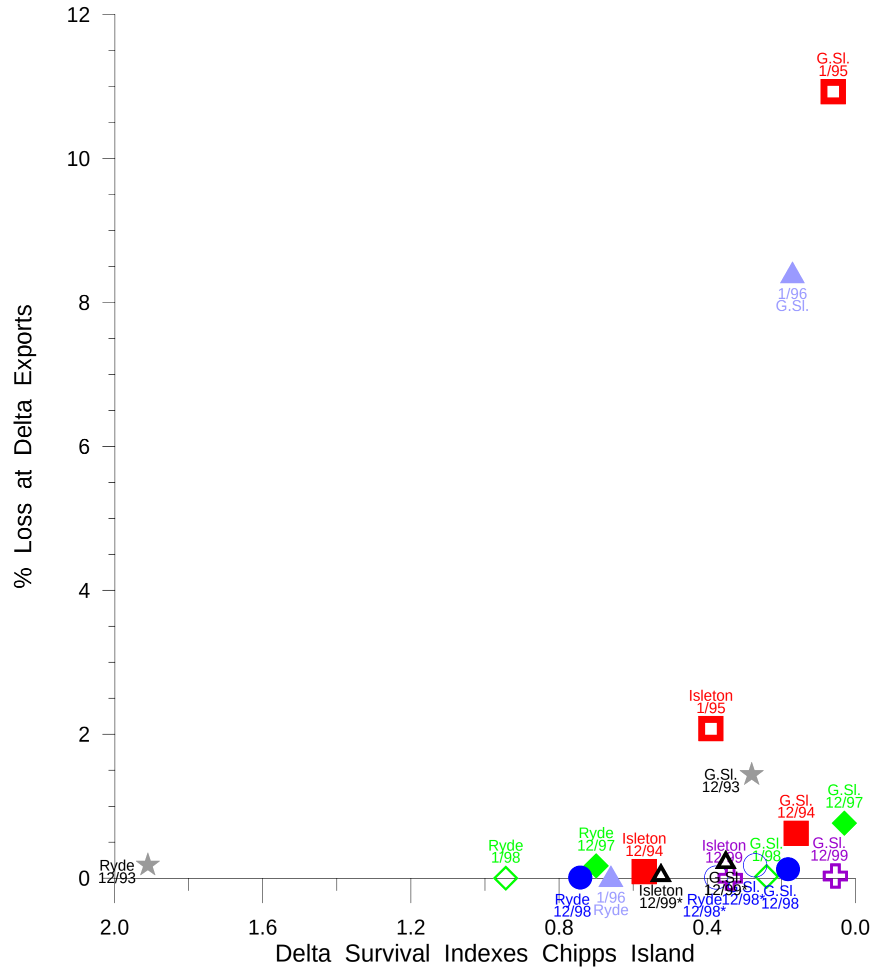


Figure 6–25 Scatterplot of Delta survival indices for Coleman Hatchery late fall-run Chinook salmon from paired release experiments in the Sacramento River and Georgiana Slough v. percentage of the release group salvaged at the CVP and SWP Delta facilities.

There was little trend of decreased relative survival with increased export to inflow ratio (Figure 6–32). The relationship between the export to inflow ratio and the percentage of late fall-run yearlings salvaged was highly insignificant (Figure 6–33), providing no evidence that entrainment is the primary mechanism for reduced relative survival. Newman and Rice (1997), and more recent work by Newman, suggests that reducing export pumping will increase the survival for smolts migrating through the lower Sacramento River in the Delta. Newman and Rice's updated 1997 extended quasi-likelihood model (Ken Newman, personal communication) provides some evidence that increasing the percent of Delta inflow diverted (export to inflow (E/I) ratio) reduces the survival of groups of salmon migrating down the Sacramento River, but the effect was slight and not statistically significant. In Newman's extended quasi-likelihood model using paired data, there was a significant export effect on survival (approximate *P* value of 0.02 for a one-sided test) (Newman 2000).

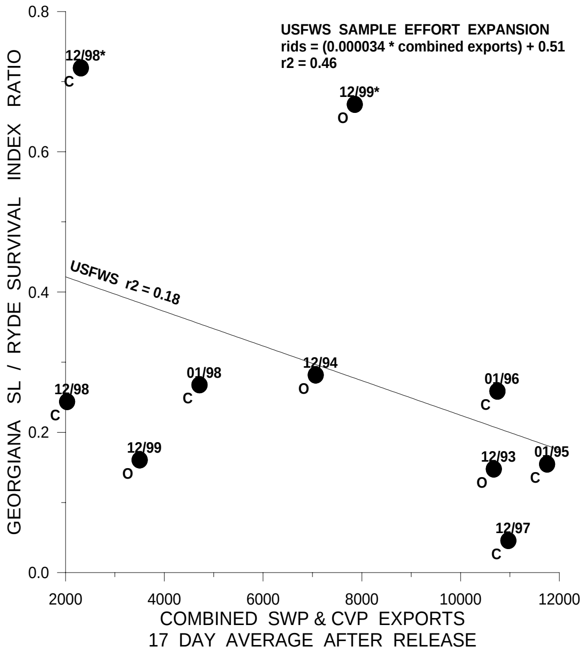


Figure 6–26 Relationship between Delta exports and the Georgiana Slough to Ryde survival index ratio. The export variable is combined average CVP and SWP exports for 17 days after release.

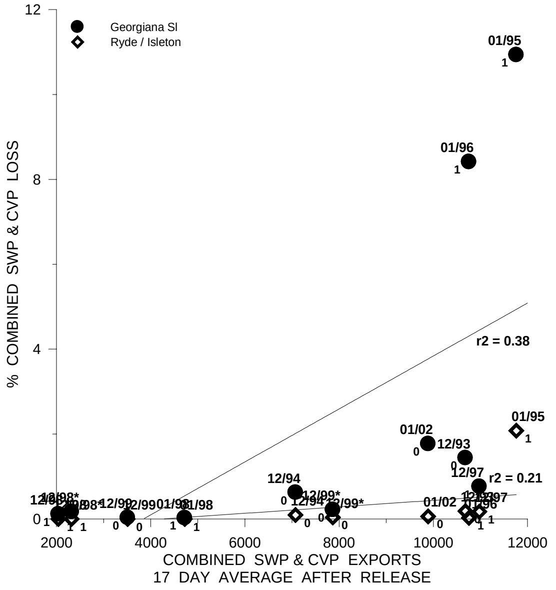


Figure 6–27 Relationship between Delta exports and percentage of late fall-run CWT Chinook salmon Delta release groups salvaged at the CVP and SWP Delta facilities. The export variable is combined average CVP and SWP exports for 17 days after release.

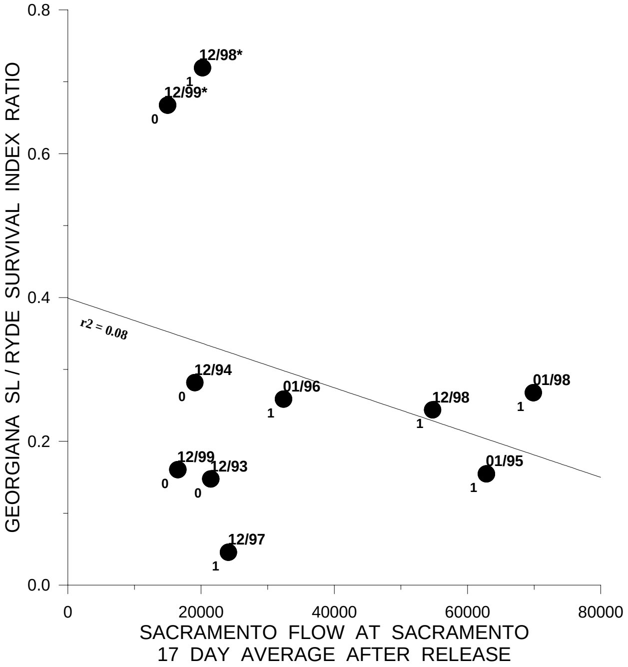


Figure 6–28 Relationship between Sacramento River flow and the Georgiana Slough to Ryde survival index ratio. The flow variable is average Sacramento River flow at Sacramento for 17 days after release.

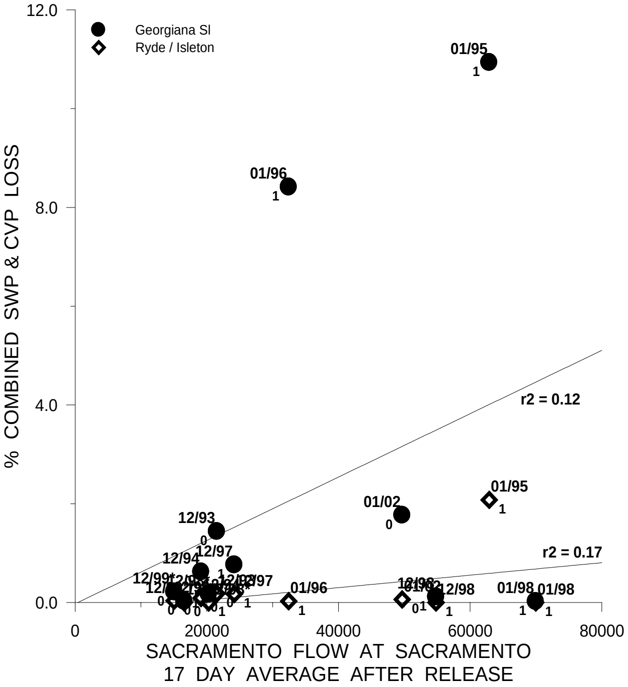


Figure 6–29 Relationship between Sacramento River flow and the percentage of late fall-run CWT Chinook salmon Delta release groups salvaged at the CVP and SWP Delta facilities. The flow variable is average Sacramento River flow at Sacramento for 17 days after release. Georgiana Slough and Ryde releases are plotted separately.

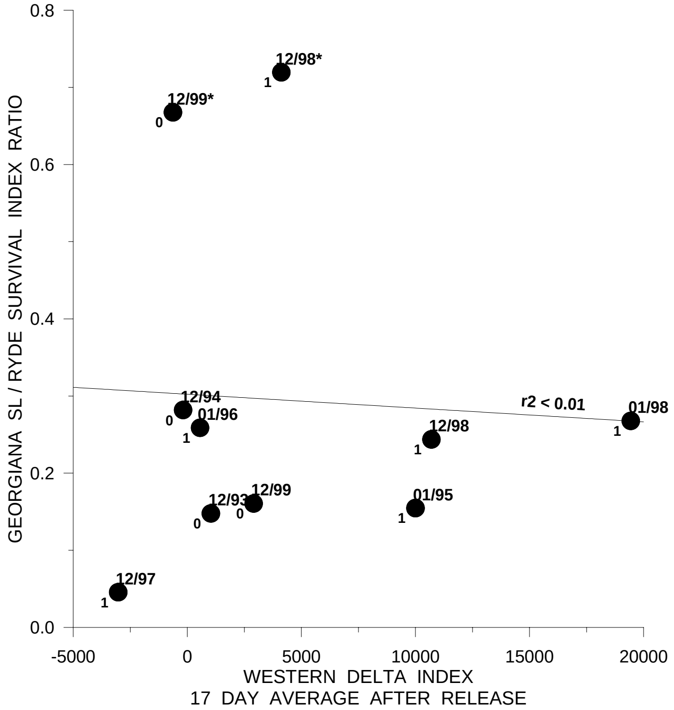


Figure 6–30 Relationship between QWEST flow and the Georgiana Slough to Ryde survival index ratio. The flow variable is average QWEST flow for 17 days after release.

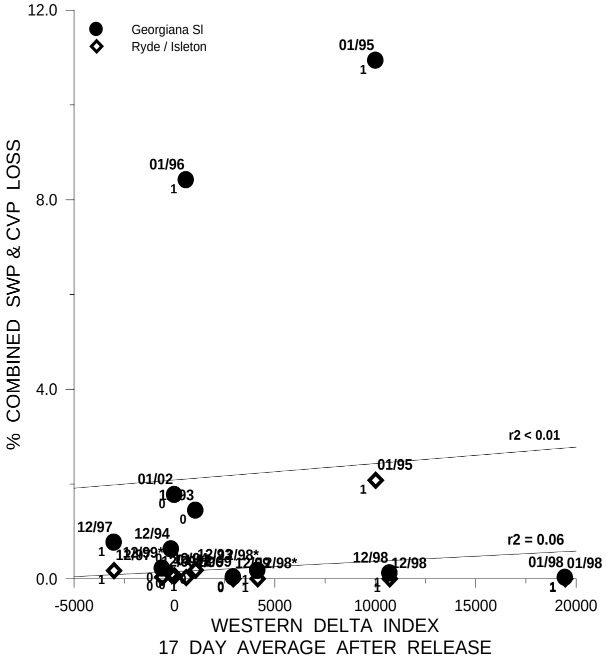


Figure 6–31 Relationship between QWEST flow and the percentage of late fall-run CWT Chinook salmon Delta release groups salvaged at the CVP and SWP Delta facilities. The flow variable is average QWEST flow for 17 days after release.

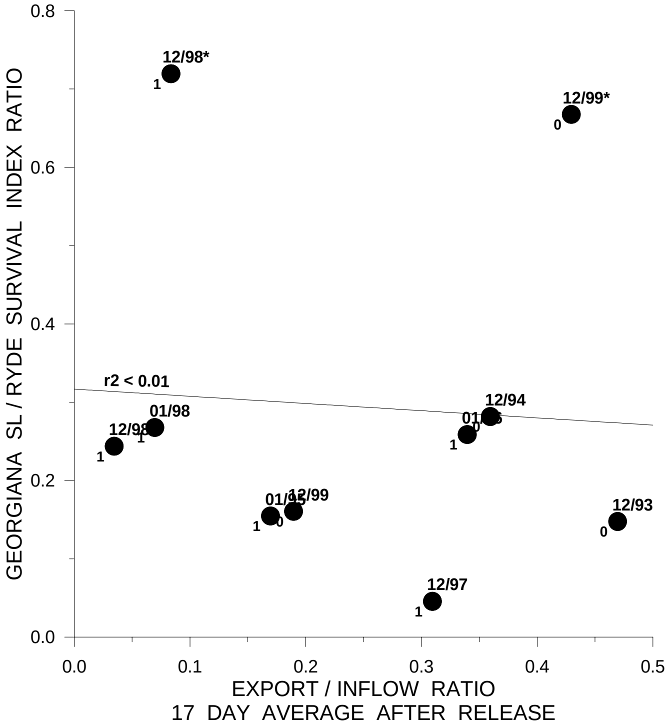


Figure 6–32 Relationship between Export/Inflow ratio and the Georgiana Slough to Ryde survival index ratio. The flow variable is average Export/Inflow ratio for 17 days after release.

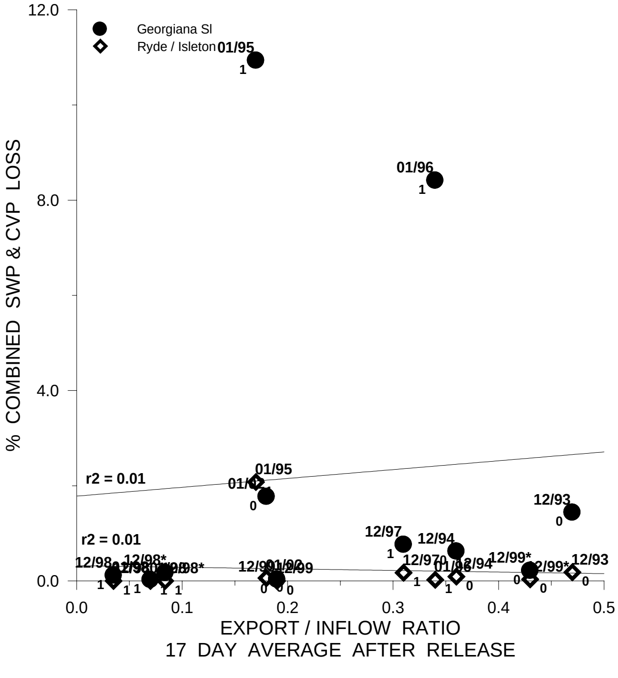


Figure 6–33 Relationship between Export/Inflow ratio and the percentage of late fall-run CWT Chinook salmon Delta release groups salvaged at the CVP and SWP Delta facilities. The flow variable is average Export/Inflow ratio for 17 days after release.

In summary, we did not find significant linear relationships between the GS-Ryde survival ratios for the Coleman late fall-run releases, or the losses of these fish at the Delta export facilities, and commonly used Delta hydrologic variables. Although not statistically significant, relative interior Delta survival was high and losses of both GS and Ryde release groups were low during one of the two low export experiments. At high exports, relative interior Delta survival was generally lower, with relatively high losses of GS release groups on two occasions. The data are not sufficient to provide the information necessary to quantify the benefit of export reductions to the Chinook population, due to the lack of information on the proportion of yearling emigrants using the DCC or Georgiana Slough routes. The data indicate it would take substantial reductions in exports to effect a modest decrease in losses or an increase in survival for Chinook emigrating through the central Delta.

FWS Delta experiments were not designed to test the effects of Delta operations on fish released by hatchery personnel upstream of the Delta. However, releases of Coleman Hatchery late-fall-run yearlings in the upper Sacramento River have occurred coincident with the Delta experiments. These were not paired releases, but they were made within a week of the Delta experiments. A comparison of the direct losses of fish released in the upper Sacramento River, and in the Delta is illustrated in Figure 6–34. The losses of the upper Sacramento releases are all very small (< two percent) even though the releases encompass a wide range of hydrologic conditions. In addition, the loss estimates for fish released upstream of the Delta are very similar to those calculated for the Ryde releases and most of the GS releases.

The survival indices of the upper Sacramento River releases may be helpful in the evaluation of effects on the population. This evaluation should be repeated when FWS completes the calculations of the upper Sacramento River releases' survival indices.

Altered Flow Patterns in Delta Channels

Flow in the Delta from results from a combination of river-derived flow and tidal movement. The relative magnitudes of river and tidal flow depend on location and river flow, with greater tidal dominance toward the west and at lower river inflows. The presence of channel barriers at specific locations has a major influence in flow dynamics. Tidal flows, because of the complex geometry of the Delta, can produce net flows independent of river flow and cause extensive mixing. During high flow periods, water flows into the Delta from Valley streams. During low flow periods, flow in the San Joaquin River is lower than export flows in the southern Delta, so water is released from reservoirs to provide for export and to meet salinity and flow standards in the Delta.

Particle tracking models, using data from direct measurement of river or channel velocities and volume transport at various Delta locations, have given us our most recent view of net flow in Delta channels. The general trend of model results seems to be that a patch of particles released in the Delta will move generally in the direction of river flow but the patch spreads extensively due to tidal dispersion. The export pumps and Delta island agricultural diversions impose a risk that the particle will be lost to the system. This risk increases with greater diversion flow, initial proximity of the particle to the diversion, and duration of the model run. The absolute magnitude of project exports was the best predictor of entrainment at the export pumps while the computed reverse flow in the western San Joaquin River (QWest) had, at most, a minor effect.

Tidal flow measurements allow calculation of tidally averaged net flows. Results indicate that tidal effects are important in net transport, and that net flow to the pumping plants is not greatly affected by the direction of net flow in the western (lower) San Joaquin River

In respect to fish movement, relatively passive life stages as delta smelt larvae should move largely under the influence of river flow with an increasing behavioral component of motion as the fish develop. Larger, strong-swimming salmon smolts are more capable of moving independently but may still be affected to some degree by river flow.

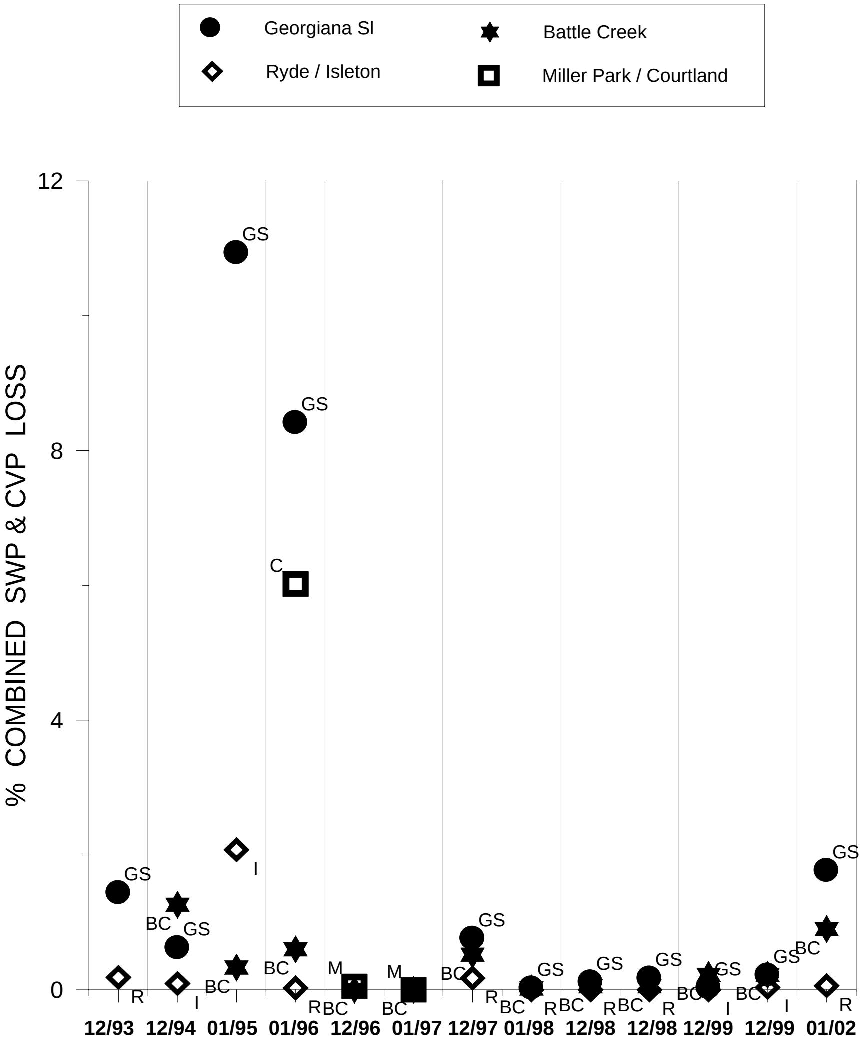


Figure 6–34 The percentage of late fall-run CWT Chinook salmon Sacramento River and Delta release groups salvaged at the CVP and SWP Delta facilities grouped by release date.

Altered Salinity in the Delta

Increasing salinity westward through the estuary may provide one of many guidance cues to emigrating juvenile salmon (DFG 1998). Salinity levels in the central and south Delta are sometimes increased above ambient conditions by agricultural return waters from the south Delta and San Joaquin River. Salmon emigrating from the Sacramento River may move into the interior and south Delta in response to the elevated salinity levels. However, it is not known whether salmon migrating through this region are confused by elevations in salinity caused by agricultural return water, which has a different chemical composition than ocean water, particularly given the magnitude of difference between tidal and net flows in the Delta (Oltmann 1998).

Contaminants

The role of potential contaminant-related effects on salmon survival in the Delta is unknown (DFG 1998). Elevated selenium levels in the estuary may affect salmon growth and survival. The EPA is pursuing reductions in selenium loadings from Bay Area oil refineries, and the San Francisco Regional Water Quality Control Board has recommended an additional 30 percent reduction in selenium levels to adequately protect the Bay’s beneficial uses. Non-point sources (including urban and agricultural runoff) contribute to elevated levels of polychlorinated biphenyls (PCBs) and chlorinated pesticides, which have been found in the stomach contents of juvenile salmon from the Bay, the Delta, and from hatcheries (NOAA fisheries 1997, as cited in DFG 1998). Collier (2002) Found that juvenile Chinook in Puget Sound estuaries were contaminated with sediment associated contaminants such as PCBs. They found a reduced immune response affecting fitness in these fish. These contaminants may also affect lower level food web organisms eaten by juvenile salmon, or bioaccumulate in higher trophic level organisms like the salmon themselves. The CALFED Bay-Delta Program has funded studies to assess contaminant effects on emigrating salmon and their potential prey organisms over the next several years.

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 salmon and steelhead and could kill fish present in the area of low dissolved oxygen.

Food Supply Limitations

Food limitation and changes in the Delta’s invertebrate species composition have been suggested as factors contributing to abundance declines and/or lack of recovery of estuarine-dependent species such as delta smelt and striped bass (Bennett and Moyle 1996; Kimmerer et al. 2000). There is no direct evidence of food limitation for salmon in the Delta or lower estuary (DFG 1998). However, there is evidence that some habitats (like non-natal tributaries and Yolo Bypass) may provide relatively better feeding and rearing opportunities for juvenile Chinook than the channelized Sacramento River (Moore 1997; Sommer et al. 2001b). Improved feeding conditions contribute to faster growth rates for fish using these habitats. Faster growth may yield at least a slight survival advantage, but the current evidence is insufficient to demonstrate this effect with statistical significance (Sommer et al. 2001b).

Predation and Competition

Predation is an important ecosystem process that helps to structure and maintain fish communities. Predation effects are very difficult to discern in nature because they are typically nonlinear and density-dependent (Bax 1999). Even without human intervention, natural predation rates are affected by spatio-temporal overlap of predators and prey, activity and metabolic needs of predators and prey at different temperatures, efficiency of different types of predators at capturing different prey, and the relative availability of appropriate prey types. Every Central Valley and Pacific Ocean predator's diet includes prey items other than salmon. Anthropogenic changes to ecosystems can alter these predator-prey dynamics, resulting in artificially elevated predation rates (Pickard et al. 1982a; Gingras 1997). Perhaps the most significant example of altered predation rates on Chinook salmon is human predation through harvest, which is discussed in the next section. Excepting direct human harvest, there are three factors that could affect predation dynamics on juvenile salmon. These are changes in the species composition and diversity of potential salmon predators through exotic species introductions, changes in the abundance of potential salmon predators (both of these may or may not be coupled to habitat alteration), and the placement of large structures in the migratory pathways of the salmon.

Changes in the species composition of predators can cause fish declines. Many potential salmon predators have been introduced to Central Valley waterways, particularly during the latter part of the 1800s and the early part of the 1900s (Dill and Cordone 1997). These included piscivorous fishes like striped bass, largemouth bass, crappies, and white catfish. Channel catfish is another common Delta-resident piscivore that seems to have become established considerably later, during the 1940s. All of these fish were establishing Central Valley populations during a time spring-run Chinook were declining for a variety of reasons. This makes it difficult to determine whether one or more of these predatory fishes significantly affected juvenile salmon survival rates.

There have been substantial changes in the abundance of several potential Chinook salmon predators over the past 20 to 30 years. These changes could have altered the predation pressure on salmon, but the data needed to determine this have not been collected. A few examples of changes in potential predator abundance are discussed below.

The striped bass is the largest piscivorous fish in the Bay-Delta. Its abundance has declined considerably since at least the early 1970s (Kimmerer et al. 2000). Both striped bass and spring-run and winter-run Chinook were much more abundant during the 1960s (DFG 1998) when comprehensive diet studies of striped bass in the Delta were last reported on. During fall and winter 1963–64, when spring-run yearlings and juvenile winter-run would have been migrating through the Delta, Chinook salmon only accounted for 0 percent, 1 percent, and 0 percent of the stomach content volume of juvenile, subadult, and adult striped bass respectively (Stevens 1961). During spring and summer 1964, Chinook salmon accounted for up to 25 percent of the stomach content volume of subadult striped bass in the lower San Joaquin River, although most values were less than 10 percent. Presumably most of these spring and summer prey were fall-run since they dominate the juvenile salmon catch during that time of year. These results do not suggest striped bass had a major predation impact on spring-run Chinook during the year studied, though year is not adequate to draw firm conclusions. Despite lower population levels, striped bass are suspected of having significant predation effects on Chinook salmon near diversion structures (see below).

Although striped bass abundance has decreased considerably, the abundance of other potential Chinook salmon predators may have increased. Nobriga and Chotkowski (2000) reported that the abundance of virtually all centrarchid fishes in the Delta, including juvenile salmon predators like largemouth bass and crappies, had increased since the latter 1970s, probably as a result of the proliferation of Brazilian water weed, *Egeria densa*. The increase in largemouth bass abundance is further corroborated by DFG fishing tournament data (Lee 2000). Predation by centrarchids such as largemouth bass and bluegill on salmon is probably minor because centrarchids are active at higher temperatures than those prefered by salmon so the two species are not likely present in the same areas at the same time.

Surveys at the Farallon Islands also indicate populations of pinnipeds (seals and sea lions) have increased substantially since the early 1970s (Sydeman and Allen 1999). High concentrations of seals and sea lions at the relatively narrow Golden Gate could impact the abundance of returning adult salmon. However, the extent to which marine mammals target the salmon populations over other prey types has not been studied thoroughly.

Predatory fish are known to aggregate around structures placed in the water, where they maximize their foraging efficiency by using shadows, turbulence, and boundary edges. Examples include dams, bridges, diversions, piers, and wharfs (Stevens 1961, Vogel et al. 1988, Garcia 1989, Decoto 1978, all as cited in DFG 1998).

In the past, salmon losses to Sacramento pikeminnow predation at RBDD were sometimes high, particularly after large releases of juvenile Chinook from Coleman Hatchery. Currently, predation mortality on spring-run at RBDD is probably not elevated above the background in-river predation rate (DFG 1998). All spring-run juvenile emigrants should pass RBDD during the gates-out period based on average run timing at RBDD (FWS 1998, as cited in DFG 1998). During the gates-out operation (September 15 through May 14) fish passage conditions are run-of-the-river and most of the adverse effects associated with the diversion dam have been eliminated. Gates-out operations are also important in preventing the large aggregations of Sacramento pikeminnow and striped bass that once occurred at RBDD.

The GCID diversion near Hamilton City is another one of the largest irrigation diversions on the Sacramento River (DFG 1998). Predation at this diversion is likely most intense in the spring when Sacramento pikeminnow and striped bass are migrating upstream, juvenile Chinook are migrating downstream, and irrigation demands are high. Predation may be significant in the oxbow and bypass system (DFG 1998), but this was not substantiated during two years of study in the GCID oxbow (Cramer et al. 1992). The GCID facility is an atypical oxbow with cooler temperatures and higher flows than most relatively high flows through the oxbow.

Predation in Clifton Court Forebay (CCF) has also been identified as a potentially substantial problem for juvenile Chinook. Between October 1976 and November 1993, DFG conducted 10 mark and recapture experiments in CCF to estimate pre-screen loss (which includes predation) of fishes entrained to the forebay (Gingras 1997). Eght of these experiments involved hatchery-reared juvenile Chinook salmon. Pre-screen loss (PSL) rates for juvenile fall-run Chinook ranged from 63 percent to 99 percent, and for late-fall-run smolts they ranged from 78 percent to 99 percent. PSL of juvenile Chinook was inversely proportional to export rate, and striped bass predation was implicated as the primary cause of the losses. Although a variety of potential sampling biases confound the PSL estimates, the results suggest salmon losses are indeed high at the times of year when the studies were conducted

Predation studies have also been conducted at the release sites for fish salvaged from the SWP and CVP Delta pumping facilities (Orsi 1967, Pickard et al. 1982, as cited in DFG 1998). Orsi (1967) studied predation at the old surface release sites, which are no longer in use. Pickard et al. (1982a) studied predation at the currently used subsurface release pipes. Striped bass and Sacramento pikeminnow were the primary predators at these sites. They were more abundant and had more fish remains in their guts at release sites than at nearby control sites. However, Pickard et al. (1982a) did not report the prey species composition found in the predator stomachs. The current release sites release fish in deeper where tidal currents distribute fish over seven miles. Therefore there is not the predation associated with the old release sites. Night releases may be most beneficial and lowering stress in fish and potentially reducing predation.

DFG conducted predator sampling at the Suisun Marsh Salinity Control Gates (SMSCG) from 1987 through 1993 and concluded the striped bass population increased substantially in the vicinity of this structure (DWR 1997). However, the sampling during 1987 through 1992 did not include a control site to measure background predation potential. During the 1993 study, a control site was added two miles upstream. Results from the 1993 study showed no significant differences in catch of predatory fishes between the control site and sampling sites at the SMSCG.

An analysis of the Suisun Marsh Monitoring database indicated few juvenile Chinook salmon (of any race) occur in Suisun Marsh (only 257 were captured by beach seine and otter trawl between 1979 and 1997). This suggests that even if striped bass have increased in abundance at SMSCG, they may not pose a predation problem for the winter-run or spring-run population as a whole. This hypothesis is supported by diet data from striped bass and Sacramento pikeminnow collected near the SMSCG. Only three Chinook salmon were found during seven years of diet studies (Heidi Rooks, personal communication, 1999). Dominant striped bass prey were fishes associated with substrate, such as 3-spine stickleback, prickly sculpin, and gobies (DWR 1997). Dominant pikeminnow prey types were gobies and smaller pikeminnows. Adult Chinook are too large to be consumed by any predatory fishes that inhabit the Delta, so delays resulting from operation of the gates would not result in predation losses.

Ocean Conditions and Harvest

The loss of inland salmonid habitat in the Central Valley to human development has resulted in substantial ecological effects to salmonids (Fisher 1994; Yoshiyama et al. 1998). Ocean sport and commercial fisheries take large numbers (> than 50 percent) of adult fish. Central Valley salmon populations are managed to maintain a fairly consistent level of spawner escapement (Figure 6–36). The ocean fishery is largely supported by hatchery-reared fall-run Chinook salmon. A large hatchery system is operated to allow these levels of harvest. Harvest may be the single most important source of salmon mortality, but all the hatchery fish probably would not be reared and released if there were no ocean harvest. During 1994 an estimated 109 coded wire tagged winter–run were harvested in the ocean troll fishery off the California coast while escapement in the Sacramento River was estimated at only 144 fish (table 5-11). Major changes in ocean harvest regulations were made in 1995, due to ESA concerns for winter-run Chinook. Harvest levels on Central Valley stocks have been lower since 1995. Strong year-classes like 1988 and 1995 were so heavily fished such that their reproductive potential was never realized. The 2000 Central Valley fall-run Chinook spawning escapement of 478,000 was the highest recorded since 1953 when an escapement of 478,000 also occurred. The high escapement in 2000 was probably due to above average precipitation during freshwater residency and good ocean conditions combined. The high escapement in 2000 was exceeded in 2001 when an estimated escapement of 599,158 occurred and again 2002 with an escapement of 850,000. The reason for the high escapement in 2001 was probably because most of the Chinook were concentrated north of the open commercial fishing area and thus were missed in the commercial fisheries and escaped. The commercial harvest in 2001 of 179,600 Chinook was the second lowest harvest since 1966. The Central Valley Index of abundance (commercial landings + escapement) in 2001 was 806,000 Chinook, which was actually lower than the forecasted production based on prior year two year old returns. The Central Valley harvest index in 2001 of 27 percent (percent of production harvested) was the lowest ever recorded. The next lowest harvest index was 51 percent in 1985 (PFMC 2002). This illustrates the substantial effect of ocean harvest on Chinook escapement. Restrictions on ocean harvest to protect southern Oregon and northern California coho salmon and Central Valley winter–run and spring–run played a role in the recent high escapements and contributed to the recent increases in winter–run and spring–run escapement to the Central Valley.

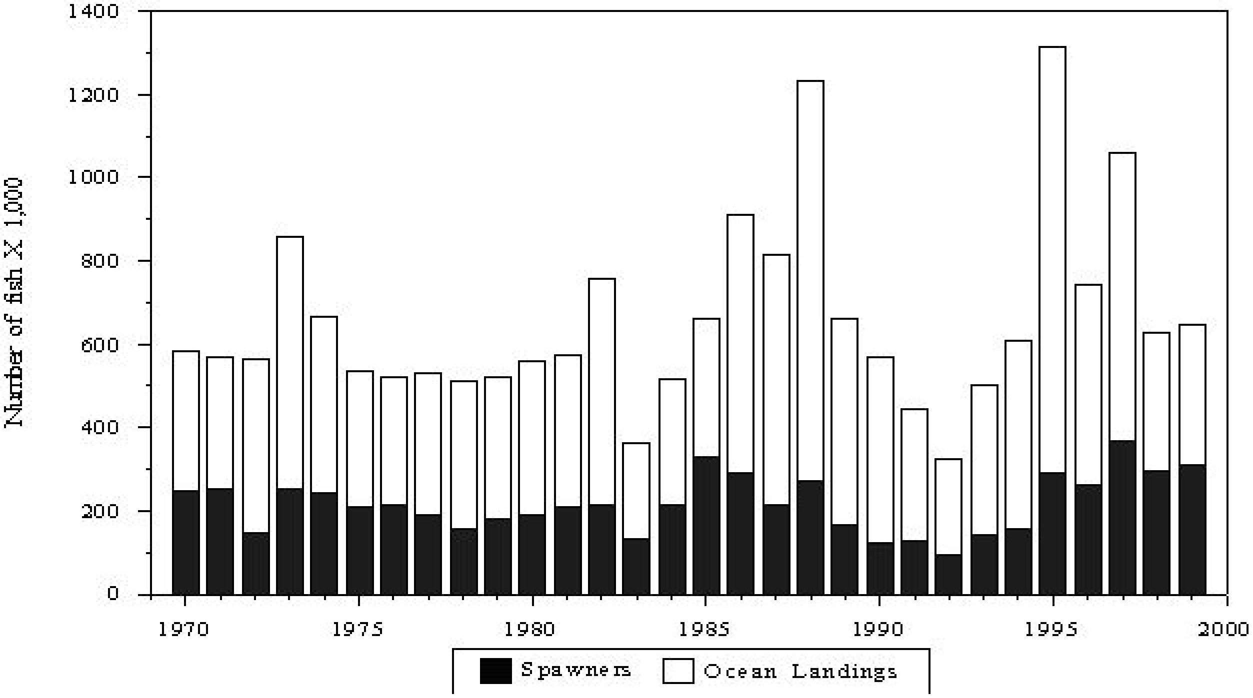


Figure 6–35 Central Valley Chinook salmon (all races) abundance index, 1970–99. 2000 = 1.74 million production with 55% harvested, 2001 = .849 million production with 27% harvested, 2002 = 1.285 million production with 34% harvested.

The percentage of Central Valley salmon harvested in ocean fisheries has averaged 66 percent since 1970 (Figure 6–22), and has approached 80 percent several times during the last 12 years. The average number of Central Valley Chinook landed in ocean fisheries between 1970 and 1999 was 442,000 fish per year (all races combined). Survival rates of young salmon are very low, meaning a large number must enter the ocean to support an average annual fishery of 442,000 fish. Beamish and Neville (1999) reported that smolt to adult survival rates for Fraser River (British Columbia) Chinook ranged from about 0.2 percent to about 6.8 percent, with an average during good ocean conditions of 4.8 percent. If the average Chinook smolt to adult survival is 4.2 percent and the pumps take 2 percent of winter–run this take would equate to 67 adults out of a winter–run escapement of 7,000, a 0.96 percent reduction in number of adults.

Assuming Central Valley smolt to adult survival rates also average 4.8 percent, 9.2 million Central Valley smolts would have to enter the ocean every year to support the average ocean fishery. Production of fall-run Chinook at Central Valley hatcheries exceeds 9.2 million smolts, and may more than support the entire ocean fishery. This number is actually higher than the total number of young salmon salvaged at both the SWP and CVP facilities (about 7 million or 230,000 per year) during the 30-year period 1970 through 1999. Salvage does not account for indirect losses attributable to project operations, which may be substantial and are estimated to be five times the direct losses. Nonetheless, this suggests that on average, indirect losses from Delta operations would have to be more than 30 times higher than the number salvaged to equal the adult-equivalent mortality contributed by the ocean fisheries, assuming 4.8 percent smolt to adult survival. Considering the projects are exporting a high portion of the total freshwater outflow, this suggests that salmon are finding their way out of the system and not being diverted at the facilities in direct proportion to the diversion rate. Both the ocean harvest and Delta salvage are managed to protect the ESA-listed races.

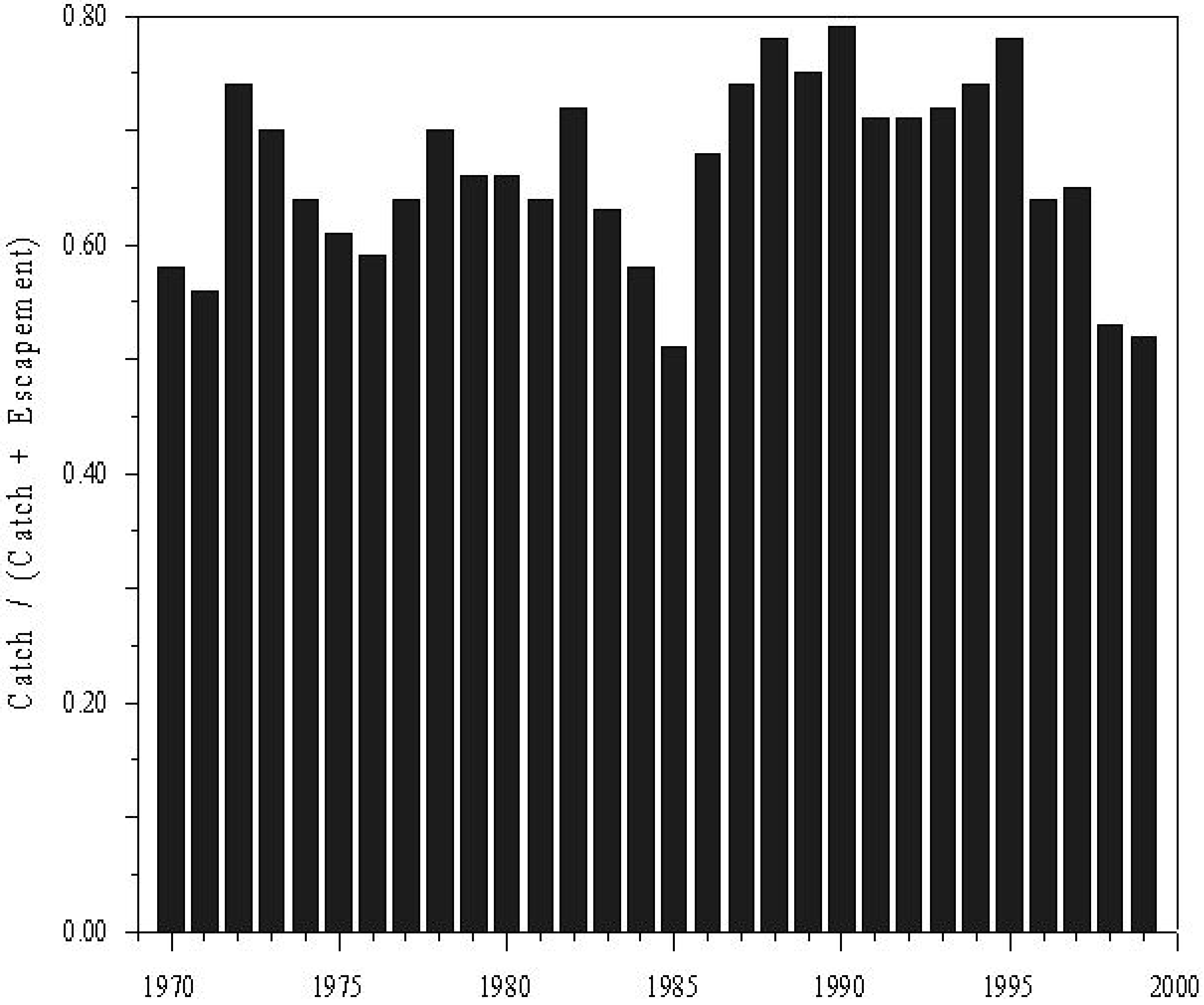


Figure 6–36 Central Valley Chinook salmon Ocean Harvest Index, 1970–99.

Recent advances in the scientific understanding of interdecadal changes in oceanographic conditions on marine fisheries were outlined in Chapter 3. The abundance of pink, chum, and sockeye salmon appears to fluctuate out of phase with Chinook stocks to the south (Beamish and Bouillon 1993, as cited in Bakun 1999; Beamish and Neville 1999). Beamish and Neville (1999) found Chinook smolt survival rates to adulthood in the Strait of Georgia (Fraser River stocks) declined from 4.8 percent prior to abrupt changes in local oceanographic conditions during the latter 1970s, to 0.7 percent after the oceanographic changes. As a consequence, adult Chinook returns to the Fraser River system decreased to about 25 percent of 1970s levels even though approximately twice as many smolts were entering the Strait during the 1980s. The specific reasons for decreased smolt survival rates were unclear, but the authors suggested that decreased coastal precipitation and resultant decreased river discharge, increased temperatures in the strait and an increased tendency for spring plankton blooms to precede the peak smolt immigration into the strait were likely contributing factors. In addition, aggregations of opportunistic predators like spiny dogfish, may have contributed to lower hatchery smolt survival rates due to the increasing density of young fish added into the Strait of Georgia by hatcheries.

No dramatic change in Central Valley salmon abundance occurred during the latter 1970s (Figure 6–35), like the one observed in Fraser River stocks. In fact, Central Valley salmon abundance was remarkably consistent during the 1970s. However, the variation in abundance of Central Valley Chinook increased dramatically beginning in 1983. Since 1983, Central Valley salmon abundance has flip-flopped by a factor of three during two periods of five years or less.

All Central Valley Chinook salmon stocks have overlapping ocean distributions (DFG 1998). This may provide the opportunity for occasional overharvest of a rare stock like winter or spring–run, relative to the abundant target stock, fall–run. This situation has occurred occasionally in the past. The brood year 1976 Feather River Hatchery spring-run was fished at levels about five to 13 times higher than the background rate on coded wire tagged fall-run Chinook by both the recreational and commercial fisheries for several years (Figure 6–37) This may also have happened to a lesser degree with the brood year 1983 spring-run from FRH. For whatever reason, these year classes remained particularly susceptible to the ocean fisheries for the duration of their ocean phase. Current ocean and freshwater fishing regulations are designed to avoid open fishing in areas where winter–run and spring–run are concentrated. Estimated harvest of winter–run coded wire tagged release groups are shown in Table 6–11.

Table 6–11 Winter–run Chinook estimated harvest of coded wire tagged release groups (expanded from tag recoveries) by harvest location (data from RMIS database).

Winter run recoveries (estimated) from RMIS database, 4/15/2003

Sum of estimated_number	run_year											
recovery_location_name	1980	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Grand Total
AMER.R. TO COLUSA									8	17		25
BATTLE CREEK												
BIG LAG.-CENTERV.BEA									4			4
BROOKINGS SPORT 6									3			3
C.VIZCAINO-NAVARR.HD	6									8		14
CARQUINEZ TO AMER. R									14			14
COLEMAN NFH												
COLUSA TO RBDD										67		67
COOS BAY SPORT 5											2	2
COOS BAY TROLL 5									4		4	8
FORT ROSS-PIGEON PT	24	5	55	8	4	18		8	25			147
GSPTS YEO PT								3				3
NEWPORT SPORT 4										2		2
NEWPORT TROLL 4										3		3
NTR 02W-118							6					6
NWTR 026-000											7	7
PIGEON PT.-POINT SUR	7	7	34	5	5	19			86	22	34	218
PIGEON PT-CA/MEX.BOR									8			8
POINT SUR-CA/MEX.BOR			20	9	5	10			3	14	8	68
PT.ARENA-PT.REYES										7	15	22
PT.REYES-PIGEON PT.										18	27	45
PT.SN.PEDRO-PIGN.PT.										4	8	12
SACRA.R, ABO FEATHER												
Grand Total	37	13	109	22	13	47	6	11	154	162	105	679
Escapement	1,142	349	144	1,159	1,001	836	2,930	3,288	1,352	7,572	7,337	27,110
# CWT fish released 2 years prior	9,988	10,866	27,383	17,034	41,412	48,154	4,553	20,846	147,393	30,433	162,198	530,653
Estimated % of cwt released fish recovered	0.37%	0.12%	0.40%	0.13%	0.03%	0.10%	0.13%	0.05%	0.10%	0.53%	0.06%	0.13%

In addition to occasional effects to particular year-classes, ocean fishing may affect the age structure of Central Valley spring-run Chinook. A DFG (1998) analysis using CWT spring-run from the Feather River Hatchery estimated harvest rates were 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. Since length tends to be correlated with age, and fecundity is correlated with length (DFG 1998), the effect of ocean fishing on the age structure of the population may have subtle effects on population fecundity.

Recent papers have re-emphasized the ecological importance of salmon carcasses to stream productivity (Bilby et al. 1996, 1998; Gresh et al. 2000). As mentioned in the preceding chapter on steelhead, the substantial declines in mass transport of 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 nutrient deficiencies (Gresh et al. 2000). The relatively high ocean harvest indices for Central Valley salmon suggest this idea should be studied locally.

In addition to ocean harvest, legal and illegal inland fishing for spring-run salmon undoubtedly occurs at fish ladders and other areas where adult fish are concentrated, such as pools below dams or other obstructions (DFG 1998). Mill, Deer, and Butte Creeks, as well as other tributaries with spring-run populations, are particularly vulnerable to poaching during the summer holding months because of the long period in which adults occupy relatively confined areas. The significance of illegal freshwater fishing to the spring-run salmon adult population, however, is unknown. The increased law enforcement programs have reduced poaching the last few years.

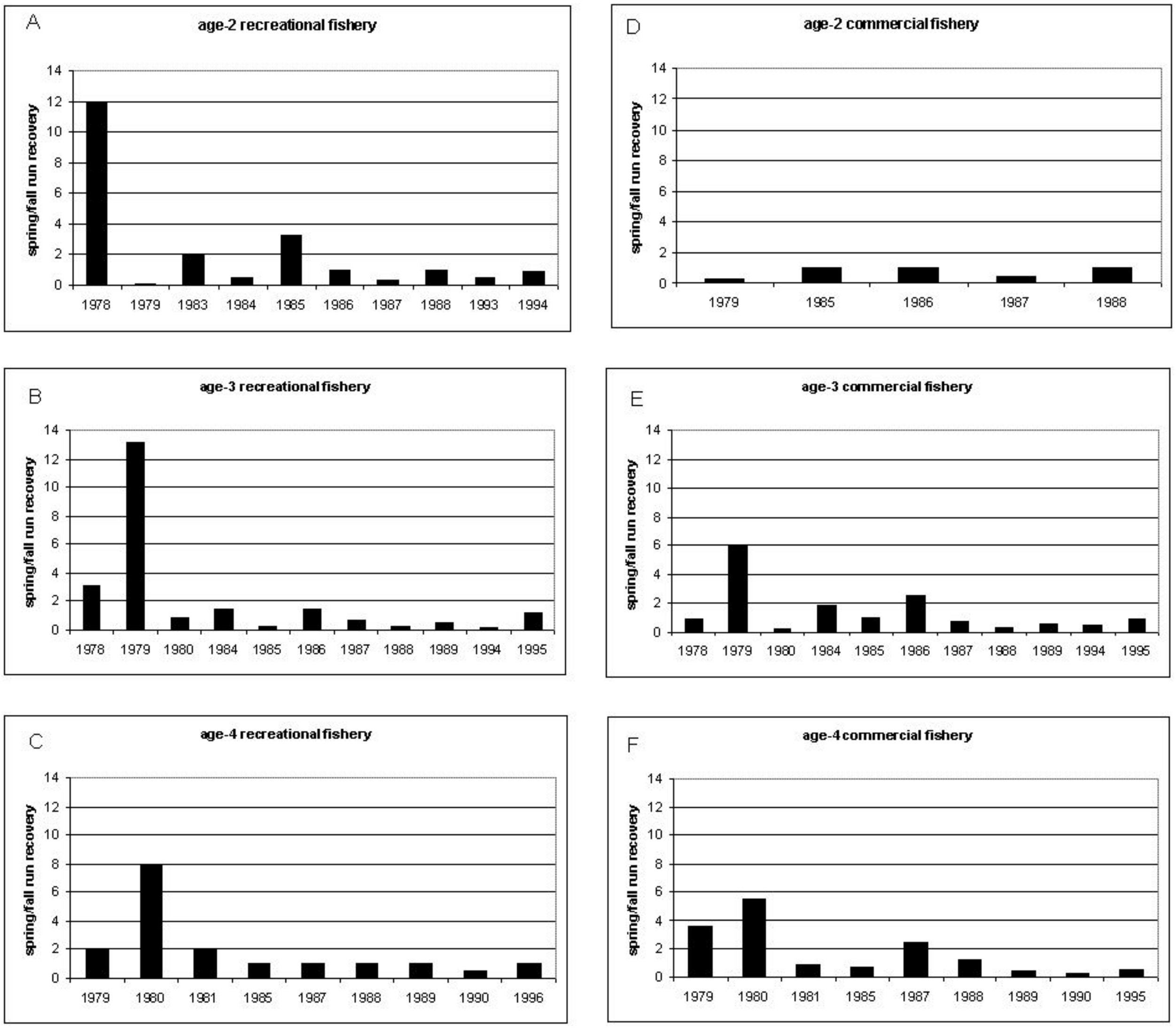


Figure 6–37 Coded-wire-tag (CWT) recovery rate of Feather River Hatchery spring-run Chinook salmon relative to the CWT recovery rate of Central Valley fall-run Chinook salmon. Data were taken from DFG (1998), and are presented individually for recreational and commercial fisheries for age-two, age-three, and age-four fish. Values greater than one indicates fishing pressure above the level sustained by the fall-run.

Hatchery Influence

Central Valley Chinook salmon runs are heavily supplemented by hatcheries to mitigate for the loss of habitat when dams were built. Table 6–12 lists salmon hatcheries operating in the Central Valley and their yearly production goals. When all hatcheries reach their production goals, over 34 million Chinook smolts are released into the system. This large number of smolts in the common ocean environment may result in competition with wild fish in times of limited food resources.

Table 6–12 Production data for hatchery produced Chinook salmon.[13]

Hatchery	*River*	*Chinook runs*	*Yearly production goal*
Coleman NFH	Battle Creek	Fall, late-fall, winter	13,200,000 smolts
Livingston Stone	Sacramento	winter	
Feather River	Feather	Fall, spring	~14,000,000 smolts
Nimbus	American	Fall	4,000,000 smolts
Mokelumne River	Mokelumne	Fall	2,500,000 post smolt
Merced River	Merced	Fall	960,000 smolts
Total			34,660,000

The percentage of the Central Valley fall-run Chinook return taken at hatcheries for spawning has shown a gradual increase since 1952 (Figure 6–38). Hatcheries have likely helped to maintain Chinook populations at a level allowing a harvestable surplus. However, hatcheries may have reduced genetic fitness in some populations, especially the more depressed runs, by increasing hybridization between different runs. Fish have been transferred between watersheds resulting in unknown genetic effects. Livingston Stone Hatchery produces winter-run Chinook and has assisted in the recent population increases for winter–run.

A majority of hatchery releases are trucked to downstream release locations and in all except Coleman and Livingston Stone hatcheries are trucked to San Pablo Bay. The downstream releases increase survival of the hatchery stocks but also increase the proportion of hatchery relative to wild survival and increase straying. Recent cwt data shows that a good portion of the Chinook in spring-run streams like Clear Creek and Mill Creek are of hatchery origin (NOAA Fisheries 2003). A recent review of hatchery practices (DFG and NOAA fisheries 2001) recommended reducing the practice of using downstream releases and instead releasing fish in the river of origin. This practice would reduce the survival of hatchery fish, but could also reduce the in-river survival of wild fish when the carrying capacity of the habitat is surpassed resulting in intraspecific competition. Currently the proportion of hatchery vs wild fish contributing to fisheries and to the escapement is unknown. Visually marking all hatchery production would allow harvest to take only hatchery fish thus allowing wild salmon populations to increase. Otolith marking would allow a better estimate of the proportion of adults consisting of hatchery produced fish to be made at a reduced cost from fin clipping or CWTs.

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[13] Source: DFG and NOAA fisheries 2001.

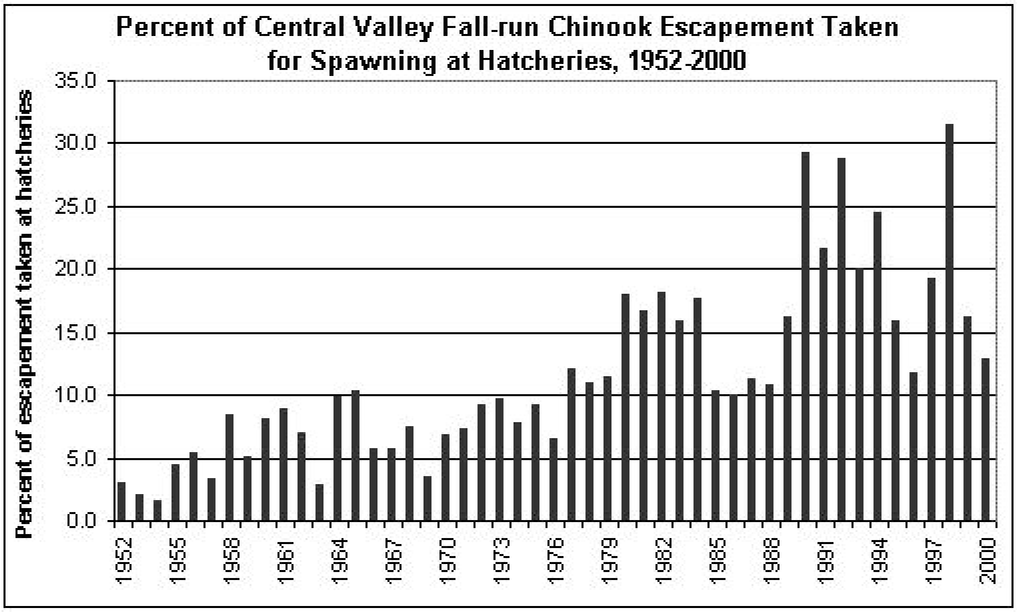

Figure 6–38 Percent of Central Valley fall-run Chinook escapement taken for spawning 1952–2000.

Feather River Hatchery-Genetics, Competition for Spawning, and Rearing Habitat

Historically, the adult spring-run salmon immigration into the upper rivers and tributaries extended from mid-March through the end of July with the peak in late May and early June (DFG 1998). Spawning started in mid-August, peaked in early September, and ceased in late September. The peaks of spawning between spring- and fall-run salmon were almost two months apart, and more than 30 days separated the end of spring-run spawning and the onset of fall-run spawning at Baird Hatchery at the end of the 1800s.

Although hydraulic mining and dams initially fostered intermixing of Chinook races in the Sacramento River system, hatchery practices have contributed as well (DFG 1998; NOAA fisheries 1998). The Feather River Hatchery (FRH) was built by DWR at the request of DFG to mitigate for the loss of habitat upstream of Oroville Dam. The hatchery was dedicated on October 1, 1967 and is operated by DFG. During the five-year period prior to the opening of the hatchery (1962 through 1966) all adult salmon were trapped and transported above the site of Oroville Dam. During 1968 and 1969 spring-run salmon were allowed to enter the hatchery as soon as they arrived. The result was greater than 50 percent mortality, because warm water temperatures resulted in an inability to hold adults during the summer months until they were ready for spawning. As a result, since 1970 hatchery policy has been to exclude spring-run salmon entry until the onset of spawning, (August through October, generally early September to October 1). This practice has resulted in the inability of the hatchery operators to clearly identify spring-run based on their adult upstream migration timing, thereby increasing the likelihood of genetic introgression of spring-run and fall-run Chinook stocks.

Coded wire tag analysis provided verification of the inter-mixing of fall and spring runs. Twenty-two percent of juveniles tagged as fall-run subsequently spawned as spring–run, and 295 juveniles tagged as spring-run were subsequently spawned as fall-run (Brown and Greene 1994). Preliminary genetic characterization results from the IEP Central Valley Salmonid Genetics Project provided additional evidence of inter-mixing. University of California geneticists presented preliminary work on Feather River spring-run genetic characterization at the 1999 Salmon Symposium in Bodega Bay. They had access to samples from Feather River hatchery "spring–run," late summer season in-river carcass surveys and a limited number of samples from spring season in-river angler surveys. They found no genetic difference between the Feather River fall and spring runs. The two groups were genetically similar, and homogenous. They were most similar to Central Valley fall-runs, and were not genetically similar to spring-run from Mill, Deer or Butte Creeks.

In 1994, the FRH fish ladder was kept open between May 16 and June 6 to assess the current numbers of Chinook that exhibited spring-run adult migration timing. Prior to June 6, only one fish had entered the hatchery. On June 6, 31 fish entered the hatchery and the ladder was closed (DFG 1998). The implication is that few fish exhibiting the "typical" spring-run salmon adult migration timing ascended the Feather River during 1994. Alternatively, many spring-run adults may have been holding, or not moving, during the period the gates were open. When the ladder was reopened on September 6, 1994, 3,641 "spring-run" Chinook entered the hatchery.

FRH spring-run have been documented as straying throughout the Central Valley for many years and have intermixed with wild-spawned spring-run and fall-run Chinook in the upper Sacramento River, although the extent of hybridization has not been determined (DFG 1998). In 1982, early returning CWT Chinook were observed at RBDD and subsequently identified as FRH fall-run from the 1980 brood year. Now it is commonplace at RBDD to intercept fish tagged as fall-run during the spring-run migration period (mid-March through the end of July) (Figure 4–4). This intermixed life history pattern was evident when FRH fish were used in an attempt to re-establish spring-run in Clear Creek. More than 523,000 FRH spring-run fry were planted at the base of Whiskeytown Dam during the three-year period 1991–93 (DFG 1998). Some of the fish were coded wire tagged. Since 1993, snorkeling surveys have been performed during the adult spring-run holding period to determine if the plants were successful. Three unmarked salmon were observed during the spring-run adult holding period in 1993 and two in 1995. However, 23 CWT adults returned between 1993 and 1995 during the adult fall-run spawning migration.

DFG (1998) questioned the viability and genetic integrity of the Butte Creek spring-run because of the potential for intermixing with Feather River salmon. Butte Creek has several different sources of introduced water, including West Branch Feather River water, main stem Feather River water, and Sacramento River water. As a consequence, it is possible that some spring-run salmon in Butte Creek could be strays from the Feather River. Despite the mixing of Feather River water into Butte Creek, DFG (1998) suggested the relative numbers of adult spring-run entering Butte Creek and FRH, for the period 1964 to 1991 did not show a strong relationship, suggesting they are generally independent. In support of this information, Banks, et al, (2000) published genetic characterization research results and determined spring-run from Deer and Mill Creeks are more closely related to Central Valley fall-run populations than Butte Creek spring-run. This result would not be expected if Butte Creek spring-run were hybridized with

FRH spring-run because FRH spring-run are known to be hybridized with FRH fall-run. More recently, Hedgecock, et al, (2002) re-exmained Feather River fall hatchery, spring hatchery and spring wild. Field biologists have found a spring-run phenotype in the Feather River. Hedgecock found that spring hatchery and spring wild form a genetically distinct population that is different from the fall–run, although the Feather River spring–run population is still more closly related to fall–run than to either Mill or Deer Creeks spring–run populations. In conclusion, Hedgecock found two distinct populations in the Feather River, one of which exhibits a spring–run phenotype. The Feather River spring–run population is not closely related to Mill and Deer Creeks spring–run and may be, therefore a spring–run in the Sacramento Valley may be polyphyletic.

The Banks et al. (2000) genetic results are surprising however, because the escapement estimates for Butte Creek and Feather River spring-run are strongly correlated over more recent years (1987 through 1998), (Spearman $R = 0.83\text{-}0.86$, $p < 0.001$). (The variability in the R-value is due to separate tests of FRH spring-run escapement v. the smallest and largest available Butte Creek escapement estimates.) In contrast, the spring-run escapement estimates for Deer and Mill Creeks, which Banks et al. (2000) found were not genetically different from each other, are not significantly correlated for the 1987 through 1998 period (Spearman $r = 0.27$, $p = 0.40$).

FRH spring-run fry and juveniles were released into Butte Creek in 1983, 1984, and 1985, Brood Years 1982, 1983, and 1984 respectively. Only BY 1983 releases affected resultant year-classes, showing large increases in BY 1986 and BY 1989. There was a significant reduction in adult returns for BY 1992, but BY 1995 was the largest observed (7,500 adults) since 1960, and BY 1998 was higher still (20,259 adults). Since 1995 there have been over 500,000 Butte Creek spring–run tagged and released. While the inland recoveries have been limited, all of the tags recovered within the spring–run population have been from spring–run tagged and released in Butte Creek. One tagged fish was recovered in the Feather River, but no Feather River or other origin fish have been found among the Butte Creek spring–run (DFG 2003).

During the 1977 drought, adult spring-run were trucked from RBDD to Mill, Deer, and Butte Creeks (DFG 1998). No appreciable effect was seen in the subsequent year class (1980) on Butte or Mill Creeks. However there was an apparent single year (1980) increase in the Deer Creek population.

The Yuba River was planted with surplus FRH spring-run in 1980 (15,925), 1983 (106,600), and 1985 (96,800) (DFG 1998). Influence of these three introductions on subsequent adult spring-run returns cannot be determined since escapement surveys were not conducted. In 1984, Antelope Creek was planted with 302,733 FRH spring-run juveniles. In 1985, the creek was planted with another 205,000 juveniles. There is no persistent spring-run population in Antelope Creek, so the effect of hatchery supplementation in this drainage is irrelevant.

The effects of introgression and planting are poorly understood. In the case of the Feather River, Sommer et al. (2001a) found evidence that hatchery operations have had major population effects. As noted previously in this chapter, the authors examined factors responsible for a long-term shift in the spawning distribution toward the low flow channel of the Feather River. While they found statistical evidence that flow and escapement may affect the distribution of spawning salmon, they concluded that hatchery operations probably account for much of the change. One hypothesis was introgression with spring-run causes the fall-run population to spawn as far upstream as possible, similar to the historical spring-run life history pattern. Another possibility was that a shift in the stocking location of young salmon to the estuary resulted in higher survival rates and an increased proportion of hatchery fish in the population. Hatchery fish would tend to spawn closer to the hatchery in the low flow channel. In support of the latter hypothesis, there has been a significant increase in the number of fish entering FRH since 1968 (Ted Sommer, DWR unpublished data). The effects of these changes for spring-run are unclear. However, a shift in spawning distribution to the heavily-used low flow channel is expected to result in exceptional spawning superimposition and egg mortality for any spring-run that may be present.

Disease and Parasites

Spring-run Chinook are susceptible to numerous diseases during different phases of their life cycle. 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.

In stream Habitat

Dam operations generally store water runoff during winter and spring to be released for in stream flows, water delivery, and water quality during late spring, summer and fall. Historical high flows in regulated rivers have been dampened for flood control and water storage. Moderate flows have been extended throughout much of the year to provide appropriate in stream flows for fish, water quality in the Delta and water for pumping in the Delta. The long term effect of the lack of high flows is the simplification of in stream habitat. High channel forming flows maintain high quality spawning habitat and riparian floodplain conditions. High flows mobilize spawning sized gravels from streambanks and incorporate them into the active channel. Low flows that typically occurred in late summer and fall do not occur because of the dampening effect of dam operations. High flows are not as high as occurred under natural conditions but the duration of high flows is longer because flood control operations spread them out over time. The longer duration of moderately high flows may be sufficient enough to wash quality spawning gravel out of riffles and deposit it in deeper water where it is unavailable for spawning but not high enough to mobilize new gravel supplies from the gravel bars, banks, and floodplain. The presence of dams has eliminated upstream sources of bedload and woody debris, increasing the importance of streamside sources. Depending on reservoir operations and whether this increases or decreases the number of bankfull days in the respective river, the availability of spawning gravel downstream could be increased or decreased.

Levees and bank protection projects have been constructed along the lower reaches of many Central Valley rivers, limiting the potential for rivers to meander. Many streambanks near developed areas have been riprapped to cut down on natural channel adjustments and streambank erosion. Natural streambanks generally provide higher quality habitat to salmonids than riprapped banks. In addition, when banks are riprapped riparian vegetation is eliminated in the riprapped portion, eliminating overhanging vegetation and future woody debris sources.

Large woody debris provides valuable habitat to salmonids. Woody debris has been removed from some rivers because it is perceived as a hazard to swimmers and boaters and impedes navigation. The habitat loss cumulatively from lack of woody debris recruitment, woody debris removal, and riprapping could be a significant factor in the current state of Central Valley salmon populations. The likelihood that this would reduce the survival of the current Chinook or steelhead populations is unknown.

Factors that May Influence Abundance and Distribution of Coho Salmon

A number of interrelated factors affect coho abundance and distribution. These include water temperature, water flow, habitat suitability, habitat availability, hatcheries, predation, competition, disease, ocean conditions and harvest. Current CVP operations affect primarily water temperature, water flow, and habitat suitability. Water temperature suitability criteria for Coho salmon are shown in Table 6–13.

Table 6–13 Water Temperature suitability criteria for Coho salmon life stages from DFG 2002a.

Life Stage	Suitable Range, degrees F	Reference or Citation
Migrating adult	44.6 – 59	Reiser and Bjornn 1979
Spawning adult	39.2 – 48.2	Bjornn and Reiser 1991
Rearing juvenile	48 – 59.9 = optimum 63.7 – 64.9 = optimum (2 studies gave optimums) 35 = lower lethal 78.8 - 83.8 = upper lethal	Bjornn and Reiser 1991; Flosi et al 1998; Ambrose et al 1996; Ambrose and Hines 1997, 1998; Hines and Ambrose ND; Welsh et al. 2001
Eggs and fry	39.2 - 55.4 = optimum 32 – 62.6	Davidson and Hutchinson 1938; Bjornn and Reiser 1991; PFMC 1999

Juvenile coho salmon spend a full year in freshwater before migrating to the ocean. Their habitat preferences change through the year and are highly influenced by water temperature. During the warmer summer months when coho are most actively feeding and growing they spend more time closer to main channel habitats. Coho tend to use slower water than steelhead or Chinook salmon. Coho juveniles are more oriented to submerged objects such as woody debris while Chinook and steelhead tend to select habitats in the summer based largely on water movement and velocities, although the species are often intermixed in the same habitat. Juvenile coho tend to use the same habitats as pikeminnows, a possible reason that coho are not present in Central Valley watersheds. Juvenile coho would be highly vulnerable to predation from larger pikeminnows during warm water periods. When the water cools in the fall, juvenile coho move further into backwater areas or into off-channel areas and beaver ponds if available. There is often no water velocity in the areas inhabited by coho during the winter. These same off-channel habitats are often dry or unsuitable during summer because temperatures get too high.

Lewiston Dam blocks access to 109 miles of upstream habitat (USDI 2000). Trinity River Hatchery produces coho salmon with a production goal of 500,000 yearlings to mitigate for the upstream habitat loss. Habitat in the Trinity River has changed since flow regulation with the encroachment of riparian vegetation restricting channel movement and limiting fry rearing habitat (Trush et al 2000). According to the Trinity River Restoration Plan higher peak flows are needed to restore attributes of a more alluvial river such as alternate bar features and more off channel habitats. These are projected in the restoration plan to provide better rearing habitat for coho salmon than the dense riparian vegetation currently present.

Chapter 7 Basic Biology and Life History of Delta Smelt and Factors that May Influence Delta Smelt Distribution and Abundance

Delta Smelt Biology and Population Dynamics

General Biology

The delta smelt is a small (adults typically < 100 mm in length) pelagic fish found in tidal fresh and brackish water habitats of the upper San Francisco Estuary (Moyle et al. 1992). It typically has an annual life cycle though a small percentage (< 10 percent) of the population can live to and possibly reproduce at age-two (Brown and Kimmerer 2001). On average, ripe females produce about 1,900 eggs, but fecundity can range from about 1,200 to about 2,600 eggs per female (Moyle et al. 1992). Moyle et al. (1992) considered delta smelt fecundity to be "relatively low", but based on Figure 2a in Winemiller and Rose (1992) delta smelt fecundity is actually fairly high for a fish its size. Delta smelt move into tidal freshwater habitats to spawn in late winter through spring. Most spawning occurs in the Delta, but some also occurs in Suisun Marsh and the Napa River (DFG unpublished). An optimal spawning temperature "window" of about 15º C -18º C (59º F - 64.4º F) has recently been reported (Bridges unpublished; Bennett unpublished). After hatching, larvae are dispersed throughout low salinity habitats, generally moving into Suisun Bay, Montezuma Slough, and the lower Sacramento River below Rio Vista as they mature (Grimaldo et al. 1998; Sweetnam 1999). Delta smelt are zooplanktivorous throughout their lives, feeding mainly on a few species of copepods with which they co-occur (Moyle et al. 1992; Lott 1998; Nobriga 2002). In the larger picture of fish life history strategies, delta smelt best fit the "opportunistic strategy" of Winemiller and Rose (1992). Opportunistic fishes are characterized as placing "a premium on early maturation, frequent reproduction over an extended spawning season, rapid larval growth, and rapid population turnover rates", and "maintain dense populations in marginal habitats (e.g. ecotones, constantly changing habitats)…(Winemiller and Rose 1992)."

Distribution, Population Dynamics, and Baseline Conditions

Distribution

Delta smelt spend most of their lives rearing in low salinity habitats of the northern estuary (Moyle et al. 1992; Sweetnam and Stevens 1993). Delta smelt can temporarily tolerate salinities as high as 19 ppt (Swanson et al. 2000) and have been collected in the field at salinities as high as 18 ppt (Baxter et al. 1999). However, most delta smelt are collected at much lower salinities-typically in the range of about 0.2 – 5.0 ppt (Sweetnam and Stevens 1993). The geographical position of these low salinity habitats varies principally as a function of freshwater flow into the estuary. Therefore, the delta smelt population's center of mass has on average been located in the western Delta during years of low freshwater flow and in Suisun Bay during years of high freshwater flow. This relationship between flow and distribution is particularly strong during the larval period (Figure 7–1), but persists throughout the first year of life (Sweetnam and Stevens 1993).

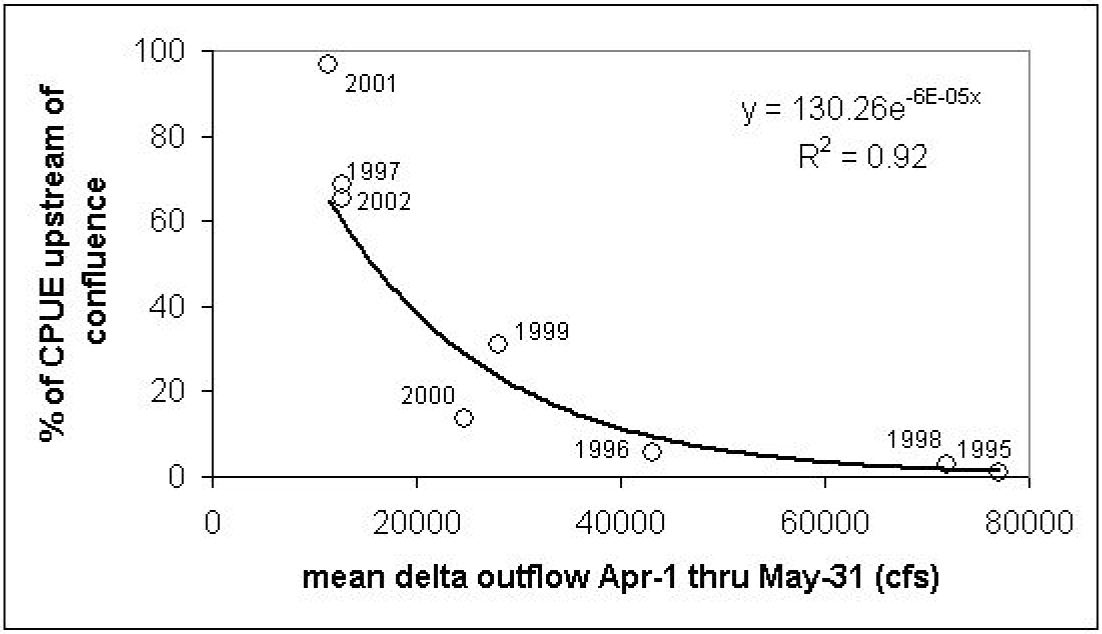

Figure 7–1 (x-axis is DAYFLOW; y-axis is first 20-mm Survey following VAMP).

Currently, the approximate spatial position of low salinity habitat in the estuary is indexed by X2, defined as the distance in km from the Golden Gate to the location of 2 ppt salinity near the bottom of the water column (Jassby et al. 1995). The longitudinal position of X2 during spring and/or early summer, which varies as a function of freshwater flow into the estuary, has been correlated with abundance or survival indices of numerous estuarine taxa (Jassby et al. 1995) including delta smelt (Kimmerer 2002). Both late larval (Bennett et al. 2002) and juvenile (Aasen 1999) delta smelt actively maintain positions in low salinity habitats by using swimming behaviors timed to tidal and diel cues.

Population Abundance Trends

The DFG Fall Midwater Trawl Survey (FMWT) provides the best long-term index of relative abundance of maturing adult delta smelt (Moyle et al. 1992; Sweetnam 1999). It has been conducted each September-December since 1967 (except 1974 and 1979). The DFG Summer Townet Survey (TNS), which has been conducted since 1959 (except 1966-68), provides an index of juvenile delta smelt abundance during June-July. These surveys cannot provide statistically defensible population abundance estimates. However, they are generally believed to provide a respectable basis for indexing long-term trends.

The TNS indices have ranged from a low of 0.9 in 1985 to a high of 62.5 in 1978 (Figure 7–2). The MWT indices have ranged from a low of 102 in 1994 to 1,653 in 1970 (Figure 7–3). Although peak high and low values have varied in time, the TNS and FMWT indices show similar time series of delta smelt relative abundance (Sweetnam 1999; Figure 7–2 and Figure 7–3).

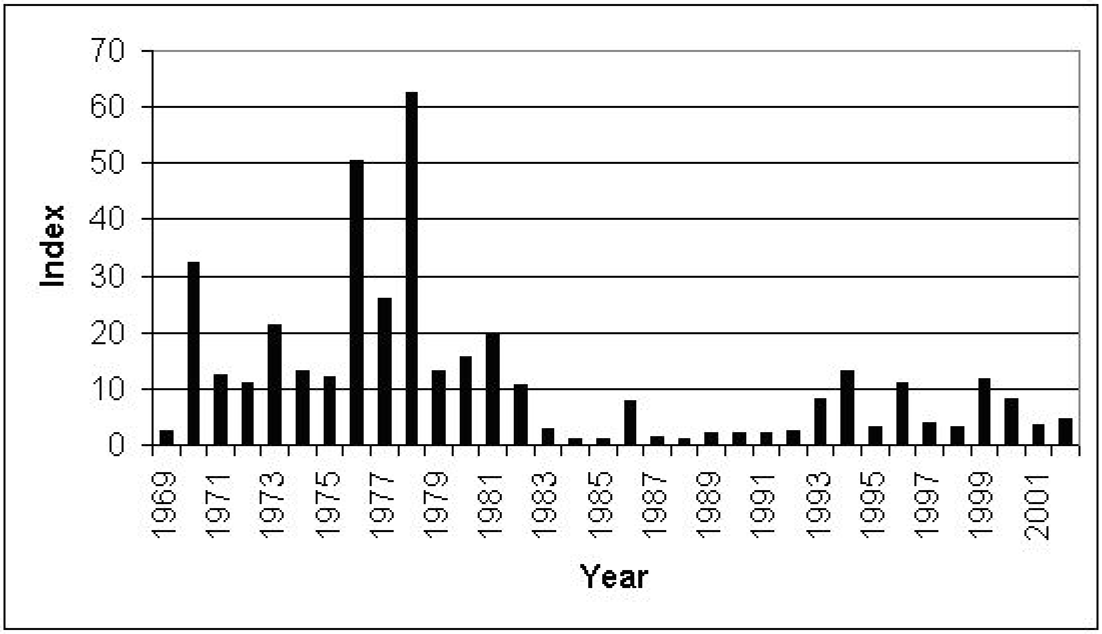

Figure 7–2 TNS indices 1969-2002.

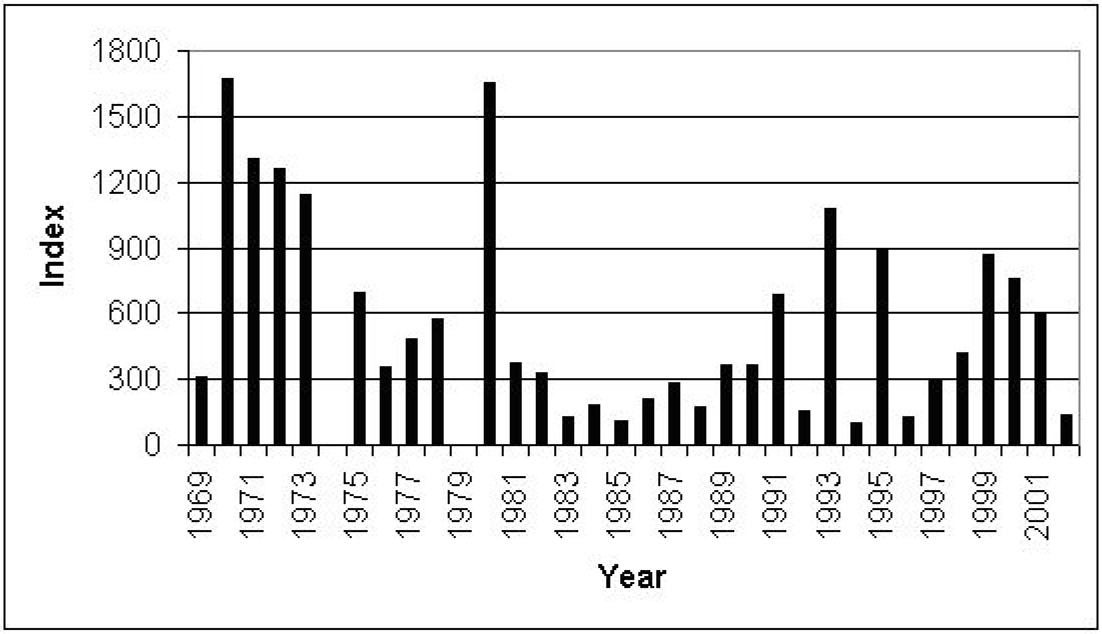

Figure 7–3 FMWT indices 1969-2002.

From 1969-81, mean delta smelt TNS and FMWT indices were 22.5 and 894 respectively. Both indices suggest the delta smelt population declined abruptly in the early 1980s (Moyle et al. 1992). From 1982-1992, mean delta smelt TNS and FMWT indices dropped to 3.2 and 272 respectively. The population has rebounded somewhat since the early 1990s (Sweetnam 1999); mean TNS and FMWT indices were 7.1 and 529 during 1993-2002.

Factors That May Influence the Abundance and Distribution of Delta Smelt

Numerous factors are hypothesized to influence the population dynamics of delta smelt (Bennett and Moyle 1996). Some of these factors (e.g., climatic influences on the physical environment) are thought to exert strong, consistent influences, while others are thought to exert more subtle influences (e.g., factors affecting growth rates), or to be important only under certain conditions (e.g., entrainment losses). Currently, most mechanistic hypotheses are based on inferences from statistical correlations of abundance and/or survival with environmental variables (see Sweetnam and Stevens 1993; Brown and Kimmerer 2001). Many of these correlative analyses are described further in appropriate sections below.

Climatic Effects on Environmental Conditions in the Estuary

Currently, X2 (which is controlled by both climate and water operations) is a strong predictor of the TNS index but curiously, the slope of the X2-TNS relationship switched sign about the time of the delta smelt decline in the early 1980s (Kimmerer 2002). During 1959-81, TNS indices were highest in years of low freshwater flow. In contrast, during 1982-2000, TNS indices were usually among the lowest recorded during years of low freshwater flow. Throughout 1959-2000, TNS indices have been comparable during years of high freshwater flow. The reason(s) for this change in the relationship of young delta smelt abundance to low spring flow conditions beginning in the early 1980s is unknown.

Currently, the number of days during spring that water temperature remained between 15º C and 20º C (59º F to 68º F), with a density-dependence term to correct for the saturating TNS-FMWT relationship (described below), is the best statistical model to explain the FMWT indices ($r^2 \approx 0.70$; $p < 0.05$; Bennett unpublished presentation at the 2003 CALFED Science Conference). The spring temperature “window” is thought to influence delta smelt abundance by influencing reproductive success - a longer period of optimal water temperatures during spring increases the number of cohorts produced. More cohorts translate into a higher probability for a strong year class. Water temperatures in the Delta and estuary are primarily affected by air temperatures and cannot be controlled by operations because water storage facilities are too far away from the Delta. Therefore, Delta water operations cannot manage water temperatures to enhance conditions for delta smelt spawning or rearing in a manner analogous to strategies used for salmonid fishes in Delta tributaries.

The number of days X2 is in Suisun Bay during spring also is weakly positively correlated with the FMWT indices (Brown and Kimmerer 2001). Hypotheses regarding potential mechanisms underlying X2-abundance relationships have been described previously (Moyle et al. 1992; Jassby et al. 1995; Bennett and Moyle 1996; Kimmerer 2002). However, it is probable that X2 position covaries with the number of days spawning temperatures remain optimal during spring, so both of these correlations may reflect the same phenomenon.

Stock-Recruitment Effects

Stock-recruitment analyses attempt to elucidate the influence of population size at a starting point on population size at another point in the future. Moyle et al. (1992) and Sweetnam and Stevens (1993) both reported that number of delta smelt spawners (indexed by the FMWT) was a poor predictor of subsequent recruits (indexed by the following year's TNS). Both linear and nonlinear Beverton-Holt models suggested that only about a quarter of the variance in delta smelt TNS abundance could be explained by the abundance of the adult spawners. This means that most of the variation in delta smelt abundance is due to environmental factors.

At present, there is an ongoing scientific debate concerning interpretation of within-year stock-recruit dynamics of delta smelt. Both the TNS and FMWT indices suggest similar long-term abundance trends for delta smelt collected in the summer and fall respectively (Figure 7–2 and Figure 7–3). However, when all of the available data are considered together, a nonlinear Beverton-Holt model describes the relationship between the TNS and FMWT data better than a linear model (Bennett unpublished; reproduced in Figure 7–4).

The standard fisheries interpretation of such a relationship is that it indicates a carrying capacity for the population - in this case during late summer of the first year of life. Phrased another way, this relationship suggests that as the number of juveniles produced increases, so does population mortality. Evidence for this density-dependent mortality was presented in Brown and Kimmerer's (2001) Figure 19. In fisheries science, density-dependence is the mechanism allowing stocks to be sustainably fished. A correlation of abundance and mortality means there is "surplus production" that can be harvested without negatively affecting a population's viability.

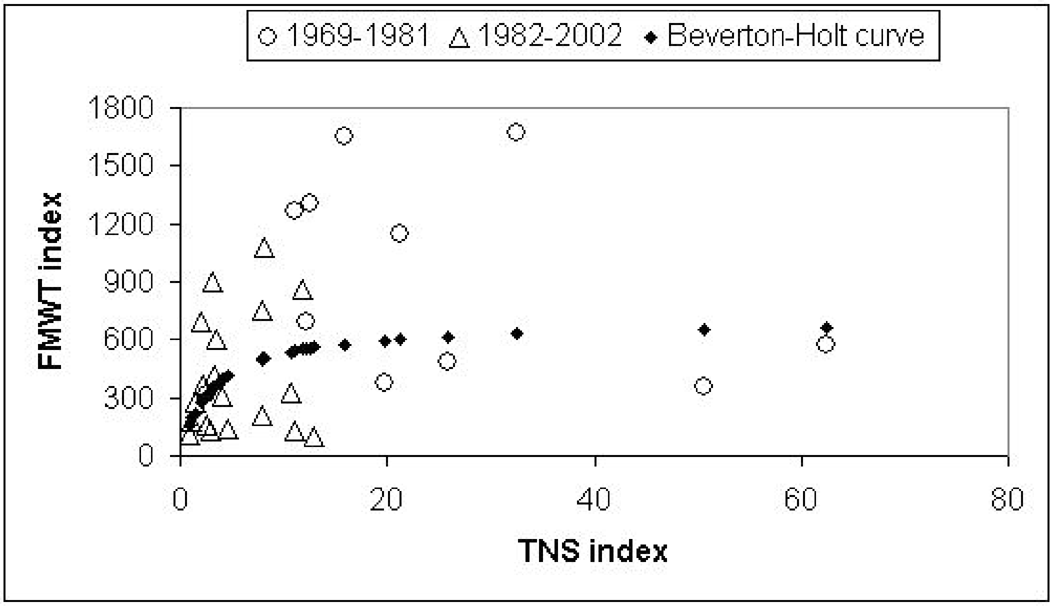

Figure 7–4 (Beverton-Holt curve was fitted to all data even though time periods are shown separately).

The evidence for density-dependent mortality in the delta smelt population has not been universally accepted by delta smelt biologists (Brown and Kimmerer 2001). One reason for this skepticism is that it may not be appropriate to pool all years of data. In Figure 7–4, the data points from the pre-decline period (1969-1981) almost all occur outside of the range of the post-decline (1982-2002) data points. Therefore, an alternative explanation of the TNS-MWT relationship is possible - the non-linearity may reflect two different relationships from two time periods with different delta smelt carrying capacities. This latter relationship suggests that summer abundance is not and has never been a statistically significant predictor of fall abundance. As stated above, which (if either) of these interpretations is correct remains a subject of debate.

One possible problem with analyses using the TNS index is that it is not considered as robust an abundance index as the FMWT (Miller 2000). However, the TNS indices are correlated with two unpublished versions of a larval abundance index derived from the DFG 20-mm Delta Smelt Survey, which has been conducted each spring-summer since 1995 (Figure 7–5).

This provides support for the density-dependent mortality hypothesis because it suggests the Townet Survey reflects the large differences in YOY delta smelt abundance that underlie the density-dependent mortality hypothesis.

Scientific debate also continues regarding the meaning of statistically significant autocorrelation in the TNS and FMWT time series. Autocorrelation means that index values within the time series are dependent in part on values that preceded them. Both sets of indices show significant autocorrelation at lag two years, meaning that successive index values are correlated with index values from two years prior. Bennett (unpublished) hypothesized the lag two-year autocorrelation was evidence for a reproductive contribution of age-two spawners, but this interpretation has not thus far been backed by strong empirical evidence. The contribution of age-two spawners to delta smelt population dynamics is currently under investigation (Brown and Kimmerer 2002).

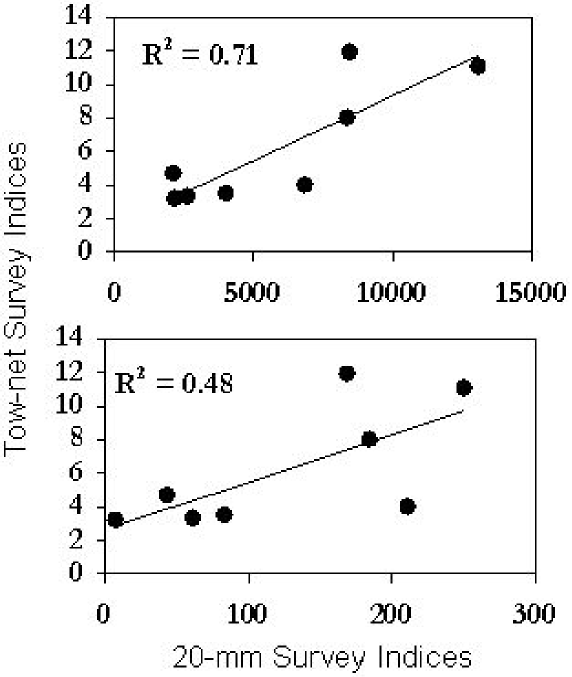

Figure 7–5 Relationships between 20-mm Survey indices and TNS indices, 1995-2002.

Reclamation and DWR (1994) were concerned about autocorrelation resulting in spurious conclusions about environmental influences on delta smelt population dynamics. Statistically speaking, autocorrelation in a time series or in the residuals from a correlative analysis of the time series and an explanatory variable can complicate interpretation because a variable may happen to covary with, but not actually influence the underlying process resulting in the autocorrelation. Recent statistical analyses have mitigated for this by using residuals from various stock-recruit relationships (Brown and Kimmerer 2001) and by testing regression residuals for significant autocorrelation.

SWP and CVP Water Export Operations

The CVP and SWP water export operations include upstream reservoirs, the DCC, the SMSCG, the North Bay Aqueduct facilities (NBA), the Contra Costa Canal facilities (CCC), CCF, the Banks Pumping Plant/Skinner Fish Facilities (hereafter SWP), the South Delta Temporary Barriers (SDTB) and the Tracy Pumping Plant/Fish Collection Facilities (hereafter CVP). The description and operation of these facilities was covered in the “Project Description” section of this Biological Assessment and will not be repeated here.

Water export operations occur primarily at SWP and CVP, with far smaller amounts of water diverted at NBA and CCC. As described in the “Project Description”, the NBA diversions have fish screens designed to FWS criteria for delta smelt protection. In addition, a larval delta smelt monitoring program occurs each spring in the sloughs near NBA. This monitoring program is used to trigger NBA export reductions when delta smelt larvae are nearby. Because the FWS deems these NBA measures to be protective of delta smelt, the NBA will not be considered further.

Direct Effects – fish entrainment into CVP and SWP facilities

The CVP and SWP export operations are most likely to impact adult delta smelt during their upstream spawning migration between December and April. A significant negative correlation between November-February delta smelt salvage and the residuals from a FMWT index at year one vs. FMWT index at year two stock-recruit relationship is evidence for an influence of adult entrainment on delta smelt population dynamics (Brown and Kimmerer 2001). Delta smelt spawn over a wide area (much of the delta and some areas downstream). In some years a fairly large proportion of the population seems to spawn in or be rapidly transported to the central and southern delta. Presumably, entrainment vulnerability is higher during those years. Unfortunately, it is not currently known what cues decisions about where to spawn.

The CVP and SWP water operations are not thought to have any impact on delta smelt eggs because they remain attached to substrates. Upon hatching, larvae are vulnerable to entrainment at all points of diversion, but are not counted in SWP or CVP fish salvage operations. Juvenile delta smelt also are vulnerable to entrainment and are counted in salvage operations once they reach 20-25 mm in length. Most juvenile salvage occurs from April-July with a peak in May-June (Nobriga et al. 2001).

Water operations impacts to the delta smelt population are greatest in dry years when a high proportion of YOY rear in the delta (Moyle et al. 1992; Reclamation and DWR 1994; Sommer et al. 1997; Figure 7–6). In recent years however, salvage also has been highest in moderately wet conditions (Nobriga et al. 2000; 2001; springs of 1996, 1999, and 2000) even though a large fraction of the population was downstream of the Sacramento-San Joaquin River confluence. Nobriga et al. (2000; 2001) attributed recent high wet year salvage to a change in operations for the VAMP that began in 1996. The VAMP provides a San Joaquin River pulse flow from mid-April to mid-May each year that probably improves rearing conditions for delta smelt larvae and also slows the entrainment of fish rearing in the delta. The high salvage events may have resulted from smelt that historically would have been entrained as larvae and therefore not counted at the fish salvage facilities growing to a salvageable size before being entrained. However, a more recent analysis summarized in Figure 7–6 provides an alternative explanation. Delta smelt salvage in 1996, 1999, and 2000 was not outside of the expected historical range when three factors are taken into account, (1) delta smelt distribution as indexed by X2 position, (2) delta smelt abundance as indexed by the TNS, and (3) the amount of water exported. Therefore, it is uncertain that operations changes for VAMP have influenced delta smelt salvage dynamics as strongly as suggested by Nobriga et al. (2000). Nonetheless, it is likely that actual entrainment has decreased since the initiation of the VAMP because of the improved transport flows it provides. In addition, "assets" from CALFED's Environmental Water Account (EWA) are often used during this time of year to further reduce delta smelt entrainment. Although the population level benefits of these actions are unknown, they appear to have been successful at keeping delta smelt salvage under the limits set by FWS (1993) (Brown and Kimmerer 2002).

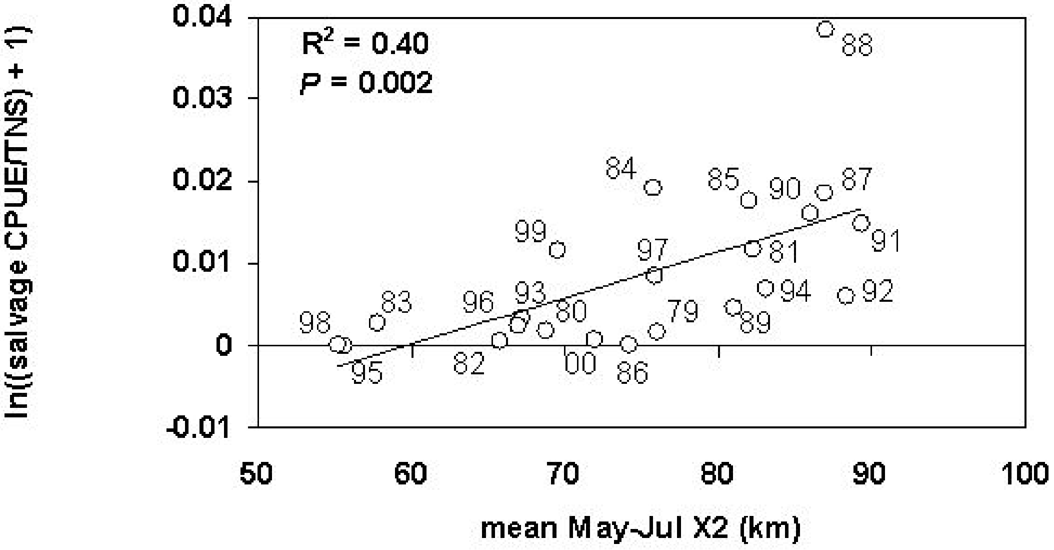

Figure 7–6 Water operations impacts to the delta smelt population.

Another possible effect on delta smelt entrainment is the SDTB. The SDTB are put in place during spring and removed again each fall (see the "Project Description" section of this Biological Assessment for more detail). Computer simulations have shown that placement of the barriers changes south delta hydrodynamics, increasing central delta flows toward the export facilities (DWR 2000). When delta smelt occur in areas influenced by the barriers, entrainment losses could increase.

Several significant correlations between delta smelt abundance and survival indices and both export and salvage variables have been recently reported (Brown and Kimmerer 2001). It should be noted that Bennett (Table 1 in Brown and Kimmerer 2001) performed 48 separate correlation analyses that included either delta smelt salvage or SWP/CVP south delta exports as explanatory variables. Of the 48 tests, only six produced a statistically significant result. Further, among the significant correlations, at least two of them are unlikely to have biological meaning because there was a mismatch between when the take was implied by the explanatory variable and when delta smelt abundance or survival was measured. For instance, a significant ($p = 0.04$) negative correlation was reported between July-October exports and the TNS abundance index. The TNS index is always set for delta smelt during late June or July, so it is unclear how exports that occurred mostly after the index was set could have affected the index values. There also was a highly significant ($p = 0.004$) negative correlation between the residuals from a MWT-TNS stock-recruit relationship and July-October exports. Briefly, this analysis suggests that exports during the summer and early fall negatively influence springtime survival. It is not readily clear how this could be possible. It is very likely that with so many correlations in the matrix, some spurious ones were generated. It should be noted that although many separate analyses were performed, two significant correlations invoking March-June export and salvage may provide evidence of negative influences of springtime water operations on delta smelt. Combined CVP/SWP exports during March-June explained a significant amount of the variation ($p = 0.046$) in the MWT-TNS stock-recruit residuals described above. In addition, March-June delta smelt salvage was significantly ($p = 0.03$) positively correlated with an index of egg-adult mortality.

At present, no demonstrable statistical relationships between delta smelt losses to water export operations and delta smelt abundance have been published in a peer-reviewed forum. It should also be noted that scientists are currently attempting to increase the sophistication of operations-related explanatory variables to test hypotheses about water diversion impacts on the delta smelt population. These new variables will combine particle tracking model results with surveys of delta smelt distribution to estimate the proportion of the population vulnerable given its distribution in the estuary and the prevailing hydrodynamic conditions in the delta. The simplest compound variable proposed is the export to inflow ratio (E/I). The Interagency Ecological Program (IEP) for the San Francisco Estuary has currently funded a particle tracking model study to examine the appropriateness of the E/I and alternatives to it for characterizing entrainment vulnerability. Unfortunately, preliminary results from this work will not be available until 2004.

Indirect Effects

By directly influencing delta smelt distribution, freshwater flow ultimately controls the sources and temporal persistence of mortality factors the population is exposed to (Bennett and Moyle 1996). Because the amount of freshwater entering the estuary is often controlled by CVP and SWP water operations, water operations may play indirect roles in delta smelt mortality through influences on population distribution. Examples of indirect effects include increased exposure of the delta smelt population to predators (Turner and Kelley 1966) or agricultural diversions (Nobriga et al. in press). However, the significance of indirect effects of CVP and SWP operations on delta smelt population dynamics is unknown.

Changes to the Food Web of the Upper Estuary

The unintentional introduction of the clam *Potamocorbula amurensis* in 1986 resulted in dramatic declines in, and upstream shifts in the abundance maxima of, phytoplankton (Alpine and Cloern 1992; Lehman 2000; Jassby et al. 2002) and zooplankton (Kimmerer et al. 1994; Kimmerer and Orsi 1996; Orsi and Mecum 1996). The *P. amurensis* introduction exacerbated long-term declines in lower food web productivity already occurring before its introduction. This has been considered potentially detrimental to delta smelt because it may represent a decrease in food availability. In addition to the declines, numerous introductions of exotic zooplankton also have occurred. It is not known whether changes in zooplankton species composition, particularly spring-summer copepods have had any positive or negative influence on delta smelt population dynamics.

Food limitation can impact the survival of larval fish directly through starvation (Hunter 1981) or indirectly by reducing growth rate (Betsill and Van den Avyle 1997), which results in higher predation mortality (Letcher et al. 1996). Food limitation primarily affects post-larval fishes via the latter mechanism (Houde 1987). Larval delta smelt feeding success varies interannually in part due to variation in copepod abundance (Nobriga 2002). This variation is most pronounced near the time of first-feeding. This means that interannual variation in starvation mortality is likely because these small larvae have limited reserves on which to survive. Despite the well-documented declines in zooplankton abundance following the *P. amurensis* invasion (Kimmerer and Orsi 1996), catastrophic changes in larval delta smelt survival attributable to *P. amurensis* impacts on the food web have not been supported by data analysis. Kimmerer (2002) examined changes in species relationships to X2 and found that delta smelt TNS abundance relative to X2 changed well before *P. amurensis* invaded and did not change again after the invasion. Therefore, it does not appear that larval delta smelt starvation mortality has changed since *P. amurensis* invaded.

It is possible that FMWT indices have remained lower than 1970s levels after the return of wet weather in the mid to late 1990s because food web alterations reduced the system carrying capacity for delta smelt. Current research is focusing on subtle influences of feeding success on survival or mortality (Brown and Kimmerer 2002). Sweetnam (1999) reported that the mean size of delta smelt collected in the FMWT had decreased significantly since the early 1990s. More recently, Bennett (unpublished) has documented individual variation in liver glycogen levels among delta smelt, suggesting some juvenile and adult individuals are food limited at times. To date no connection has been made between feeding success or growth and survival.

Changes in Predation Pressure

Predator-prey dynamics in the San Francisco Estuary are poorly understood, but are currently receiving considerable research attention by the IEP and CALFED. Studies during the early 1960s found delta smelt were an occasional prey fish for striped bass, black crappie and white catfish (Turner and Kelley 1966). This, coupled with the substantial decline in striped bass abundance has been taken as evidence that delta smelt are not very vulnerable to predation (Sweetnam and Stevens 1993). In recent years, it has become clear that the prey choices of piscivorous fishes switch as the relative abundances of species in the prey field change (Buckel et al. 1999). Even in the 1960s, delta smelt was rare relative to the dominant prey fishes of striped bass (age-zero striped bass and threadfin shad) (Turner and Kelley 1966). Therefore, there should have been no expectation that delta smelt would be commonly found in stomach contents samples. Because delta smelt are still rare relative to currently common prey fishes, the same holds true today (Nobriga et al. 2003). Because of the limitations of using stomach samples, IEP researchers are attempting to model potential impacts of striped bass on delta smelt using bioenergetics and individual-based approaches.

Bennett and Moyle (1996) proposed that inland silverside may be impacting delta smelt through predation (on delta smelt eggs and/or larvae) and competition (for copepod prey). This hypothesis is supported by recent statistical analyses showing negative correlations between inland silverside abundance and delta smelt TNS indices, and two indices of egg and/or larval survival (Brown and Kimmerer 2001). The hypothesis also is consistent with the recent analysis by Kimmerer (2002) showing a change in the sign of the delta smelt X2-TNS relationship (described above) because inland silversides began to increase in abundance about the same time the relationship changed sign (Brown and Kimmerer 2001). It should be noted however that since the early 1980s, there also have been increases in other potential larval fish predators such as coded wire tagged Chinook salmon smolts released in the Delta for survival experiments (Brandes and McLain 2001) and centrarchid fishes (Nobriga and Chotkowski 2000). In addition, striped bass appear to have switched to piscivorous feeding habits at smaller sizes than they historically did following severe declines in the abundance of mysid shrimp (Feyrer et al. in press). We suspect that CWT salmon and centrarchid abundance, as well as the striped bass diet switch have covaried with the increase in inland silverside abundance and the declines in phytoplankton and zooplankton abundance mentioned above. We caution that all assertions regarding predatory impacts on delta smelt, including inland silverside, are speculation.

Contaminants

Agricultural sources are untreated and unmeasured but probably vary widely in concentration and composition in time and space (Kuivila and Foe 1995). There have been strong shifts in recent years toward newer types of contaminants and various regulatory efforts to reduce contaminant impacts have often generated shifts from one type of compound to another. Contaminant concentrations are often sufficient to kill invertebrates and larval cyprinids in bioassay tests. Chronic effects are largely uninvestigated for any fish in the estuary Delta smelt may suffer from contaminant effects directly in either acute or chronic forms and may also be affected by contaminant effects on populations of their prey (Kuivila and Moon 2002). However, examination of the 1999 and 2000 cohorts using COMET assays of blood cell DNA did not find a high proportion of delta smelt collected in the TNS and FMWT surveys with broken DNA. This suggests that at least in the very recent past, contaminants were not a major stressor for the delta smelt population (Brown and Kimmerer 2002).

Agricultural Water Diversion Operations

There are 2,209 agricultural diversions in the Delta and an additional 366 diversions in Suisun Marsh used for enhancement of waterfowl habitat (Herren and Kawasaki 2001). The vast majority of these diversions do not have fish screens to protect fish from entrainment. It has been recognized for many years that delta smelt are entrained in these diversions (Hallock and Van Woert 1959; Pickard et al. 1982). In the early 1980s delta smelt were the most abundant fish entrained in the Roaring River diversion in Suisun Marsh (Pickard et al. 1982), so it is possible the waterfowl diversions are detrimental. However, delta smelt may not be especially vulnerable to Delta agricultural diversions for several reasons. First, adult delta smelt move into the Delta to spawn during winter-early spring when agricultural diversion operations are at a minimum. Second, larval delta smelt occur transiently in most of the Delta. Third, Nobriga et al. (2002; in press) examined delta smelt entrainment at an agricultural diversion in Horseshoe Bend during July 2000 and 2001, when much of the YOY population was rearing within one tidal excursion of the diversion. Delta smelt entrainment was low compared to density estimates from the DFG 20 mm Delta Smelt Survey. Low entrainment was attributed to (1) offshore distribution of delta smelt, and (2) the extremely small hydrodynamic influence of the diversion relative to the channel it was in. Because Delta agricultural diversions are typically close to shore and probably take small amounts of water relative to what is in the channels they draw water from, delta smelt vulnerability may be low despite their modest swimming ability and their poor performance near simulated fish screens in laboratory settings (Swanson et al. 1998; 2002). It should be noted however that DWR screened five agricultural diversions around Sherman Island, an area consistently used by delta smelt of all life stages.

Pacific Gas & Electric Company

PG&E operates two power generation facilities within the range of delta smelt: Contra Costa Power Plant and Pittsburg Power Plant. Contra Costa Power Plant is about six miles east of the confluence of the Sacramento and San Joaquin rivers. Pittsburg Power Plant is on the south shore of Suisun Bay, in the town of Pittsburg. Each power plant has seven generating units that rely on diverted water for condenser cooling. Cooling water is diverted at a rate as high as about 1,500 cfs for the Contra Costa plant and 1,600 cfs for the Pittsburg plant, forming a thermal plume as it is discharged back into the estuary. Pumping rates are often significantly lower under normal operation. Potential impacts of the power plants fall into two categories - direct and indirect. Previous data on direct and indirect impacts of the power plants were summarized by Reclamation and DWR (1994). However, robust data analyses of population level effects of power plant operation on delta smelt and other fishes have not been performed. Briefly, the direct impact of the power plants comes from the removal of fish during diversion operations. Indirect effects stem from water temperature increases when the cooling water is returned to the estuary. Intakes at all units at both power plants employ a screening system to remove debris, but the screens allow entrainment of fish smaller than about 38 mm and impingement of larger fish.

Since the 1978–79 studies were completed, PG&E has implemented a resource management program to reduce striped bass loss. During the period of peak striped bass entrainment (May to mid-July), power generation units are operated preferentially, using fish monitoring data. This program has reduced entrainment losses of larval and juvenile striped bass by more than 75 percent (PG&E 1992a). Given its timing, this management program also may be beneficial to delta smelt. PG&E also is reportedly considering use of better fish exclusion devices, known as a gunderbooms, at their facilities which are expected to reduce entrainment to nearly zero.

Genetic Introgression with Wakasagi

Hybridization and genetic introgression are not currently thought to represent a threat to the persistence of delta smelt. Hybridization between delta smelt and wakasagi has been shown to be very low due to a more distant taxonomic relationship than was previously thought (Trenham et al. 1998).

Chapter 8 Hydrologic and Temperature Modeling with 3406 (b)(2) and EWA Analyses

The effects of proposed CVP and SWP operations on steelhead , coho salmon, delta smelt winter-run and spring-run Chinook salmon were evaluated using results from a series of monthly simulation models. The changes in operations relative to current assumptions that are expected to impact the CVP and SWP are Lewiston releases on the Trinity River (368,600-452,600 af to 368,600-815,000 af annually), the Freeport project, Level of Development, CVP/SWP Integration Agreement (100,000 af dedicated CVP Refuge Level 2 Pumping at Banks and 75,000 af of CVP releases for SWP COA requirements), the Intertie, and the South Delta Improvement Project (increase Banks pumping capacity from 6680 cfs to 8500 cfs). CALSIM II for the OCAP BA studies has the most current assumptions of the (b)(2) policy, May 2003. Studies 3 & 5 have the most current assumptions for the EWA program as agreed to October 2003.

Assumptions and methodologies for CALSIM II and the temperature conditions are described in the sections below. CALSIM II results were used in a series of temperature models that provide estimates of mean monthly temperatures at a variety of locations along CVP and SWP influenced rivers. Modeled temperatures were then compared to thermal criteria for specific life stages in the months when they would be present in the given river as the primary means of assessing potential effects of proposed CVP and SWP operations.

Hydrologic Modeling Methods

The DWR/Reclamtion Joint CALSIM II planning model was used to simulate the CVP and SWP water operations on a monthly time step from water year 1922 to 1994. CALSIM II utilizes optimization techniques to route water through a network. A linear programming (LP)/mixed integer linear programming (MILP) solver determines an optimal set of decisions for each time period given a set of weights and system constraints (DWR 2002). The physical description of the system is expressed through a user-interface with tables outlining the system characteristics. The priority weights and basic constraints are also entered in the system tables. The programming language used, Water Resources Engineering Simulation Language (WRESL), serves as an interface between the user and the LP/MILP solver, time-series database, and relational database. Specialized operating criteria are expressed in WRESL (DWR 2000).

The hydrology in CALSIM II was developed jointly by DWR and Reclamation. Water diversion requirements (demands), stream accretions and depletions, rim basin inflows, irrigation efficiency, return flows, non-recoverable losses, and groundwater operation are components that make up the hydrology used in CALSIM II. Sacramento Valley and tributary rim basin hydrologies are developed using a process designed to adjust the historical sequence of monthly stream flows to represent a sequence of flows at a future level of development. Adjustments to historic water supplies are determined by imposing future level land use on historical meteorological and hydrologic conditions. San Joaquin River basin hydrology is developed using fixed annual demands and regression analysis to develop accretions and depletions. The resulting hydrology represents the water supply available from Central Valley streams to the CVP and SWP at a future level of development (DWR 2002).

CALSIM II uses DWR's Artificial Neural Network (ANN) model to simulate the flow-salinity relationships for the Delta. The ANN model correlates DSM2 model-generated salinity at key locations in the Delta with Delta inflows, Delta exports, and Delta Cross Channel operations. The ANN flow-salinity model estimates electrical conductivity at the following four locations for the purpose of modeling Delta water quality standards: Old River at Rock Slough, San Joaquin River at Jersey Point, Sacramento River at Emmaton, and Sacramento River at Collinsville. In its estimates, the ANN model considers antecedent conditions up to 148 days, and considers a "carriage-water" type of effect associated with Delta exports (DWR 2002).

CALSIM II uses logic for determining deliveries to north-of-Delta, and south-of-Delta CVP and SWP contractors. The delivery logic uses runoff forecast information, which incorporates uncertainty and standardized rule curves (i.e. Water Supply Index versus Demand Index Curve). The rule curves relate forecast water supplies to deliverable "demand", and then use deliverable "demand" to assign subsequent delivery levels to estimate the water available for delivery and carryover storage. Updates of delivery levels occur monthly from January 1 through May 1 for the SWP and March 1 through May 1 for the CVP as water supply parameters (i.e. runoff forecasts) become more certain. The south-of Delta SWP delivery is determined based upon water supply parameters and operational constraints. The CVP system wide delivery and south-of-Delta delivery are determined similarly upon water supply parameters and operational constraints with specific consideration for export constraints (DWR 2002).

CVPIA 3406 (b)(2) and Environmental Water Account Modeling

CALSIM II dynamically models CVPIA 3406(b)(2) and the Environmental Water Account (EWA). CVPIA 3406(b)(2) accounting procedures in CALSIM II are based on system conditions under operations associated with SWRCB D-1485 and D-1641 regulatory requirements (DWR 2002). Similarly, the operating guidelines for selection of actions and allocation of assets under the EWA are based on system conditions under operations associated with a Regulatory Baseline as defined by the CALFED ROD, which includes SWRCB D-1641 and CVPIA 3406 (b)(2) among other elements. Given the task of simulating dynamic EWA operations, and the reality of interdependent operational baselines embedded in EWA's Regulatory Baseline, a modeling analysis has been developed to dynamically integrate five operational baselines for each water year of the hydrologic sequence. These five steps constitute a position analysis with five cases linked to different regulatory regimes: D1485, D1641, B2, JPOD, and EWA. The results from the final case of the position analysis (EWA) is accepted as the end-of-year system state, and serve as the initial conditions for each of the five cases in the following year's position analysis. The general modeling procedure is outlined below, and shown on Figure 8-1:

1. Run the D1641 simulation for Oct-Sep of the current water year.
2. Run the D1485 simulation for Oct-Sep of the current water year and compute annual water costs for implementing D1641 operations relative to D1485 operations (i.e. Water Quality Control Plan costs).
3. Run the B2 simulation for Oct-Sep of the current water year, dynamically accounting for the (b)(2) account balance with knowledge of annual Water Quality Control Plan costs, and implementing fish protection actions according to preferences defined for OCAP.

4. Run the JPOD simulation for Oct-Sep of the current water year, repeating B2 actions from Step 3, assessment of Joint Point of Diversion (JPOD) capacity, and simulated CVP usage of 50% of JPOD capacity.
5. Run the EWA simulation for Oct-Sep of the current water year, repeating B2 actions from Step 3, repeating CVP usage of 50% of JPOD capacity from Step 4, taking EWA actions, comparing Step 4 and 5 results to assess EWA debt, and managing EWA debt through acquisition and application of assets (e.g., SWP transfer or 50% of B2 gains to EWA, EWA usage of 50% of JPOD capacity, fixed purchases north and south of Delta).
6. Accept the state of the system from end-of-September in Step 5 as the initial condition for the following year's position analysis cases (i.e. D1641, D1485, B2, JPOD, and EWA).

Repeat steps 1-6 for all years of the period of record.

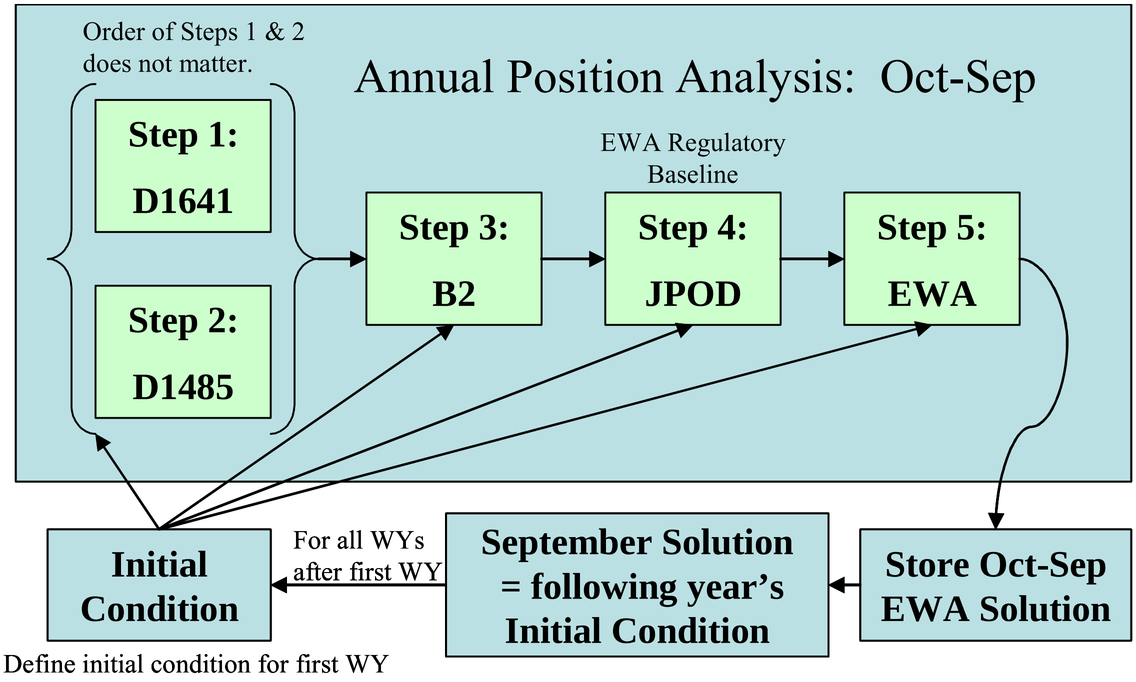

Figure 8-1. CALSIM II procedure to simulate EWA operations. (Note: Step 4 is named "JPOD" in the OCAP Today Studies and "SDIP" in the OCAP Future Studies.)

CVPIA (b)(2)

According to the 1992 Central Valley Project Improvement Act (CVPIA) the Central Valley Project must "dedicate and manage annually 800,000 acre-feet of Central Valley Project yield for the primary purpose of implementing the fish, wildlife, and habitat restoration purposes and measures authorized by this title; to assist the State of California in its efforts to protect the waters of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary; and to help to meet such obligations as may be legally imposed upon the Central Valley Project under State or Federal law following the date of enactment of this title, including but not limited to additional obligations under the Federal Endangered Species Act." This dedicated and managed water or (b)(2) water, as it is called, is water FWS in consultation with Reclamation and other agencies (See the Chapter 2 describtion of B2IT in Adaptive Management) has at its disposal to use to meet the CVP's Water Quality Control Plan (WQCP) obligations and meet any reqirements imposed after 1992. CVPIA 3406 (b)(2) water may be used to augment river flows and also to curtail pumping in the Delta to supplement the WQCP requirements.

To simulate the 3406 (b)(2) accounting the model uses metrics calculated in the (b)(2) simulation. The metrics measure the flow increases and export decreases from D1485 to D1641 WQCP Costs, and from D1485 to (b)(2), total (b)(2) costs. The following assumptions were used to model the May 2003 3406 (b)(2) Dept. of the Interior decision.

- Allocation of (b)(2) water is 800,000 af/YR, 700,000 af/YR in 40-30-30 Dry Years, and 600,000 af/YR in 40-30-30 Critical years
- Upstream flow metrics are calculated at Clear Creek, Keswick, Nimbus and Goodwin Reservoirs where (b)(2) water can be used to increase flow for fishery purposes. The assumptions used in CALSIM II for taking an upstream action at one of the previously mentioned reservoirs are:
  - Oct-Jan
    - Clear Creek Releases: Action is on if Trinity Beginning of Month Storage > 600,000 af.
    - Keswick Releases: Action is on if Shasta Beginning-of-Month Storage > 1,900,000 af.
    - Nimbus Releases: Action is on if Folsom Beginning-of-Month Storage > 300,000 af.
    - For all releases if the 200,000 af target is projected to be violated the model will try to reduce the magnitude of the actions in December and/or January.
  - Feb-Sep
    - Clear Creek Releases: Action is on if Trinity Beginning of Month Storage > 600,000 af.
    - Keswick Releases: Action is on if Shasta Beginning-of-Month Storage > 1,900,000 af and if remaining b2 account > projected coming WQCP costs.
    - Nimbus Releases: Action is on if Folsom Beginning-of-Month Storage > 300,000 af and if remaining b2 account > projected coming WQCP costs.
- The export metric is the change in total CVP pumping (Tracy + CVP Banks) from the base case (D1485). Assumptions used in CALSIM II for taking a delta action are:
  - Winter Actions (December thorugh February) and Pre-VAMP (April Shoulder) actions are off

  - VAMP Actions: Always taken and done at a 2:1 ratio if non-VAMP Vernalis flows are greater than 8600 cfs
  - May Shoulder: Action turned on if the remaining (b)(2) is greater than or equal to the discounted remaining WQCP cost + anticipated Clear Creek cost (25,000 af). DISCOUNT = If the annual WQCP cost > 500,000 af, the difference is subtracted from the remaining WQCP cost.
  - June Ramping: Action turned on if the remaining (b)(2) is greater than or equal to the discounted remaining WQCP cost + anticipated Clear Creek cost (20,000 af).
  - Both May Shoulder and June Ramping are further restricted to stay within the remaining (b)(2)account – remaining WQCP costs.

Environmental Water Account

Three Management Agencies (i.e. FWS, NOAA Fisheries and DFG) and two Project Agencies (i.e. Reclamation and DWR) share responsibility in the implementation and management of the Environmental Water Account (EWA). The Management Agencies manage the EWA assets and exercise the biological judgment to recommend operation changes in the CVP and SWP that are beneficial to the Bay-Delta system. Together, the Management and Project Agencies form an EWA Team, or EWAT.

The objective of simulating EWA for OCAP modeling is to represent the functionality of the program in three ways: as it was designed in the CALFED ROD, as it's been implemented by EWAT during WY2001-2003, and as it's foreseen to be implemented in coming years by CALFED Operations. The EWA representation in CALSIM II simulates is not a prescription for operations; it is only a representation of the following EWA operating functions:

- implementing actions at projects' export facilities
- assessing debt caused by these actions, including year-to-year carryover debt
- acquiring assets for managing debt
- storing assets in San Luis, and transferring (or losing) stored assets to the projects due to projects' operations to fill San Luis during winter months
- spending assets to compensate SOD debt
- tracking and mitigating the effects of NOD debt and NOD backed-up water
- spilling carryover debt at SWP San Luis
- wheeling assets from NOD to SOD for storage or usage
- accounting system re-operation effects due to EWA operations

For the OCAP modeling, action definitions reflect monthly to seasonal aggregate actions implemented by EWAT from WY2001-2003 and in the foreseeable future. Assets in OCAP modeling reflect a subset of actions that CALSIM II can simulate. Several types of assets were not simulated in CALSIM II and consequently the simulated actions have been modulated to be in balance with their absence. Accounting for these additional assets is discussed in the EWA OCAP Modeling Chapter.

The following actions are simulated in the OCAP modeling for EWA fishery purposes:

- Winter-period Export Reduction (December – February):

  Definition: "Asset spending goal" where a constraint is imposed on total Delta exports that equals 50,000 af less per month relative to the amount of export under the Regulatory Baseline. This is modeled as a monthly action and conceptually represents EWAT implementation of multiple several-day actions during the month.

  Trigger: All years for December and January; also in February if the hydrologic year-type is assessed to be Above Normal and Wet according to the Sac 40-30-30 Index.

- VAMP-period Export Reduction (April 15 – May 15):

  Definition: Reduce exports to a target-restriction level during the VAMP-period, regardless of the export level under the Regulatory Baseline; target depends on San Joaquin River flow conditions.

  Trigger: All years. Taking action during the VAMP period has been a EWAT high priority in 2001-2003, and is therefore modeled as a high priority.

- Pre-VAMP "Shoulder-period" Export Reduction (April 1 – April 15):

  Definition: Extend the target-restriction level applied for VAMP-period into the April 1 – April 15 period.

  Trigger: Never. It was not simulated to occur based on actions implemented by EWAT from WY2001-2003 and in the foreseeable future.

- Post-VAMP "Shoulder-period" Export Reduction (May 16 – May 31):

  Definition: Extend the target-restriction level applied for VAMP-period into the May 16 – May 31 period.

  Trigger: In any May if collateral exceeds debt at the start of May.

- June Export Reduction:

  Definition: Steadily relieve the constraint on exports from the target-restriction level of the Post-VAMP period to the June Export-to-Inflow constraint level. Complete this steady relief on constraint during a 7-day period.

  Trigger: If the Post-VAMP "Shoulder-period" Export Reduction was implemented and if collateral exceeds debt at the start of June.

The following assets are included in the OCAP modeling:

- Allowance for Carryover Debt (Replacing "One-Time Acquisition of Stored-Water Equivalent" defined in the CALFED ROD)
- Water Purchases, North and South of Delta
- 50% Gain of SWP Pumping of (b)(2)/ERP Upstream Releases
- 50% Dedication of SWP Excess Pumping Capacity (i.e. JPOD)
- Jul-Sep Dedicated Export Capacity at Banks

The role of these fixed and operational assets in mitigating the effects of EWA actions is dependent upon operational conditions and is ascertained dynamically during the simulation. On the issue of the one-time acquisition of stored-water equivalent, the CALFED ROD specified the acquisition of initial and annual assets dedicated to the EWA, and EWA was to be guaranteed 200,000 acre-feet of stored water south of Delta. This SOD groundwater bank was excluded in the CALSIM II studies for OCAP given its absence in actual EWAT operations from WY2001-2003. Since development of this asset has been delayeed, EWAT developed a replacement asset (i.e. allowance for carryover debt and subsequent debt spilling) and operational procedures for managing this asset. OCAP modeling reflects EWAT guidelines for carrying over and spilling debt in the case of debt situated at SWP San Luis.

Several potential assets are excluded from the OCAP modeling with CALSIM II, and are addressed in CALSIM II post-processing through the EWA OCAP Modeling Chapter:

- Export/Inflow Ratio Flexibility
- Source-Shifting Agreements
- Exchanges

The impacts of actions on system operations is assessed in the OCAP modeling as EWA debt. Debt is defined as a reduction in project deliveries and/or storage relative to the EWA Regulatory Baseline (i.e. results from Step 4). CALSIM II tracks three general types of EWA debt:

- Deliveries to contractors south of Delta (SOD)
- Storage levels SOD
- Storage levels north of Delta (NOD)

Occurrence of SOD deliveries debt and subsequent failure to immediately payback this debt is an indicator that the simulated EWA program's assets are not in balance with the assumed actions. Occurrence of storage debt does not require immediate debt management.

Carried-over SOD storage debt is simulated to be managed through either: (1) direct dedication of assets, or (2) debt spilling. Dedication of assets involves transferring the accumulated purchases and variable assets from EWA San Luis into the projects' shares of San Luis to repay impacts caused by this year's actions and/or carried-over impacts from last year. The second tool, debt spilling, involves elimination of carried-over SOD debt at SWP San Luis given that several conditions were met at the end of the previous month (as described by EWAT).

- there was remaining capacity at Banks,
- there was surplus water in the Delta that could have been exported,
- the summation of end-of-month debt and stored water at SWP San Luis exceeded the summation of storage capacity and the "Article 21 deficit" (Figure 8-2); an Article 21 deficit represents demand minus what was delivered.
- there was carried-over debt left to be spilled at SWP San Luis.

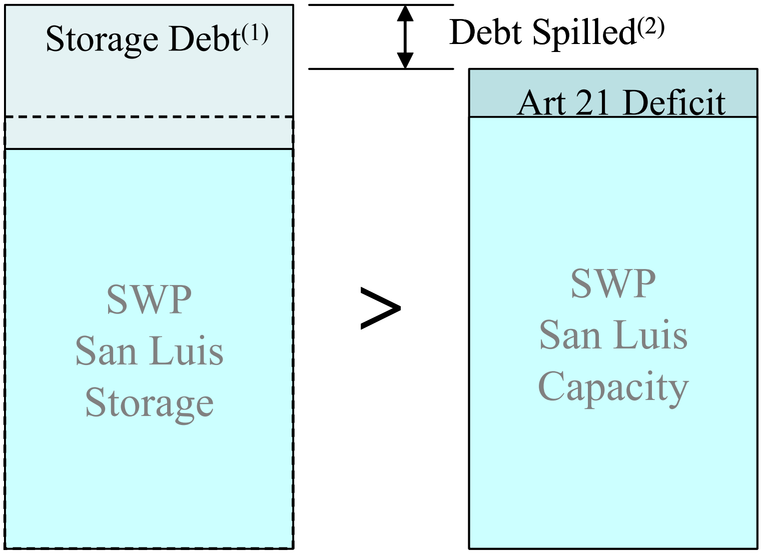

Figure 8-2 Conditions for spilling carried-over debt at SWP San Luis in CALSIM II. Notes

1. Since the Regulatory Baseline cannot exceed SWP San Luis Capacity (i.e. the dashed line in Stack A), then the debt above this capacity line must be carried-over debt. Therefore, this spill tool will only be applicable to erasing carried-over debt and will not affect "new" debt conditions due to this year's actions.
2. Spill amount is limited by the availability of excess capacity at Banks and surplus water in the Delta

CALSIM II Modeling Studies

The two Benchmark Studies (2001 and 2020 LOD) have been developed by staff from both DWR and Reclamation for the purpose of creating a CALSIM II study that is to be used as a basis in comparing project alternatives. From the Benchmark Studies five studies have been developed to evaluate the impacts of changes in operations for the Trinity River, Freeport Project, Intertie, Level of Development, CVP/SWP Project Integrations and SDIP. Table 8-1 shows the five studies developed for OCAP and how the previously mentioned changes in operations are incorporated into them.

Table 8-1. Summary of Assumptions in the OCAP CALSIM II runs

	Trinity Min Flows	CVPIA 3406 (b)(2)	Level of Development	EWA	SDIP	CVP/SWP Integration	Freeport	Intertie
Study 1 D1641 with b(2) (1997)	340,000 af/yr	May '03	2001					
Study 2 Today b(2)	368,600-452,600 af/yr	Same as above	Same as above					
Study 3 Today EWA	Same as above	Same as above	Same as above	X				
Study 4 Future SDIP	368,600-815,000 af/yr	Same as above	2020		X	X	X	X
Study 5 Future EWA	Same as above	Same as above	Same as above	X	X	X	X	X

Study 1 is used evaluate how the operations and regulations have been impacted since the Delta Smelt Biological Opinion with (b)(2) operations acting as a surrogate for the 2:1 VAMP restrictions. Studies 2 and 4 are to evaluate the Tier 1 environmental regulatory effects that are mandated by law. Studies 3 and 5 were run to evaluate the EWA costs as the modeling can best simulate the current actions taken by the EWA program. The current EWA program may be regarded as representative of foreseeable future EWA operations. However, it is noted that the EWA has not been finalized with a long-term plan of operations.

Table 8-2 shows the detailed assumptions of the five studies. The table illustrates specific operational changes regarding regulatory and operational rules. It also details assumptions within the major changes to operations in Table 8-1. Table 8-3 and Table 8-4 show the changes in demand from the Today to the Future studies for American River system for diversion dynamically modeled in CALSIM II.

Table 8-2 Assumptions for the Base and Future Studies

	Study 1	Study 2	Study 3	Study 4	Study 5
	D1641 w/ CVPIA 3406 (b)(2) (1997)	**Today CVPIA 3406 (b)(2)**	**Today CVPIA 3406 (b)(2) with EWA**	**Future 3406 (b)(2) and SDIP**	**Future 3406 (b)(2) and SDIP with EWA**
Period of Simulation	73 years (1922-1994)	Same	Same	Same	Same
HYDROLOGY					
Level of Development (Land Use)	2001 Level, DWR Bulletin 160-98[14]	Same as Study 1	Same as Study 1	2020 Level, DWR Bulletin 160-98	Same as Study 4
Demands					
North of Delta (exc American R)					
CVP	Land Use based, limited by Full Contract	Same	Same	Same	Same
SWP (FRSA)	Land Use based, limited by Full Contract	Same	Same	Same	Same
Non-Project	Land Use based	Same	Same	Same	Same
CVP Refuges	Firm Level 2	Same	Same	Same	Same
American River Basin					

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[14] 2000 Level of Development defined by linearly interpolated values from the 1995 Level of Development and 2020 Level of Development from DWR Bulletin 160-98

	Study 1	Study 2	Study 3	Study 4	Study 5
Water rights	2001[15]	Same as Study 1	Same as Study 1	2020, as projected by Water Forum Analysis[16]	Same as Study 4
CVP	2001[17]	Same as Study 1	Same as Study 1	2020, as projected by Water Forum Analysis [18]	Same as Study 4
San Joaquin River Basin					
Friant Unit	Regression of historical	Same	Same	Same	Same
Lower Basin	Fixed annual demands	Same	Same	Same	Same
Stanslaus River Basin	New Melones Interim Operations Plan	Same	Same	Same	Same
South of Delta					
CVP	Full Contract	Same	Same	Same	Same
CCWD	124,000 af/YR[19]	Same as Study 1	Same as Study 1	158,000 af/YR[20]	Same as Study 4

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[15] Presented in attached

Table 8-3 2001 American River Demand Assumptions (Note that cuts are not made predicated on Inflow to Folsom for the 2001 **Demands)**

[16] Presented in attached Table 8-4 2020 American River Demand Assumptions

[17] Same as footnote 2

[18] Same as footnote 3 but modified with PCWA 35 TAF CVP contract supply diverted at the new American River PCWA Pump Station

[19] Delta diversions include operations of Los Vaqueros Reservoir and represents average annual diversion

	Study 1	Study 2	Study 3	Study 4	Study 5
SWP (w/ North Bay Aqueduct)	3.0-4.1 MAF/YR	Same as Study 1	Same as Study 1	3.3-4.1 MAF/YR	Same as Study 4
SWP Article 21 Demand	MWDSC up to 50,000 af/month, Dec-Mar, others up to 84,000 af/month	Same	Same	Same	Same
FACILITIES					
Freeport Regional Water Project	None	Same as Study 1	Same as Study 1	Included[21]	Same as Study 4
Banks Pumping Capacity	6680 cfs	Same as Study 1	Same as Study 1	8500 cfs	Same as Study 4
Tracy Pumping Capacity	4200 cfs + deliveries upstream of DMC constriction	Same as Study 1	Same as Study 1	4600 cfs w/ intertie	Same as Study 4
REGULATORY STANDARDS					
Trinity River					
Minimum Flow below Lewiston Dam	340,000 af/YR	368,600-452,600 af/YR	Same as Study 2	Trinity EIS Preferred Alternative (368,600-815,000 af/YR)	Same as Study 4
Trinity Reservoir End-of-September Minimum Storage	Trinity export-to-inflowS Preferred Alternative (600,000 af as able)	Same	Same	Same	Same

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[20] Same as footnote 6

[21] Includes modified EBMUD operations of the Mokelumne River

	Study 1	Study 2	Study 3	Study 4	Study 5
Clear Creek					
Minimum Flow below Whiskeytown Dam	Downstream water rights, 1963 USBR Proposal to USFWS and NPS, and USFWS use of CVPIA 3406(b)(2) water	Same	Same	Same	Same
Upper Sacramento River					
Shasta Lake End-of-September Minimum Storage	SWRCB WR 1993 Winter-run Biological Opinion (1.9 Million af)	Same	Same	Same	Same
Minimum Flow below Keswick Dam	Flows for SWRCB WR 90-5 and 1993 Winter-run Biological Opinion temperature control, and USFWS use of CVPIA 3406(b)(2) water	Same	Same	Same	Same
Feather River					
Minimum Flow below Thermalito Diversion Dam	1983 DWR, DFG Agreement (600 CFS)	Same	Same	Same	Same
Minimum Flow below Thermalito Afterbay outlet	1983 DWR, DFG Agreement (1000 – 1700 CFS)	Same	Same	Same	Same
American River					
Minimum Flow below Nimbus Dam	SWRCB D-893 (see accompanying Operations Criteria), and USFWS use of	Same	Same	Same	Same

	Study 1	Study 2	Study 3	Study 4	Study 5
	CVPIA 3406(b)(2) water				
Minimum Flow at H Street Bridge	SWRCB D-893	Same	Same	Same	Same
Lower Sacramento River					
Minimum Flow near Rio Vista	SWRCB D-1641	Same	Same	Same	Same
Mokelumne River					
Minimum Flow below Camanche Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (100 – 325 CFS)	Same	Same	Same	Same
Minimum Flow below Woodbridge Diversion Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (25 – 300 CFS)	Same	Same	Same	Same
Stanislaus River					
Minimum Flow below Goodwin Dam	1987 USBR, DFG agreement , and USFWS use of CVPIA 3406(b)(2) water	Same	Same	Same	Same
Minimum Dissolved Oxygen	SWRCB D-1422	Same	Same	Same	Same
Merced River					
Minimum Flow below Crocker-Huffman Diversion Dam	Davis-Grunsky (180 – 220 CFS, Nov – Mar), and	Same	Same	Same	Same

	Study 1	Study 2	Study 3	Study 4	Study 5
	Cowell Agreement				
Minimum Flow at Shaffer Bridge	FERC 2179 (25 – 100 CFS)	Same	Same	Same	Same
Tuolumne River					
Minimum Flow at Lagrange Bridge	FERC 2299-024, 1995 (Settlement Agreement) (94,000 – 301,000 af/YR)	Same	Same	Same	Same
San Joaquin River					
Maximum Salinity near Vernalis	SWRCB D-1641	Same	Same	Same	Same
Minimum Flow near Vernalis	SWRCB D-1641, and Vernalis Adaptive Management Program per San Joaquin River Agreement	Same	Same	Same	Same
Sacrameto River-San Joaquin River Delta					
Delta Outflow Index (Flow and Salinity)	SWRCB D-1641	Same	Same	Same	Same
Delta Cross Channel Gate Operation	SWRCB D-1641	Same	Same	Same	Same
Delta Exports	SWRCB D-1641, USFWS use of CVPIA 3406(b)(2) water	Same as Study 1	Same as Study 1 with CALFED Fisheries Agencies use of EWA assets	Same as Study 1	Same as Study 3

	Study 1	Study 2	Study 3	Study 4	Study 5
OPERATIONS CRITERIA					
Subsystem					
Upper Sacramento River					
Flow Objective for Navigation (Wilkins Slough)	3,250 – 5,000 CFS based on Lake Shasta storage condition	Same	Same	Same	Same
American River					
Folsom Dam Flood Control	SAFCA, Interim-Reoperation of Folsom Dam, Variable 400/670 (without outlet modifications)	Same	Same	Same	Same
Flow below Nimbus Dam	Operations criteria corresponding to SWRCB D-893 required minimum flow	Same	Same	Same	Same
Sacramento Water Forum Mitigation Water	None	Same as Study 1	Same as Study 1	Sacramento Water Forum (up to 47,000 af/YR in dry years)[22]	Same as Study 4
Feather River					
Flow at Mouth	Maintain the DFG/DWR flow target above Verona or 2800 cfs for Apr – Sep dependent on Oroville inflow and FRSA allocation	Same	Same	Same	Same

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[22] This is implemented only in the PCWA Middle Fork Project releases used in defining the CALSIM II inflows to Folsom Lake

	Study 1	Study 2	Study 3	Study 4	Study 5
Stanislaus River					
Flow below Goodwin Dam	1997 New Melones Interim Operations Plan	Same	Same	Same	Same
San Joaquin River					
Flow near Vernalis	San Joaquin River Agreement in support of the Vernalis Adaptive Management Program	Same	Same	Same	Same
System-wide					
CVP Water Allocation					
CVP Settlement and Exchange	100% (75% in Shasta Critical years)	Same	Same	Same	Same
CVP Refuges	100% (75% in Shasta Critical years)	Same	Same	Same	Same
CVP Agriculture	100% - 0% based on supply	Same	Same	Same	Same
CVP Municipal & Industrial	100% - 50% based on supply	Same	Same	Same	Same
SWP Water Allocation					
North of Delta (FRSA)	Contract specific	Same	Same	Same	Same
South of Delta	Based on supply; Monterey Agreement	Same	Same	Same	Same
CVP/SWP Coordinated Operations					
Sharing of Responsibility for In-Basin-Use	1986 Coordinated Operations Agreement	Same	Same	Same	Same

	Study 1	Study 2	Study 3	Study 4	Study 5
Sharing of Surplus Flows	1986 Coordinated Operations Agreement	Same	Same	Same	Same
Sharing of Restricted Export Capacity	Equal sharing of export capacity under SWRCB D-1641; use of CVPIA 3406(b)(2) only restricts CVP exports; EWA use restricts CVP and/or SWP exports as directed by CALFED Fisheries Agencies	Same	Same	Same	Same
Transfers					
Dry Year Program	None	Same	Same	Same	Same
Phase 8	None	Same	Same	Same	Same
MWDSC/CVP Settlement Contractors	None	Same	Same	Same	Same
CVP/SWP Integration					
Dedicated Conveyance at Banks	None	Same as Study 1	Same as Study 1	SWP to convey 100,000 af of Level 2 refuge water each year at Banks PP.	Same as Study 4
NOD Accounting Adjustments	None	Same as Study 1	Same as Study 1	CVP to provide the SWP a max of 75,000 af of water to meet in-basin requirements through adjustments in COA accounting.	Same as Study 4
CVPIA 3406(b)(2)	Dept of Interior 2003 Decision	Same	Same	Same	Same
Allocation	800,000 af/YR, 700,000 af/YR in 40-30-30 Dry Years, and 600,000 af/YR in 40-30-30 Critical years	Same	Same	Same	Same
Actions	1995 WQCP, Fish flow objectives (Oct-Jan), VAMP	Same	Same	Same	Same

	Study 1	Study 2	Study 3	Study 4	Study 5
	(Apr 15- May 16) CVP export restriction, 3000 CFS CVP export limit in May and June (D1485 Striped Bass continuation), Post (May 16-31) VAMP CVP export restriction, Ramping of CVP export (Jun), Upstream Releases (Feb-Sep)				
Accounting Adjustments	Per May 2003 Interior Decision, no limit on responsibility for D1641 requirements no Reset with the Storage metric and no Offset with the Release and Export metrics,	Same	Same	Same	Same
CALFED Environmental Water Account	None	None	Modeled	None	Same as Study 3
Actions			Dec-Feb reduce total exports by 50,000 af/month relative to total exports without EWA; VAMP (Apr 15- May 16) export restriction on SWP; Post (May 16-31) VAMP export restriction on SWP and potentially on CVP if B2 Post-VAMP action is not taken; Ramping of exports (Jun)		Same as Study 3
Assets			Fixed Water Purchases 250,000 af/yr, 230,000 af/yr in 40-30-30 dry years, 210,000 af/yr in 40-30-30 critical years. The purchases range from 0 af in Wet Years to approximately 153,000 af in Critical Years NOD, and 57,000 af in Critical Years to 250,000 af in Wet Years SOD. Variable assets		Same as Study 3

	Study 1	Study 2	Study 3	Study 4	Study 5
			include the following: used of 50% JPOD export capacity, acquisition of 50% of any CVPIA 3406(b)(2) releases pumped by SWP, flexing of Delta Export/Inflow Ratio (post-processed from CALSIM II results), dedicated 500 CFS pumping capacity at Banks in Jul – Sep		
Debt restrictions			Delivery debt paid back in full upon assessment; Storage debt paid back over time based on asset/action priorities; SOD and NOD debt carryover is allowed; SOD debt carryover is explicitly managed or spilled; NOD debt carryover must be spilled; SOD and NOD asset carryover is allowed.		Same as Study 3

Table 8-3 2001 American River Demand Assumptions (Note that cuts are not made predicated on Inflow to Folsom for the 2001 Demands)

	ALLOCATION TYPE (MAXIMUM)					
Location / Purveyor	**CVP AG**	**CVP MI**	**CVP Settlement / Exchange**	**Water Rights / Non-CVP / No Cuts**	**CVP Refuge**	**Total**
Auburn Dam Site (D300)						
Placer County Water Agency	0	0	0	8,500	0	8,500
Total	**0**	**0**	**0**	**8,500**	**0**	**8,500**
Folsom Reservoir (D8)						
Sacramento Suburban	0	0	0	0	0	0
City of Folsom (includes P.L. 101-514)	0	0	0	20,000	0	20,000
Folsom Prison	0	0	0	2,000	0	2,000
San Juan Water District (Placer County)	0	0	0	10,000	0	10,000
San Juan Water District (Sac County) (includes P.L. 101-514)	0	11,200	0	33,000	0	44,200
El Dorado Irrigation District	0	7,550	0	0	0	7,550
El Dorado Irrigation District (P.L. 101-514)	0	0	0	0	0	0
City of Roseville	0	32,000	0	0	0	32,000
Placer County Water Agency	0	0	0	0	0	0
Total	**0**	**50,750**	**0**	**65,000**	**0**	**115,750**
Folsom South Canal (D9)						
So. Cal WC/ Arden Cordova WC	0	0	0	3,500	0	3,500
California Parks and Recreation	0	100	0	0	0	100
SMUD (export)	0	0	0	15,000	0	15,000

South Sacramento County Agriculture (export, SMUD transfer)	0	0	0	0	0	0
Canal Losses	0	0	0	1,000	0	1,000
Total	**0**	**100**	**0**	**19,500**	**0**	**19,600**
Nimbus to Mouth (D302)						
City of Sacramento	0	0	0	63,335	0	63,335
Arcade Water District	0	0	0	2,000	0	2,000
Carmichael Water District	0	0	0	8,000	0	8,000
Total	**0**	**0**	**0**	**73,335**	**0**	**73,335**
Sacramento River (D162)						
Placer County Water Agency	0	0	0	0	0	0
Total	**0**	**0**	**0**	**0**	**0**	**0**
Sacramento River (D167/D168)						
City of Sacramento	0	0	0	38,665	0	38,665
Sacramento County Water Agency (SMUD transfer)	0	0	0	0	0	0
Sacramento County Water Agency (P.L. 101-514)	0	0	0	0	0	0
EBMUD (export)	0	0	0	0	0	0
Total	**0**	**0**	**0**	**38,665**	**0**	**38,665**
Total	**0**	**50,850**	**0**	**166,335**	**0**	**217,185**

Table 8-4 2020 American River Demand Assumptions

	ALLOCATION TYPE (MAXIMUM)									
Location / Purveyor	**CVP AG**	**CVP MI**	**CVP Settlement / Exchange**	**Water Rights / Non-CVP / No Cuts**	**CVP Refuge**	**Total**	FUI (Mar - Sep +60 TAF)			**Notes**
							>	>	<	
							1600	950	400	
Auburn Dam Site (D300)										
Placer County Water Agency	0	35,000	0	35,500	0	70,500	70,500	70,500	70,500	1/2/3/12
Total	**0**	**35,000**	**0**	**35,500**	**0**	**70,500**	**70,500**	**70,500**	**70,500**	
Folsom Reservoir (D8)										
Sacramento Suburban	0	0	0	29,000	0	29,000	29,000	0	0	4/5/11
City of Folsom (includes P.L. 101-514)	0	7,000	0	27,000	0	34,000	34,000	34,000	20,000	1/2/3
Folsom Prison	0	0	0	5,000	0	5,000	5,000	5,000	5,000	
San Juan Water District (Placer County)	0	0	0	25,000	0	25,000	25,000	25,000	10,000	1/2/3/11
San Juan Water District (Sac County) (includes P.L. 101-514)	0	24,200	0	33,000	0	57,200	57,200	57,200	44,200	1/2/3
El Dorado Irrigation District	0	7,550	0	17,000	0	24,550	24,550	24,550	22,550	1/2/3
El Dorado Irrigation District (P.L. 101-514)	0	7,500	0	0	0	7,500	7,500	7,500	0	1/2/3
City of Roseville	0	32,000	0	30,000	0	62,000	54,900	54,900	39,800	1/2/3/11/12
Placer County Water Agency	0	0	0	0	0	0	0	0	0	11
Total	**0**	**78,250**	**0**	**166,000**	**0**	**244,250**	**237,150**	**208,150**	**141,550**	
Folsom South Canal (D9)										
So. Cal WC/ Arden Cordova WC	0	0	0	5,000	0	5,000	5,000	5,000	5,000	
California Parks and Recreation	0	5,000	0	0	0	5,000	5,000	5,000	5,000	

SMUD (export)	0	15,000	0	15,000	0	30,000	30,000	30,000	15,000	1/2/3
South Sacramento County Agriculture (export, SMUD transfer)	0	0	0	0	0	0	0	0	0	1/2/3
Canal Losses	0	0	0	1,000	0	1,000	1,000	1,000	1,000	
Total	**0**	**20,000**	**0**	**21,000**	**0**	**41,000**	**41,000**	**41,000**	**26,000**	
Nimbus to Mouth (D302)										
City of Sacramento	0	0	0	96,300	0	96,300	96,300	96,300	50,000	6/7/8
Arcade Water District	0	0	0	11,200	0	11,200	11,200	11,200	3,500	13
Carmichael Water District	0	0	0	12,000	0	12,000	12,000	12,000	12,000	
Total	**0**	**0**	**0**	**119,500**	**0**	**119,500**	**119,500**	**119,500**	**65,500**	
Sacramento River (D162)										
Placer County Water Agency	0	0	0	0	0	0	0	0	0	
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
Sacramento River (D167/D168)										
City of Sacramento	0	0	0	34,300	0	34,300	34,300	34,300	80,600	8
Sacramento County Water Agency (SMUD transfer)	0	30,000	0	0	0	30,000				10
Sacramento County Water Agency (P.L. 101-514)	0	15,000	0	0	0	15,000				10
EBMUD (export)	0	133,000	0	0	0	133,000				
Total	**0**	**178,000**	**0**	**34,300**	**0**	**212,300**	**34,300**	**34,300**	**80,600**	
Total	**0**	**133,250**	**0**	**342,000**	**0**	**475,250**	**468,150**	**439,150**	**303,550**	

Notes

1/ Wet/average years for this diverter are defined as those years when the projected March through November unimpaired inflow to Folsom Reservoir is greater than 950,000 af.

2/ Drier years for this diverter are defined as those years when the projected March through November unimpaired inflow to Folsom Reservoir is less than 950,000 af but greater than 400,000 af.

3/ Driest years for this diverter are defined as those years when the projected March through November unimpaired inflow to Folsom Reservoir is less than 400,000 af.

4/ Wet/average years for this diverter are defined as those years when the projected March through November unimpaired inflow to Folsom Reservoir is greater than 1,600,000 af.

5/ Drier years for this diverter are defined as those years when the projected March through November unimpaired inflow to Folsom Reservoir is less than 1,600,000 af.

6/ Wet/average years as it applies to the City of Sacramento are time periods when the flows bypassing the E. A. Fairbairn Water Treatment Plant diversion exceed the "Hodge flows."

7/ Drier years are time periods when the flows bypassing the City's E.A. Fairbairn Water Treatment Plant diversion do not exceed the "Hodge flows."

8/ For modeling purposes, it is assumed that the City of Sacramento's total annual diversions from the American and Sacramento River in year 2030 would be 130,600 af.

10/ The total demand for Sacramento County Water Agency would be up to 78,000 af. The 45,000 af represents firm entitlements; the additional 33,000 af of demand is expected to be met by intermittent surplus supply. The intermittent supply is subject to Reclamation reduction (50%) in dry years.

11/ Water Rights Water provided by releases from PCWA's Middle Fork Project; inputs into upper American River model must be consistent with these assumptions.

12/ Demand requires "Replacement Water" as indicated below

13/ Arcade WD demand modeled as step function: one demand when FUI > 400, another demand when FUI < 400.

Temperature and Mortality Modeling Methods

The objective of the temperature models is to assist in the fisheries impact evaluations of alternative CVP/SWP operation scenarios required for the CVP-OCAP analysis. The Reclamation temperature model was used to estimate temperatures in the Trinity, Sacramento, Feather, American, and Stanislaus River systems. The joint DWR/Reclamation simulation model CALSIM II provided monthly CVP/SWP project operations input to the temperature model for a 72-year hydrologic period (1922-93). Because of the CALSIM Model's complex structure of CALSIM II, flow arcs were combined at appropriate nodes to insure compatibility with the temperature model. The Reclamation salmon mortality model computed salmon spawning losses in the five rivers based on the temperature model estimates. The temperatures and salmon losses for each alternative were compared to a base study.

Model Description

The Reclamation temperature models for the Sacramento, Feather, and American Rivers are documented in a 1990 Reclamation report (1). The Trinity River temperature model is documented in a 1979 Reclamation report (7). The Stanislaus River temperature model is documented in a 1993 Reclamation report (3). The models are also described in Appendix IX of the 1997 Reclamation Draft CVPIA-PEIS (2). The reservoir temperature models simulate monthly mean vertical temperature profiles and release temperatures for Trinity, Whiskeytown, Shasta, Oroville, Folsom, New Melones and Tulloch Reservoirs based on hydrologic and climatic input data. The temperature control devices (TCD) at Shasta, Oroville, and Folsom Dams can selectively withdraw water from different reservoir levels to provide downstream temperature control. The TCD's are generally operated to conserve cold water for the summer and fall months when river temperatures become critical for fisheries. The models simulate the TCD operations by making upper level releases in the winter and spring, mid-level releases in the late spring and summer, and low level releases in the late summer and fall.

Temperature changes in the downstream regulating reservoirs: Lewiston, Keswick, Thermalito, Natomas, and Goodwin are computed from equilibrium temperature decay equations in the reservoir models, which are similar to the river model equations. The river temperature models output temperatures at 3 locations on the Trinity River from Lewiston Dam to the North Fork, 12 locations on the Sacramento River from Keswick Dam to Freeport, 12 locations on the Feather River from Oroville Dam to the mouth, 9 locations on the American River from Nimbus Dam to the mouth, and 8 locations on the Stanislaus River from Goodwin Dam to the mouth. The river temperature calculations are based on regulating reservoir release temperatures, river flows, and climatic data. Monthly mean historical air temperatures for the 72-year period and other long-term average climatic data for Trinity, Shasta, Whiskeytown, Redding, Red Bluff, Colusa, Oroville, Marysville, Folsom, Sacramento, New Melones, and Stockton were obtained from National Weather Service records and are used to represent climatic conditions for the five river systems.

The Reclamation salmon mortality model is documented in a 1994 CVPIA-PEIS report (6) and a 1993 Reclamation report (3). The model's generalized salmon loss calculation procedure is documented in Appendix A of the 1991 Reclamation Shasta TCD EIS (4). The model uses DFG and FWS data on Chinook salmon spawning distribution and timing in the five rivers (4)(5)(6).

Temperature-exposure mortality criteria for 3 life stages (pre-spawned eggs, fertilized eggs, and pre-emergent fry) are used along with the spawning distribution data and output from the river temperature models to compute salmon spawning losses in percent. Temperature units (TU), defined as the difference between river temperatures and 32° F, are calculated daily by the mortality model and used to track life-stage development. Eggs are assumed to hatch upon exposure to 750 TUs following fertilization. Fry are assumed to emerge from the gravel after exposure to 750 TUs following egg hatching into the pre-emergent fry stage. The temperature mortality rates for fertilized eggs, the most sensitive life stage, range from 8% in 24 days at 57° F to 100% in 7 days at 64° F or above (6). Most salmon spawning generally occurs above the North Fork on the Trinity River, above Red Bluff on the Sacramento River for all four salmon runs, above Honcut Creek on the Feather River, above Watt Avenue on the American River, and above Riverbank on the Stanislaus River. Fall-run salmon spawning usually occurs from mid-October thru December, peaking about mid-November. Winter-run salmon usually spawn on the Sacramento River during May-July, and spring-run salmon during August-October.

CALSIM II, Temperature, and Salmon Mortality Model Limitations

The main limitation of CALSIM II and the temperature models used in the study is the time-step. Mean monthly flows and temperatures do not define daily variations that could occur in the rivers due to dynamic flow and climatic conditions. However, monthly results are still useful for general comparison of alternatives. The temperature models are also unable to accurately simulate certain aspects of the actual operations strategies used when attempting to meet temperature objectives, especially on the upper Sacramento River. To account for the short-term variability and the operational flexibility of the system to respond to changing conditions, cooler water than that indicated by the model is released in order to avoid exceeding the required downstream temperature target. There is also uncertainty regarding performance characteristics of the Shasta TCD. Due to the hydraulic characteristics of the TCD, including leakage, overflow, and performance of the side intakes, the model releases are cooler than can be achieved in real-time operations; therefore, a more conservative approach is taken in real-time operations that is not fully represented by the models.

The salmon model is limited to temperature effects on early life stages of Chinook salmon. It does not evaluate potential direct or indirect temperature impacts on later life stages, such as emergent fry, smolts, juvenile out-migrants, or adults. Also, it does not consider other factors that may affect salmon mortality, such as in-stream flows, gravel sedimentation, diversion structures, predation, ocean harvest, etc. Since the salmon mortality model operates on a daily time-step, a procedure is required to utilize the monthly temperature model output. The salmon model computes daily temperatures based on linear interpolation between the monthly temperatures, which are assumed to occur on the 15th day of the month.

CALSIM II cannot completely capture the policy-oriented operation and coordination the 800,000 af of dedicated CVPIA 3406 (B)(2) water and the CALFED EWA. Because the model is set up to run each step of the 3406(B)(2) on an annual basis and because the WQCP and ESA actions are set on a priority basis that can trigger actions using 3406(b)(2) water or EWA assets, the model will exceed the dedicated amount of 3406(b)(2) water that is available. Moreover, the

3406(b)(2) and EWA operations in CALSIM II are just one set of plausible actions aggregated to a monthly representation and modulated by year type. However, they do not fully account for the potential weighing of assets versus cost or the dynamic influence of biological factors on the timing of actions. The monthly time-step of CALSIM II also requires day-weighted monthly averaging to simulate minimum instream flow levels, VAMP actions, export reductions, and X2-based operations that occur within a month. This averaging can either under- or over-estimate the amount of water needed for these actions.

Since CALSIM II uses fixed rules and guidelines results from extended drought periods might not reflect how the SWP and CVP would operate through these times. The allocation process in the modeling is weighted heavily on storage conditions and inflow to the reservoirs that are fed into the curves mentioned previously in the Hydrologic Modeling Methods section beginning on page 8-1 and does not project inflow from contributing streams when making an allocation. This curve based approach does cause some variation in results between studies that would be closer with a more robust approach to the allocation process.

CALSIM Modeling Results

A summary of long-term averages and critical drought-period averages (i.e. Water Years 1928 to 1934) can be found in Table 8-5 for flows, storages, delta output, and deliveries. The rest of this section will be broken up into either subsystems of the CVP and SWP or grouped into results for 3406 CVPIA (b)(2) accounting and EWA.

For more results including month-by-year tables, exceedance charts, monthly averages by water year type and monthly percentiles for selected CALSIM II outputs refer to the CALSIM II Modeling Appendix. The appendix contains a directory of spreadsheets that compare all five studies simulated and directories that contain spreadsheets that directly compare two studies (includes month by year difference tables). The Temperature Modeling appendix includes temperature results from both the Bend Bridge and Balls Ferry compliance points. The appendix also includes mortality results for the Balls Ferry compliance runs, source code, and the raw output files for the CALSIM II studies. Raw output files and documentation for the tempertare and mortality models are also provided.

Post-processing of the CALSIM II simulation of EWA operations was completed by the DWR Transfers Office. This post-processing involved further annual operations simulation, which is described in the OCAP EWA Modeling appendix. The results in this appendix are based on post-processing the Future EWA model (Study 5) and show increased use of assets as mentioned in the Environmental Water Account section

The results in this chapter are generally shown in exceedance charts for a particular month or set of months, average and percentile monthly data, and on a sort by water year type for a particular month. The probability of exceedance charts show values on the y-axis with the percent of time (probability of exceedance) that the value was exceeded. An expample, the end of September exceedance charts show the probability that the revervoir was able to carryover storage into the next water year for each of the five studies. The exceedance charts are also a good measure of trend between the studies either higher or lower on average. Averages by water year type are sorted in this chapter on the 40-30-30 Sacramento Valley Index and show how average changes from Wet to Critical years. The 60-20-20 San Joaquin Valley Index was used for sorting temperature and CALSIM II output from the Stanislaus and San Joaquin Rivers. The percentile graphs show monthly values for the 50th, 5th, and 95th percentiles for a given output variable and were used to indicate how flows are being effected by flood and minimum flow requirements.

Table 8-5 Long term Averages and 28-34 Averages from each of the five studies

	Study 1: D1641 with (b)(2) (1997)		Study 2: Today (b)(2)		Study 3: Today EWA		Study 4: Future SDIP		Study 5: Future EWA	
	Average	28-34	Average	28-34	Average	28-34	Average	28-34	Average	28-34
End of Sep Storages (TAF)										
Trinity	1418	790	1341	722	1335	694	1286	657	1289	641
Whiskeytown	234	227	234	219	233	219	232	211	232	211
Shasta	2705	1595	2663	1476	2659	1471	2532	1372	2529	1341
Oroville	2085	1502	2091	1558	2079	1454	2050	1576	2044	1507
Folsom	545	454	543	448	535	415	504	378	500	361
New Melones	1390	910	1390	911	1389	911	1390	910	1391	910
CVP San Luis	213	296	215	302	231	303	238	320	245	314
SWP San Luis	401	318	395	280	355	301	375	305	302	313
Total San Luis	614	614	609	581	674	716	614	625	634	802
River Flows (cfs)										
Trinity Release	611	473	729	590	726	590	927	648	928	651
Clear Creek Tunnel	1054	682	940	565	944	565	749	494	748	490
Spring Creek Tunnel	1235	696	1123	582	1127	587	933	519	931	513
Clear Creek Release	166	104	164	101	163	97	163	96	163	97
Keswick Release	8673	5876	8563	5776	8567	5788	8375	5754	8373	5754
Nimbus Release	3477	2401	3478	2402	3477	2393	3228	2181	3227	2184
Mouth of American	3347	2260	3347	2261	3347	2252	3032	1991	3031	1994
Red Bluff Diversion Dam	11251	7457	11147	7372	11150	7382	10981	7399	10977	7401
Wilkin's Slough	9176	6142	9090	6056	9098	6067	8930	6048	8925	6047
Feather Low Flow Channel	709	600	709	600	600	600	705	600	600	600

Flow Below Thermolito	4177	2505	4177	2503	4177	2510	4176	2528	4175	2519
Feather Flow Below Yuba Mouth	6287	3678	6287	3675	6285	3684	6278	3698	6276	3689
Feather Mouth	7500	4169	7500	4166	7499	4174	7503	4192	7500	4184
Sac at Freeport	22476	13951	22376	13870	22390	13867	22193	13893	22200	13879
Tulloch Release	604	307	604	307	604	306	604	308	604	308
Stanislaus Mouth	892	550	892	550	892	550	892	551	892	551
SJR Flow w/o Stanislaus	2866	1567	2865	1566	2866	1566	2866	1569	2867	1569
Flow at Vernalis	3723	2081	3722	2079	3723	2079	3723	2083	3723	2083
Mokelumne	2079	187	2073	181	2060	193	2040	211	2025	219
Yolo Bypass	878	436	878	436	878	436	881	445	881	445
Delta Parameters										
SWP Banks (cfs)	4448	3244	4443	3265	4180	2985	4671	3429	4404	3083
CVP Banks (cfs)	109	59	108	53	180	80	157	45	202	44
Tracy (cfs)	3396	2560	3364	2484	3207	2344	3335	2409	3198	2330
Total Banks (cfs)	4557	3303	4551	3318	4499	3262	4828	3474	4748	3344
Cross Valley Pumping (cfs)	109	59	108	53	109	53	107	45	107	44
Sac Flow at Freeport (cfs)	22362	13951	22264	13870	22277	13867	22089	13893	22095	13879
Flow at Rio Vista (cfs)	18392	9233	18307	9165	18291	9156	18121	9222	18095	9196
Excess Outflow (cfs)	12001	2705	11929	2686	12110	2783	11406	2650	11565	2727
Required Outflow (cfs)	7716	6510	7722	6501	7750	6609	7773	6514	7822	6641
X2 Position (km)	75.8	80.6	75.9	80.7	75.8	80.4	76.2	80.7	76.1	80.4
Yolo Bypass (cfs)	2053	187	2047	181	2034	193	2014	211	2000	219
Mokelumne Flow (cfs)	869	436	869	436	869	436	872	445	872	445
SJR + Calaveras Flow (cfs)	3888	2178	3887	2176	3888	2176	3888	2181	3888	2181
Modeled Required DO (cfs)	7488	6280	7524	6281	7501	6263	7545	6274	7526	6258

Flow at Georgiana Slough (cfs)	3803	2684	3790	2674	3792	2673	3767	2677	3768	2675
DXC Flow (cfs)	1740	1701	1734	1693	1749	1712	1731	1684	1748	1708
Flow below DXC (cfs)	16818	9566	16739	9504	16736	9482	16591	9532	16580	9496
North Bay Aqueduct (cfs)	54	37	54	38	54	37	73	54	74	52
CCWD (cfs)	171	168	171	168	171	168	218	208	218	208
Total Inflow (cfs)	29171	16752	29067	16664	29068	16672	28863	16730	28855	16724
Total Outflow (cfs)	19717	9215	19651	9188	19860	9392	19179	9164	19387	9368
Allocations (%)	**Average**	**29-34***	**Average**	**29-34***	**Average**	**29-34***	**Average**	**29-34***	**Average**	**29-34***
CVP										
North of Delta										
Agriculture	73%	15%	71%	12%	71%	11%	67%	11%	67%	10%
M&I	89%	64%	88%	61%	88%	60%	87%	60%	87%	59%
South of Delta										
Agriculture	61%	15%	60%	12%	61%	11%	61%	11%	61%	10%
M&I	87%	64%	86%	61%	87%	60%	86%	60%	86%	59%
SWP										
Agriculture	80%	39%	80%	40%	80%	37%	80%	42%	80%	40%
M&I (non-MWD)	84%	44%	84%	45%	84%	42%	82%	44%	83%	42%
Metropolitan Water Dist.	81%	39%	81%	41%	81%	38%	80%	43%	81%	41%
Deliveries (TAF)	**Average**	**29-34***	**Average**	**29-34***	**Average**	**29-34***	**Average**	**29-34***	**Average**	**29-34***
CVP										
North of Delta										
Agriculture	246	55	240	43	240	40	237	39	238	37
Settlement Contracts	1831	1747	1832	1747	1832	1747	1876	1749	1876	1751
M&I	30	28	30	27	30	27	38	41	38	41

Refuge	105	90	105	90	105	90	105	89	105	90
Total	2123	1919	2208	1907	2207	1905	2183	1918	2189	1919
South of Delta										
Agriculture	1102	279	1079	217	1110	206	638	195	659	185
Exchange	847	736	847	736	847	736	864	736	864	736
M&I	123	92	122	87	124	86	108	86	107	85
Refuge	280	240	280	240	280	240	288	240	288	240
Total**	2536	1530	2512	1464	2545	1451	2088	1440	2111	1429
SWP										
Metropolitan Water Dist.	1319	759	1320	782	1317	730	1522	832	1532	792
Agriculture	885	434	885	447	708	338	877	475	708	373
M&I (non-MWD)	777	372	777	383	777	358	778	414	785	394
Article 21	175	141	170	131	168	168	152	122	138	145
Water Rights	185	185	185	185	185	185	185	185	185	185
Total***	3045	1630	3047	1676	2867	1490	3242	1786	3090	1623

* Represents 1929 - 1934 Delivery Years, Mar - Feb for CVP and Jan - Dec for SWP

** Total includes canal losses due to evaporation

*** Total is MWD + Ag + M&I (non-MWD) + canal losses

CVPIA 3406 (b)(2)

For the purposes of analyzing water use for the CVPIA Section 3046 (b)(2) actions the Today (b)(2) and Future SDIP studies (i.e. Study 2 and Study 4) will be used in this section.

From Table 8-6 and Table 8-7 the average annual cost of (b)(2) water used increases from 735 TAF annually to 743 TAF annually on an long-term average basis with most of the increases occurring during the Oct – Jan period see Figure 8-5. The probability of exceeding 200 TAF target during the Oct-Jan period increases from 26 percent to 35 percent from the Today (b)(2) to the Future SDIP studies. Exceeding the 200 TAF target is generally due to the model taking high costs actions at Nimbus and Keswick before the accounting algorthims can reduce costs for this period. Another reason for high costs during this period is from Delta salinity requirements during dry and critical years in the WQCP accounting.

Annual (b)(2) modeled costs exceed their allocated amount 54% in the Today (b)(2) run and 51% in the Future SDIP run, Figure 8-3 and Figure 8-4. The annnual costs exceeding the allocated amount of (b)(2) water available is generally due to years where there are a combination of high release costs due to X2 Roe Island requirements, high VAMP costs for the Apr 15 to May 15 export curtailments (triggered in every year of simulation), and not anticipating payback pumping costs in the late summer. CALSIM II also does not use any forecasting algorthim for overall (b)(2) costs. This also results in over and under utilization of the allocated amount of (b)(2) water. Years when the (b)(2) costs are less than the allocated amount are generally in wet years, because flood releases are, generally, nearly identical between the D1485 baseline and (b)(2) annual simulations, and VAMP export cutailments are up to the 2:1 ratio when non-VAMP flows are greater than 8600 cfs.

Table 8-8 shows the average required costs for a (b)(2) export action and what the (b)(2) operation was actually able to support given the water available in the account and anticipated WQCP costs for both the Today (b)(2) and Future SDIP studies. The ability for (b)(2) water to support various actions decreases in the Future SDIP due to increased release costs. The Above and Below Normal years are more costly than dry or critical years due to full VAMP restrictions and the ability to pump more water in the D1485 baseline.

Table 8-9 displays the percentage of times that the simulated actions were triggered given the assumptions for taking an action. Reduction in the percentage of times that the releases were reduced are due to reduction in upstream storages in the Future SDIP study. Reduction in percentage of times that the May Shoulder and June Ramping are triggered are due to increased release metric costs in the Future SDIP study.

Table 8-6 Average Monthly WQCP and Total (b)(2) Costs by Month, Total Oct – Jan Costs, and Total Annual Costs for Study 3 Today (b)(2)

Today b2	Oct	Nov	Dec	Jan	Oct-Jan Subtotal	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
WQCP Release Cost	15	16	7	3	40	24	22	30	13	48	10	21	32	241
WQCP Export Cost	1	5	8	3	17	5	23	45	12	2	28	89	4	225
WQCP Total Cost	15	20	15	6	57	29	45	75	26	50	38	110	36	466
(b)(2) Release Cost	24	42	41	32	139	36	52	56	39	37	12	21	27	419
(b)(2) Export Cost	1	2	4	3	10	5	28	77	57	11	31	92	5	316
(b)(2) Total Cost	25	44	45	34	149	41	79	133	97	47	43	114	32	735

Table 8-7 Average Monthly WQCP and Total (b)(2) Costs by Month, Total Oct – Jan Costs, and Total Annual Costs for Study 4 Future SDIP

Future SDIP	Oct	Nov	Dec	Jan	Oct-Jan Subtotal	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
WQCP Release Cost	17	13	4	3	37	22	21	32	11	48	16	16	28	232
WQCP Export Cost	0	8	11	6	25	5	24	33	15	5	22	91	7	227
WQCP Total Cost	17	21	15	9	62	28	45	65	26	52	37	108	35	459
(b)(2) Release Cost	33	44	45	28	150	36	46	59	40	36	16	18	27	427
(b)(2) Export Cost	2	5	7	7	21	9	34	60	57	12	24	92	8	316
(b)(2) Total Cost	34	49	52	35	170	44	80	119	97	48	40	110	35	743

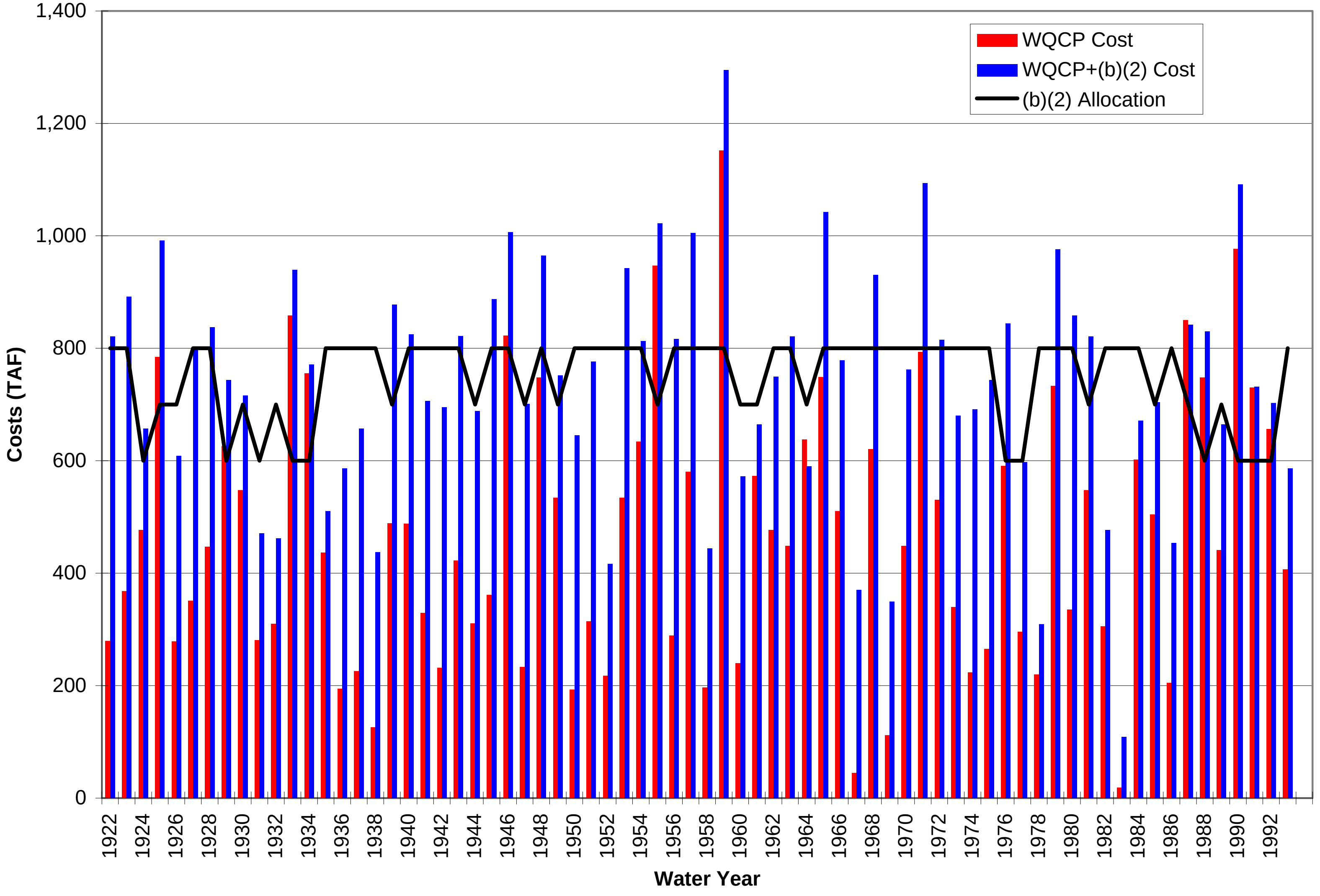

Figure 8-3 Today (b)(2) Total Annual WQCP and Total (b)(2) costs

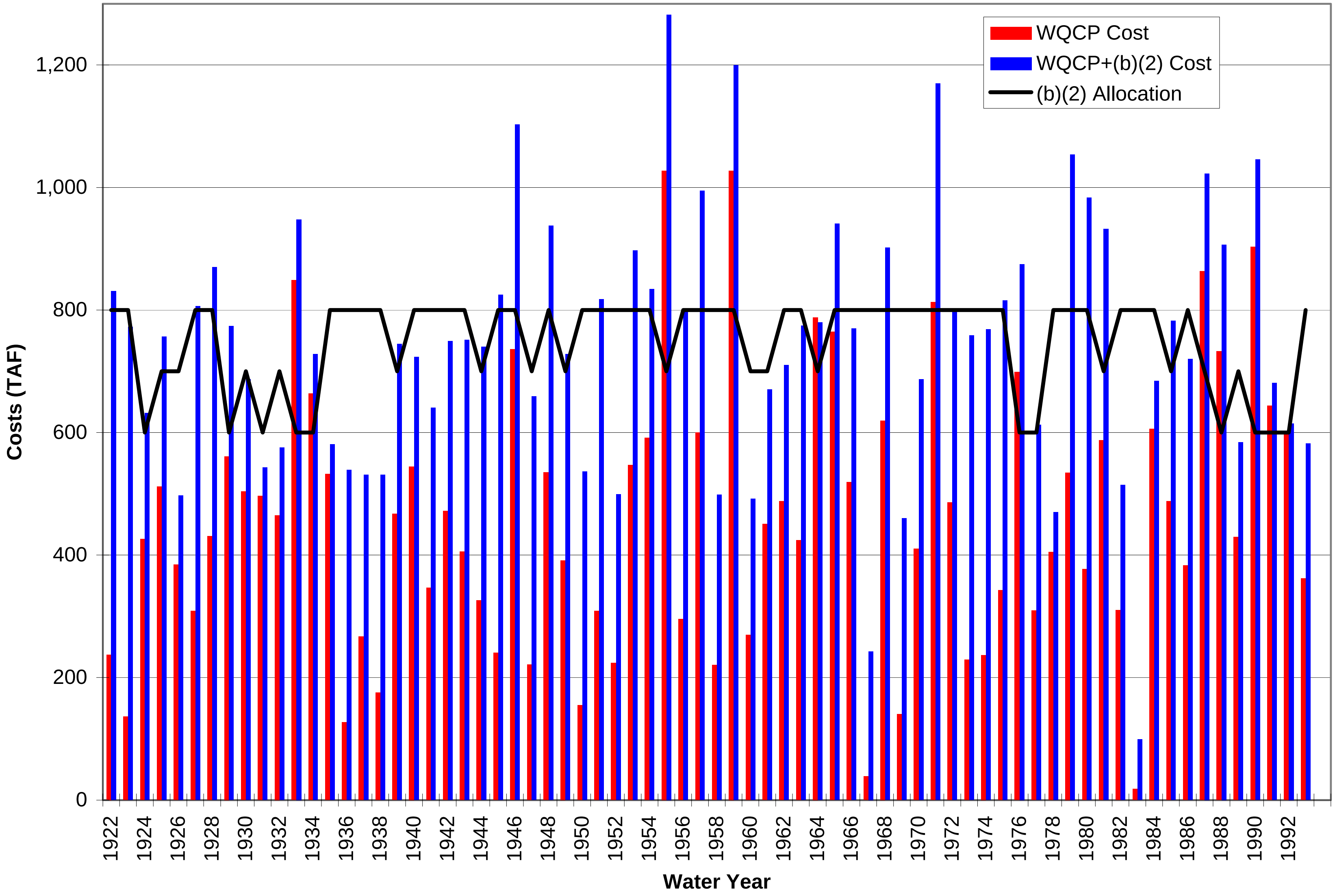

Figure 8-4 Future SDIP Total Annual WQCP and Total (b)(2) costs

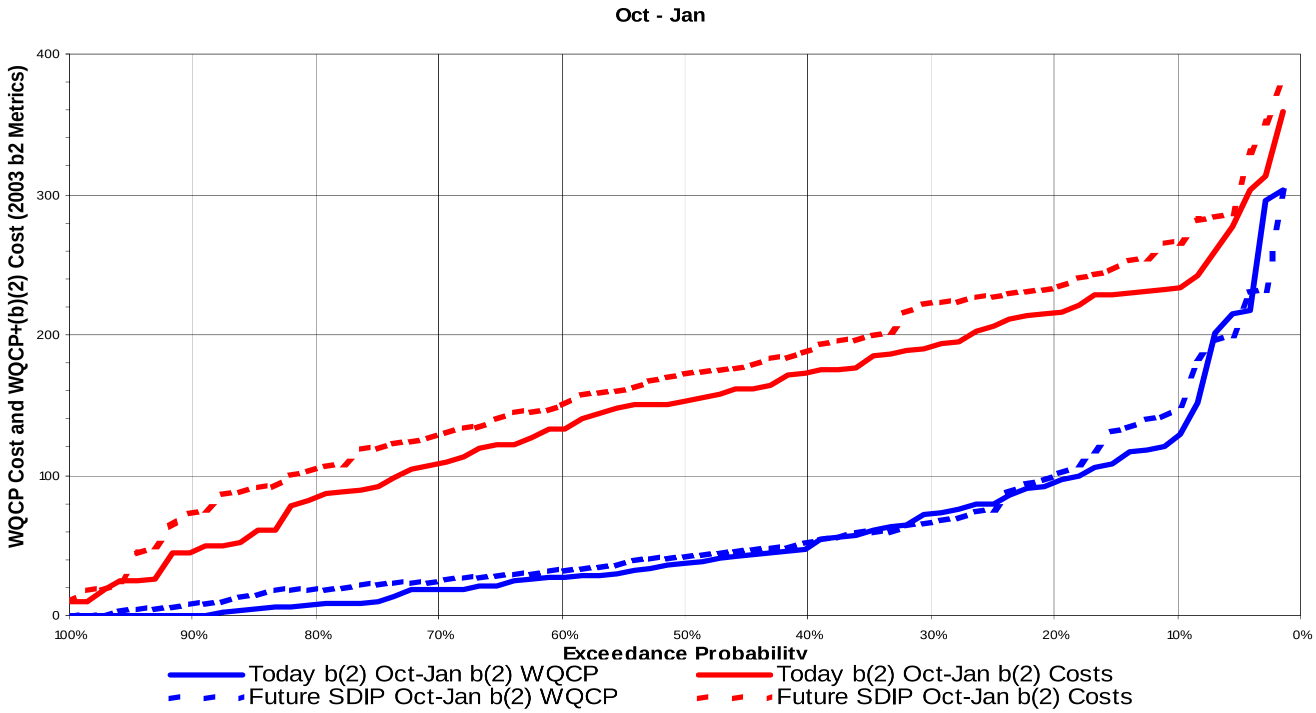

Figure 8-5 Oct – Jan WQCP and Total (b)(2) Costs probability of exceedance

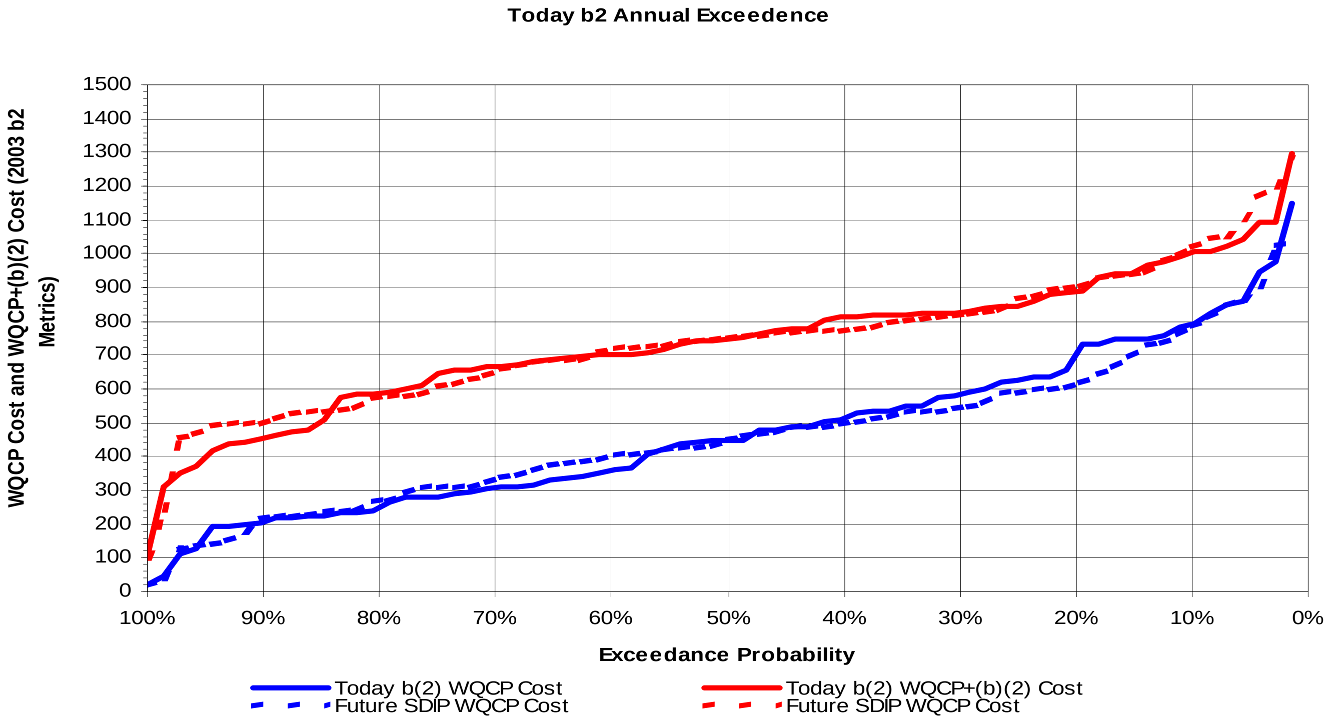

Figure 8-6 Annual WQCP and Total (b)(2) Costs probability of exceedance

Table 8-8 Total (b)(2) water required for export actions versus amount of (b)(2) water used

	Total (b)(2) Water Required			Actually (b)(2) Water Used		
Today (b)(2)	Apr-May Vamp	May Shoulder	June Ramping	Apr-May Vamp	May Shoulder	June Ramping
Average	108	41	18	108	19	7
W	95	35	15	95	22	7
AN	138	53	23	138	27	10
BN	141	57	26	141	25	8
D	110	40	21	110	18	6
C	57	24	2	57	3	2
Future SDIP	Apr-May Vamp	May Shoulder	June Ramping	Apr-May Vamp	May Shoulder	June Ramping
Average	96	19	8	96	14	5
W	85	27	8	85	18	5
AN	128	10	4	128	10	4
BN	129	29	8	129	24	8
D	94	11	11	94	9	5
C	52	8	10	52	1	1

Table 8-9 Percent of possible occurrences action was triggered

Actions	Today (b)(2)	Future SDIP
Keswick Releases	66%	64%
Whiskeytown Releases	94%	93%
Nimbus Releases	69%	67%
Dec-Jan Export Cuts	n/a	n/a
VAMP Export Cuts	100%	100%
Late May Export Cuts	79%	76%
Jun Export Cuts	60%	50%
Early Apr Export Cuts	n/a	n/a
Feb-Mar Export Cuts	n/a	n/a

Environmental Water Account

This section summarizes results from the two OCAP studies that included EWA operations: Study 3 (i.e. Today EWA) and Study 5 (i.e. Future EWA). Operations are summarized for the following categories:

- Annual costs of EWA actions (i.e. expenditures) measured as export reductions
- Delivery debt status and payback (i.e. adherence to the No Harm Principle)
- Carryover debt conditions from year to year
- Annual accrual of EWA assets to mitigate impacts of EWA actions (i.e. water purchases, B2 gains, use of JPOD capacity, wheeling of backed-up water)
- Spilling of carryover debt situated at SWP San Luis
- Annual costs specific to each EWA action measured as export reductions

The annual EWA expenditures for the simulation are shown on Figure 8-7, first as the summation of expenditures associated with Winter and Spring EWA actions, and second as the expenditures only associated with the Spring VAMP action (i.e. EWA Action 3). For the combination of Winter and Spring EWA actions, both Today EWA and Future EWA studies had similar extremes in annual expenditures (i.e. cost ranges of approximately 100,000 to 600,000 af). However, in between these extremes, costs for Future EWA operations tended to be slightly higher. For VAMP costs only, low-cost years tended to be similar between Today EWA and Future EWA, but higher cost years tended to result in greater spending with Future EWA.

Another way of viewing annual EWA Expenditures is to consider their year-type dependent averages. Sacramento 40-30-30 index was used to classify and sort years. Average annual expenditures by year-type are listed in Table 8-10. Comparing Today EWA and Future EWA results, the year-type dependent averages for Critical and Dry years are very similar. However, the averages for Below Normal, Above Normal, and Wet years tend to be higher under Future EWA conditions as opposed to Today EWA conditions. In these years, when supplies are greater relative to Critical and Dry years, the expanded capacity of 8500 Banks is more utilized and it appears that, on average, the cost of simulated EWA actions increases. Another contributing factor to increased cost of EWA actions in Future EWA relative to Today EWA is that SWP has higher South-of-Delta (SOD) deliveries, based on a long-term annual average, in Future EWA relative to Today EWA (Table 8-5).

Continue...