Juvenile Chinook Salmon Abundance, Distribution, and Survival in the Sacramento-San Joaquin Estuary

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Abstract

All four races of juvenile Central Valley chinook salmon migrate through and many rear in the Sacramento-San Joaquin Delta and Estuary. Delta residence and migration is considered important in determining adult production, as it is generally believed that density dependent effects are minimal after this life stage. Populations of winter run and spring run are presently listed as endangered and threatened species, while the remaining populations in the Central Valley are candidate species. Actions in the Delta to improve survival are likely important in the recovery of these depressed populations. The tidally influenced freshwater Delta also is an important area for water management in California, as it is where the Central Valley and State Water Project pump large volumes of water to southern California, the San Joaquin Valley and the Bay area. To document the effect of these various water management activities in the Delta on juvenile salmon, monitoring and special studies have been conducted since the early 1970s to the present. Changes in abundance in the Delta and estuary appear related to flow; high flows increase the use of the Delta and San Francisco Bay by fry. Relative survival of fry appears greater in the upper Sacramento River than in the Delta or bay, especially in the wetter years. Survival appears lower in the Central Delta relative to that in the North Delta in drier years for both fry and smolts. Fall-run smolt and late-fall-run yearling survival studies have found that diversion into the Central Delta via the Delta Cross Channel or Georgiana Slough reduces survival through the Delta. Experiments in the San Joaquin Delta have shown that survival appears greater for smolts that migrate down the mainstem San Joaquin River rather than through upper Old River. A temporary barrier in upper Old River was tested and found to improve survival for smolts originating in the San Joaquin basin. These specific experiments have identified management actions that could improve juvenile salmon survival through the Delta. In addition, indices of annual survival provide a way to compare survival through the Delta and could be used to assess restoration and management actions. This work demonstrates how long-term scientific studies can be applied to address management and restoration issues.

Introduction

The Sacramento-San Joaquin Estuary is one of the largest estuaries on the West Coast draining the majority of the Central Valley watershed of California. The Sacramento River from the north and San Joaquin River from the south converge in the freshwater, tidally influenced Delta (Figure 1). The Delta consists of nearly 1,200 km of freshwater channels, with most channels edged with riprap (Kjelson and others 1982). The bays downstream of the Delta are generally shallow, with salinities varying seasonally and affected by a combination of tidal flows and freshwater.

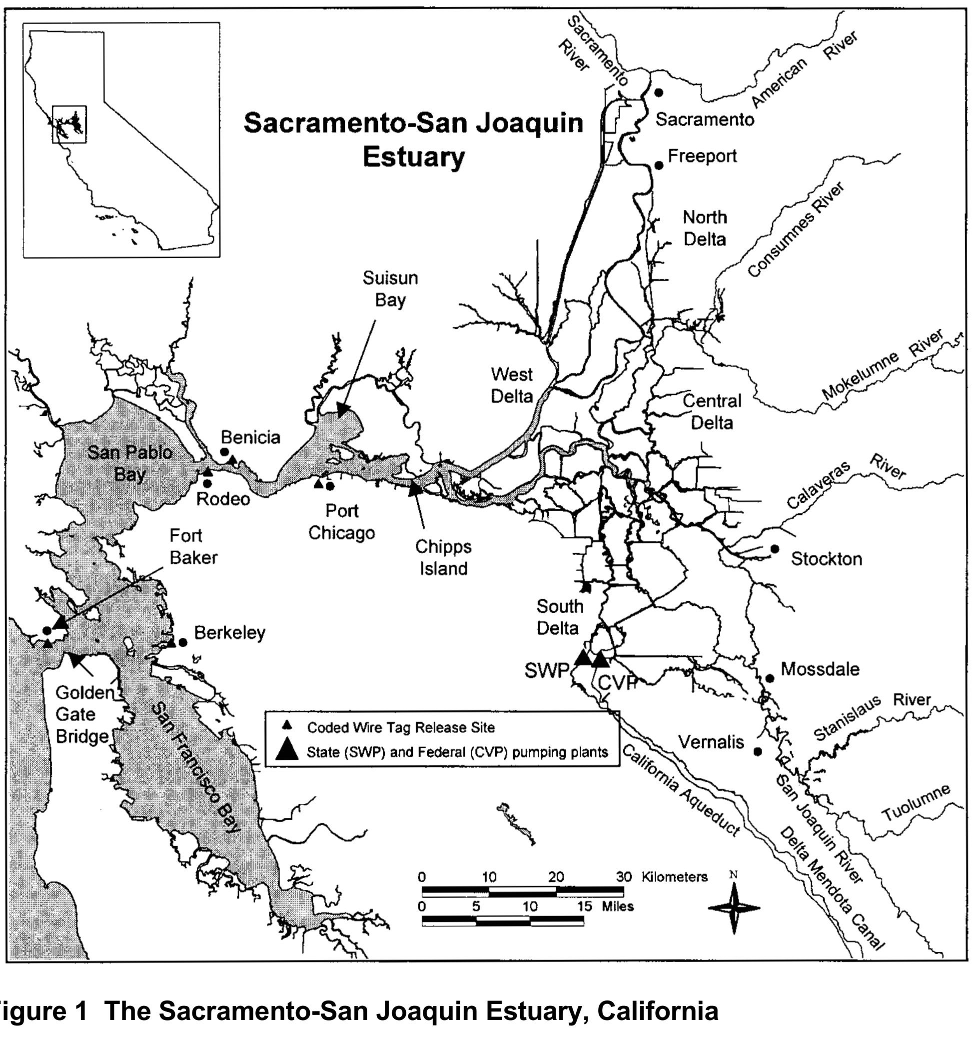

Figure 1 The Sacramento-San Joaquin Estuary, California

There are four races of chinook salmon in the Central Valley: fall, late-fall, spring, and winter. Races are based on their timing of return to freshwater for spawning (Fisher 1994). Historical documents indicate the start of the salmon fishery in California at about 1850 (USFWS 1995). Central Valley salmon continue to support valuable, economically important commercial and recreational fisheries.

During the past 30 years, overall escapement of Central Valley salmon has declined (Fisher 1994). Only the fall run continues to maintain stable spawning runs, likely because they are heavily supported by hatchery production (Fisher 1994). Winter-run chinook salmon were federally listed as threatened in 1990 and endangered in 1994 by the National Marine Fisheries Service. Spring run were recently listed as threatened in 1998 by the State of California. The remaining races and natural populations of chinook salmon in the Central Valley are presently considered candidate species under the Federal Endangered Species Act (NMFS 1999).

All of the various races of chinook salmon in the Central Valley use the Delta as a migration corridor to the ocean and many rear there before emigration. The survival of juvenile salmon through the Delta is considered critical to year class success, as density-dependent mortality after Delta residence is believed to be minimal (Junge 1970). Thus for any given set of ocean conditions, increasing the number of juveniles emigrating from the Delta will increase the production of adults. Actions in the Delta to improve survival are considered important in increasing the production of these Central Valley salmon populations.

In addition to the Delta being important to juvenile salmon, it is also critical to water management in California. Water resource project operations have altered the natural distribution, timing, and magnitude of flows in the Delta (Kjelson and others 1982). The State Water Project (SWP) and the Central Valley Project (CVP) use the Delta to move water from reservoirs in the North to the pumping plants located in the South Delta (Figure 1). The water is pumped (exported) into the State (California Aqueduct) and federal (Delta-Mendota Canal) aqueduct system for agriculture, municipal, and industrial use in the San Joaquin Valley, the Bay area, and southern California. Mean daily exports from the Delta have increased dramatically since the late 1950s and 1960s to peaks in the late 1980s (Figure 2). Due to population growth in California and other factors, there is a continued desire to increase exports further to meet the increased demands.

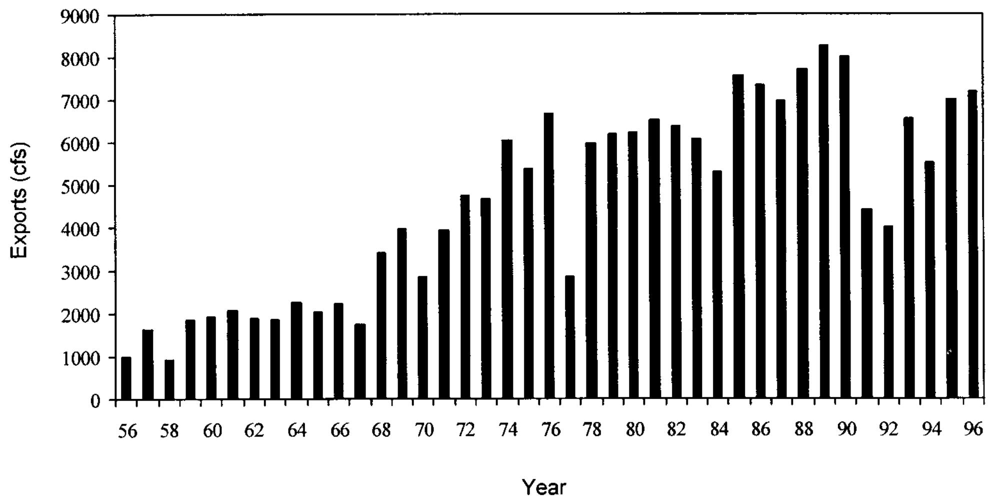

Figure 2 Mean daily combined (SWP + CVP) exports (cfs) between 1956 and 1996. Source: Department of Water Resources, DAYFLOW.

Although tidal fluctuations in the Delta are large relative to net downstream flows, an effect of the present export levels is that net flows in the South Delta often move upstream instead of downstream during periods of low Delta inflows. These net "reverse flows" occur when combined CVP and SWP export rates are higher than the net downstream flow in the San Joaquin River. The remaining water to meet the export needs originates from the Sacramento River. This process creates net flows in the South Delta that move upstream towards the pumping plants instead of downstream toward the ocean (Figure 3). For anadromous fish, such as chinook salmon, these reverse flows may cause confusion or divert them from their main migration routes to the sea. Delays in migration would expose juveniles to various mortality factors for a longer period of time and decrease their survival through the Delta.

Other habitat alterations by the two water projects are the construction of the Delta Cross Channel and the amount of water diverted from the mainstem San Joaquin River into upper Old River (Figure 3). The Delta Cross Channel, located in the North Delta, was built to increase the amount of water originating from the Sacramento River that flows into the Central Delta. The water in the Central Delta is then available by means of gravity to be pumped by the State Water and Central Valley projects located in the South Delta. In addition, the amount of water diverted into upper Old River from the San Joaquin River increases as project exports increase (Oltmann 1995). The CVP diverts water directly from Old River and the SWP diverts water from Clifton Court Forebay, and its intake is on Old River.

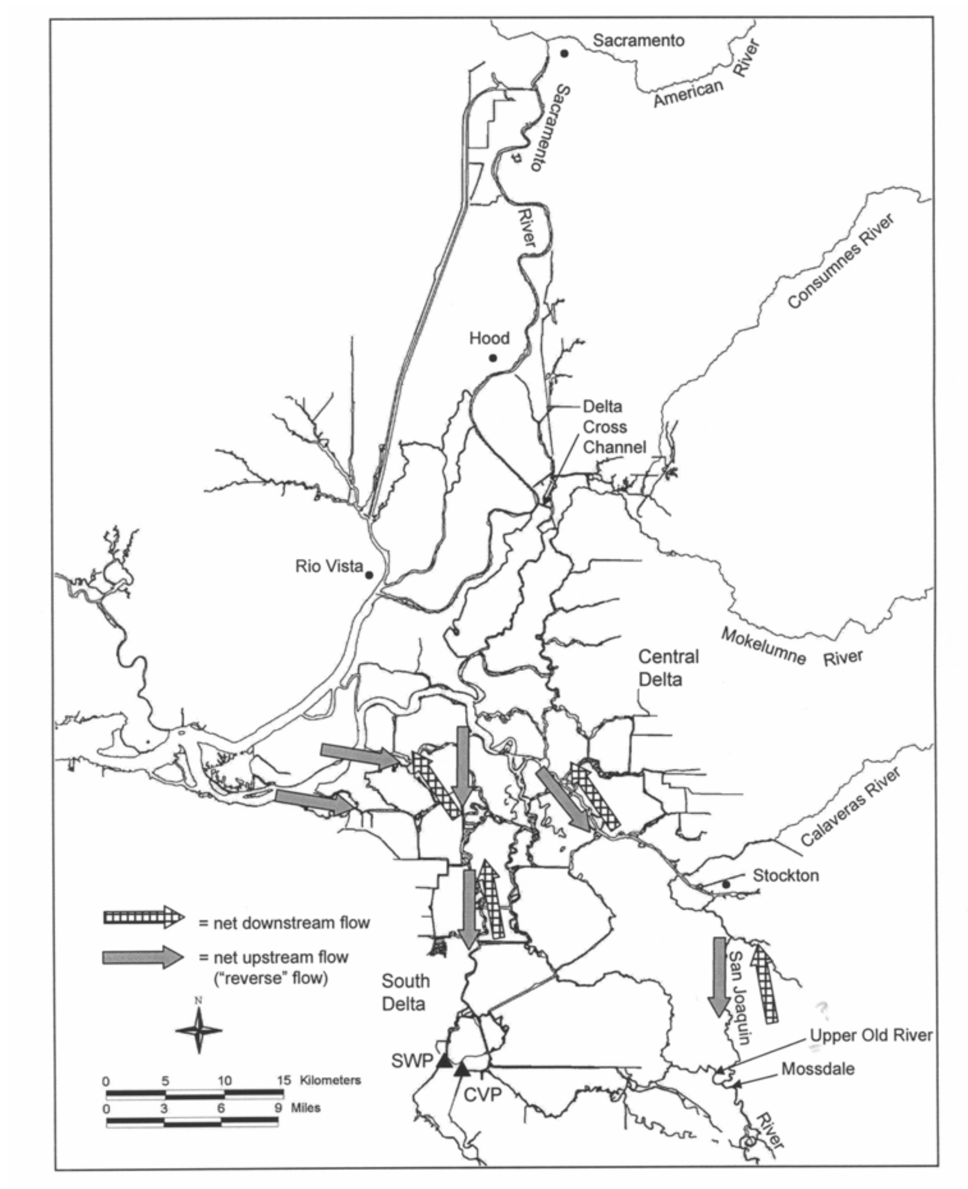

Figure 3 The Sacramento-San Joaquin Estuary, California. Arrows depict net downstream flow and "reverse flows."

The work presented in this report is derived from juvenile salmon monitoring and special studies conducted by the US Fish and Wildlife Service's (USFWS) Sacramento-San Joaquin Fishery Resource Office on behalf of the Interagency Ecological Program for the Sacramento-San Joaquin Delta (IEP). The IEP is a consortium of six federal and three State agencies charged with providing information on the factors that affect the ecological resources in the Sacramento-San Joaquin Estuary to allow more efficient management of the estuary. Agencies in the IEP, in addition to the USFWS, include the US Bureau of Reclamation, US Geological Survey, National Marine Fisheries Service (NMFS), US Army Corps of Engineers, US Environmental Protection Agency, California Department of Water Resources, California Department of Fish and Game, and California State Water Resources Control Board.

The IEP has been conducting juvenile salmon studies in the Delta since the early 1970s. The initial goals of the salmon studies were to define the impacts of water development on the estuarine salmon population and to document the water quality requirements (including flow standards) needed to both sustain and enhance salmon production (Kjelson and others 1981). The goals have been broadened since the program's inception and reflect an overall desire to gain information on what management actions can be taken to improve the survival of juvenile salmon rearing or migrating through the Delta.

The results of these studies have been shared in the past in various ways: workshops, *IEP Newsletter* articles, gray literature in the form of annual reports, testimony to the State Water Resources Control Board (USFWS 1987, 1992a) and peer-reviewed journal and symposium articles (Kjelson and others 1981, 1982; Kjelson and Brandes 1989). The purpose of this paper is to consolidate, update, and summarize the juvenile salmon information gained from the IEP salmon studies. Data from some of the studies are limited and do not provide statistically significant results. They are included to provide a more complete record of the results of the various studies. Many times inferences have been made based on limited data, but we acknowledge in that case there is a risk in drawing wrong conclusions. To lessen that risk, we have tried to draw on a variety of independent pieces of information to reach conclusions.

Specific studies were conducted on juvenile salmon abundance, distribution, and survival using beach seines, Kodiak and midwater trawls, and mark and recapture techniques. The beach seine and the trawls are size and habitat selective, with the beach seine targeting smaller fish (fry) near the shore and the midwater and Kodiak trawls generally capturing larger juveniles (smolts and yearlings) that migrate in the center of the channel. Mark and recapture experiments have been conducted with hatchery fry, smolts, and yearlings released in the upper Sacramento River, Delta, San Francisco Bay, and San Joaquin tributaries (Figures 1, 4 and 5) to estimate survival and examine the importance to survival of different environmental conditions (Kjelson and Brandes 1989).

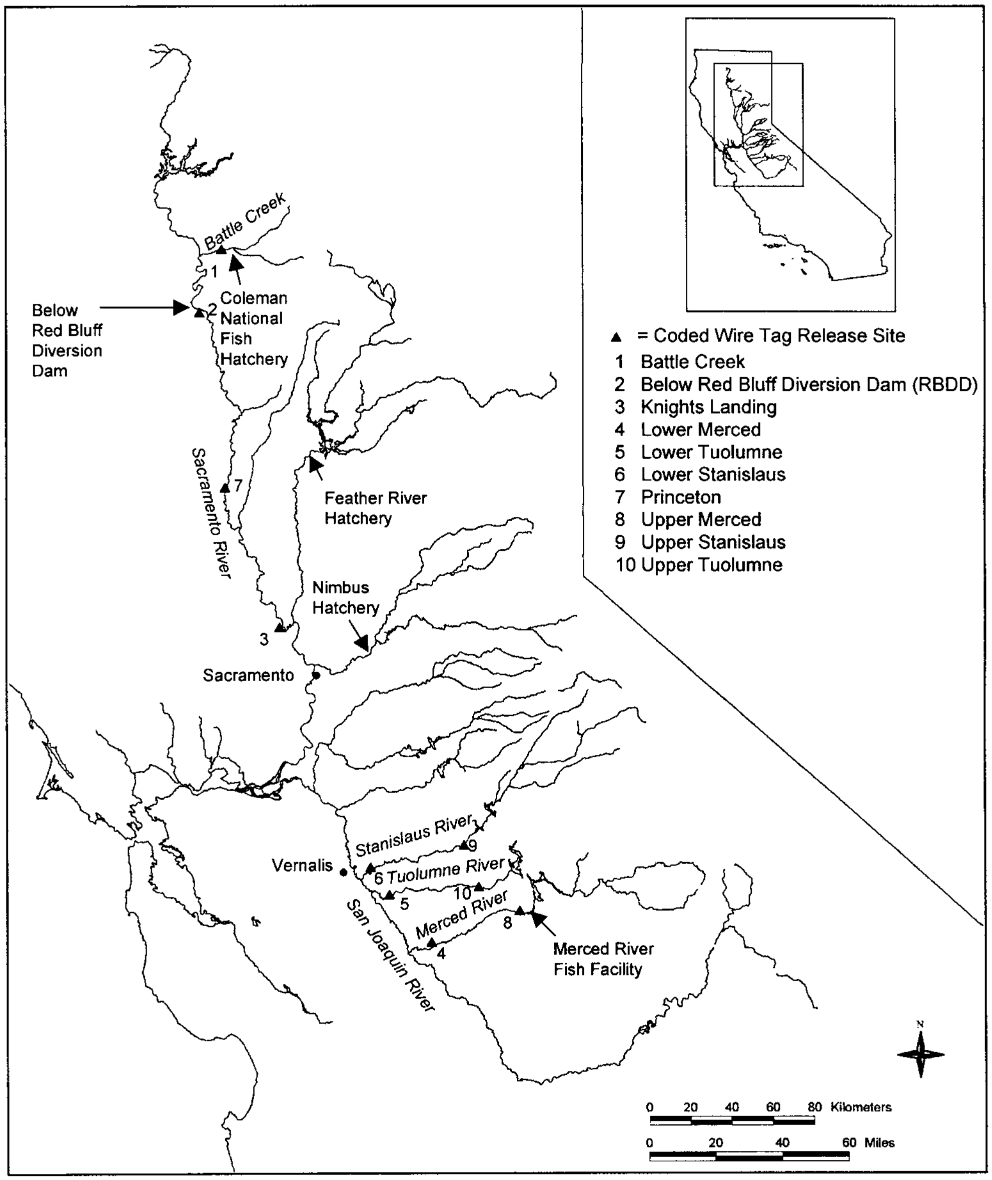

Figure 4 Map of coded wire tag release locations in the upper Sacramento River and San Joaquin River tributaries

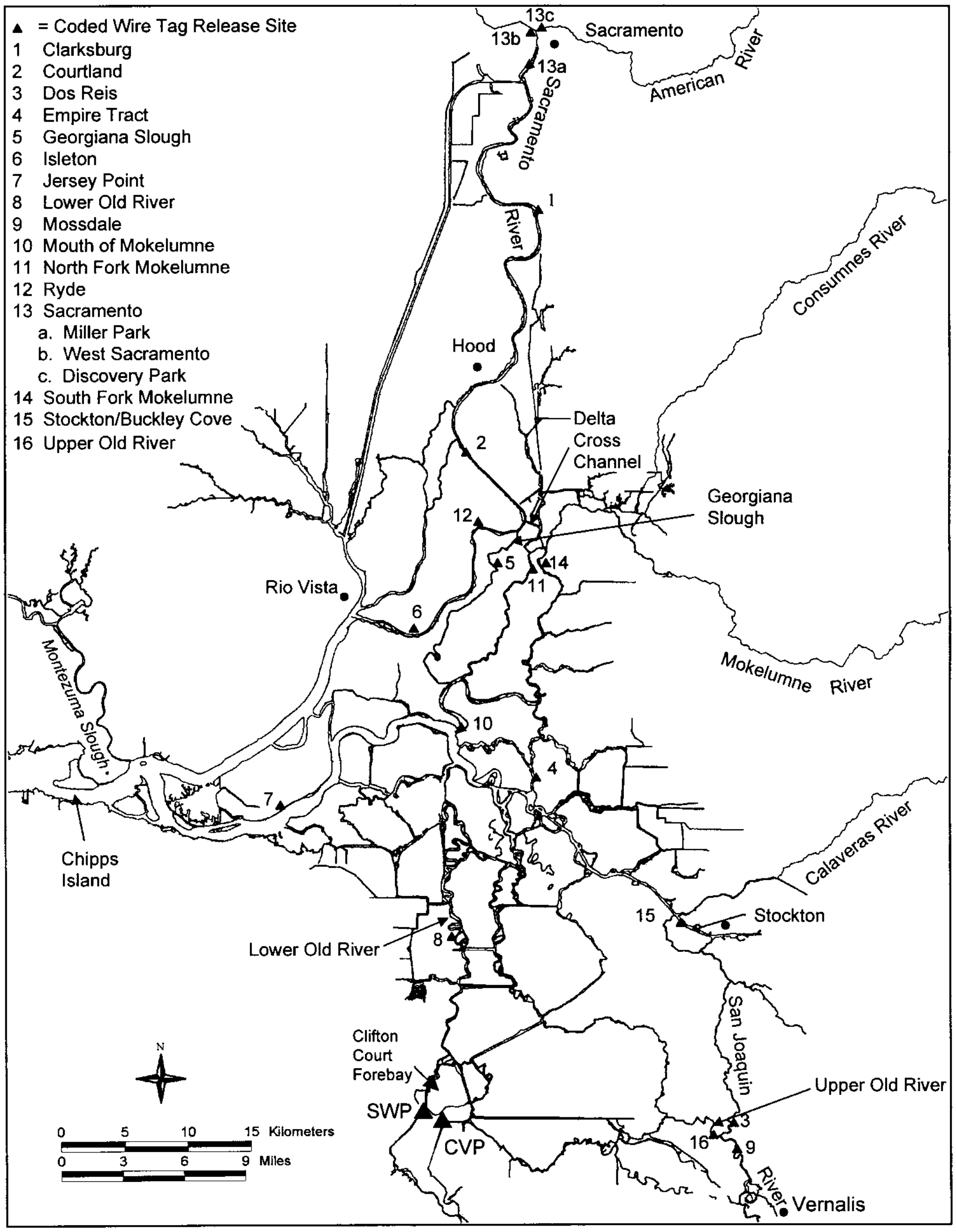

Figure 5 Detailed map of the Sacramento-San Joaquin Delta indicating coded wire tag release locations used between 1978 and 1997

There are many assumptions made in using hatchery fish to estimate the survival of wild fish. It is likely that wild fish survive at a greater rate than those released and reared at a hatchery (Reisenbichler and others 1992), but relative differences in survival of hatchery fish between different locations, times, sizes or other parameters can be informative. Using hatchery smolts to investigate factors affecting wild fish also seems appropriate (Kjelson and Brandes 1989) and we have found it useful in gaining information for managing and protecting wild juvenile salmon.

Chinook "fry," as defined in this report, is the life stage between emergence from the spawning gravel to the completion of upstream or estuarine rearing (<70 mm fork length). Juveniles that are starting to undergo behavioral and physiological changes to prepare for the transition to salt water are termed "smolts." In this report they are identified as juveniles equal to and greater than 70 mm fork length. Yearlings are defined as juveniles greater than 100 mm that have over-summered in freshwater.

Information contained in this paper is presented by topic: "Fry Abundance," "Smolt Abundance," "Fry Survival," and "Smolt Survival." Each topic includes methods, and results and discussion sections. The results and discussion sections under smolt survival are further sub-divided by basin (Sacramento and San Joaquin) and specific management issues.

The California Department of Water Resources provided flow and project export information via their DAYFLOW program. River flows were measured on the Sacramento River at "I" Street (in downtown Sacramento) and at Freeport, and on the San Joaquin River at Vernalis (Figure 1). River flows were estimated using calculations at Rio Vista and Stockton. Exports are the combined mean daily rate at the SWP and CVP in cubic feet per second (cfs).

A variety of statistical methods was used to evaluate relationships between abundance and survival and environmental conditions. Data used in the regression analyses were assessed for normality and heterogeneity of variance using the descriptive statistics function in SYSTAT 7.0 for Windows. Variables were transformed when necessary to meet the assumptions of parametric statistics.

Fry Abundance

Methods

Seasonal abundance and spatial distribution of juvenile salmon in the Sacramento-San Joaquin Estuary were estimated using beach seine surveys at sites in the Delta, lower Sacramento River and San Francisco Bay. Sites within the Delta and on the lower San Joaquin River were added in recent years to provide additional information on juvenile salmon distribution. Abundance and distribution data were collected to document the use of the Delta as a rearing area and evaluate its use relative to flow.

Beach seine sampling was made with a 15.2 by 1.2 m (50 ft by 4 ft) seine, with 3.2-mm (1/8-inch) mesh, during daylight hours. One seine haul was made at each sampling station. Thirty stations have been sampled weekly in the Delta and lower Sacramento River during the spring since 1979 and constitute core "historical" sites. Seven of the stations are located on the lower Sacramento River between Colusa and Elkhorn (10 miles north of Sacramento) and twenty-three sites are located in the Delta (Figure 6). The sites in the Delta were divided into three areas: the North Delta, Central Delta, and South Delta.

In addition, between 1981 and 1986, 16 stations were sampled twice a month in Suisun, San Pablo, and San Francisco bays (Figure 6) of which ten were re-sampled during the spring in 1997. Sites include boat ramps, mud banks, and sandy beaches. There were times when sampling was not possible due to changes in flow or other conditions that prevented site access. The beach seining sites added in recent years are located primarily in the South Delta and lower San Joaquin River (Figure 6). Additional sites on the Sacramento River have also been sampled in recent years, but discussion of these sites is not included in this report.

Water temperature was measured, and all fish species captured were identified and enumerated at each sample site. In each sample, up to 50 juvenile salmon were measured to the nearest millimeter fork length. All tagged salmon were kept for subsequent tag decoding.

Relative juvenile salmon abundance was compared within and between years using catch per haul or catch per cubic meter at the core "historical" sites sampled during similar periods between years. Average catch per haul is defined as the number of juvenile salmon caught divided by the number of seine hauls performed.

It became possible to calculate catch per cubic meter starting in 1985, when the depth, length, and width of the area swept by the beach seine were measured as part of the normal sampling protocol. Depth is the maximum depth swept by the seine haul. Length of the seine haul is the distance the haul was taken from shore and width is the measured scope of the seine haul, which is parallel to shore. The area of the seine haul was used to estimate the volume of water sampled, which was calculated by multiplying the depth of the sample by 0.5, then multiplying the product by the length and width of the seine haul. Catch per cubic meter (C/m^3) is estimated by dividing the catch by the volume of water sampled and yields a more robust density measurement than catch per haul.

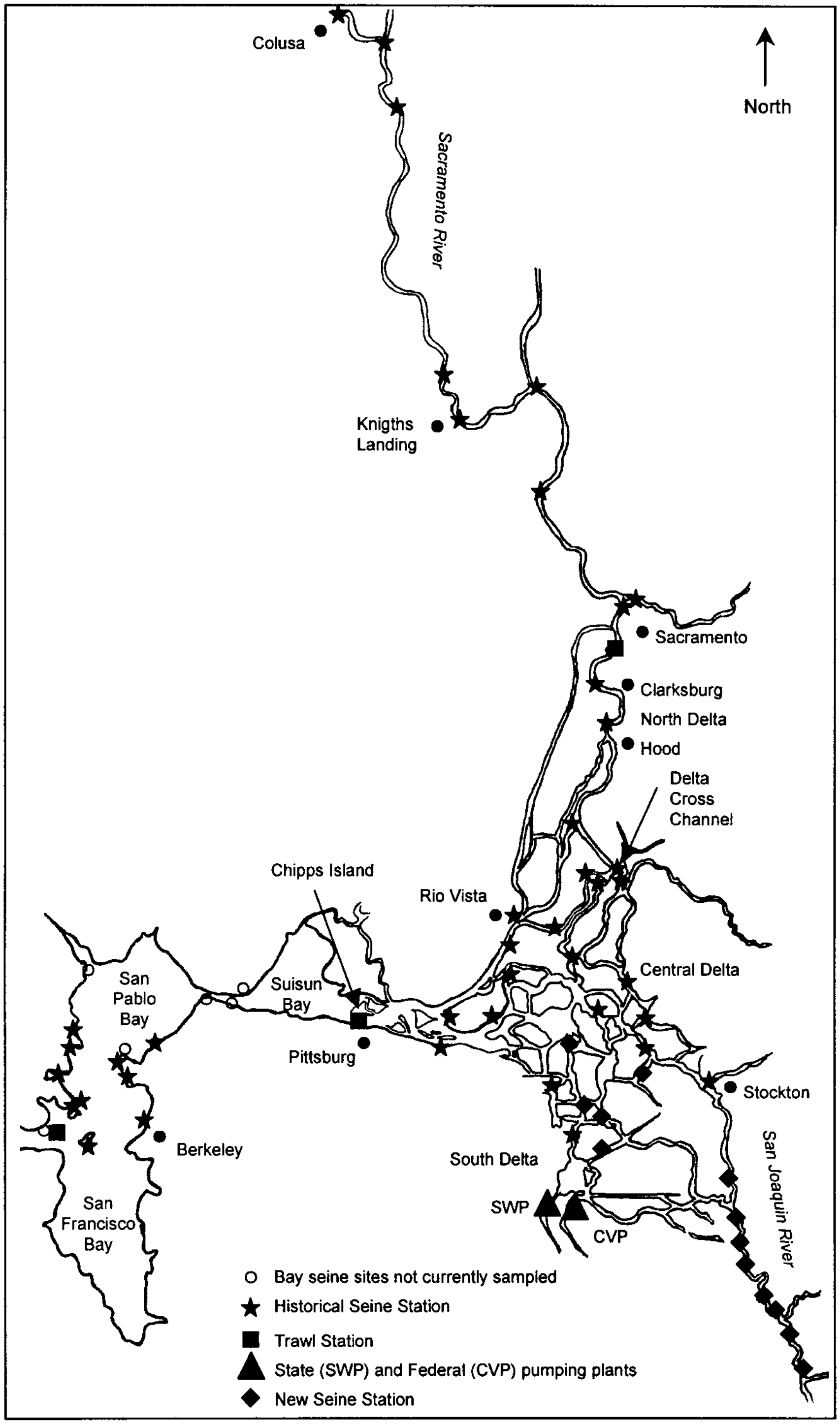

Figure 6 Sampling sites located in the Sacramento-San Joaquin Estuary, California

The average monthly C/m^3 and catch per haul, by area, was calculated by summing the average monthly C/m^3 or catch per haul for all sites within an area, and dividing by the number of sites sampled. The average monthly C/m^3 or catch per haul by site was estimated by summing the monthly C/m^3 or catch per haul for each site and dividing by the number of months sampled. Each monthly C/m^3 or catch per haul by site was estimated by summing the daily C/m^3 or catch per haul and dividing by the number of times the site was sampled within the month. The daily C/m^3 by site was estimated by dividing the catch by the volume of water sampled. Only one sample was taken at each site per day and generally each site was sampled once per week.

Simple linear regression analyses were used to determine if fry abundance in the North Delta and bay varied with flow. A constant 0.0001 was added to the catch per cubic meter in the bay before being log transformed. Sacramento River flow at Freeport was also log transformed for the regression analyses between catch per cubic meter in the bay and flow.

Results and Discussion

The number of fry in the estuary is influenced by the number of eggs deposited and environmental conditions during spawning, incubation, and rearing. Kjelson and others (1982) found that peak catches of fry in the Delta in the spring followed major runoff periods. We found that the annual spring abundance of fry in the Delta was also related to flow, with the highest abundance observed in wet years. Fry abundance in the North Delta between January and March, using catch per cubic meter in the beach seine, was significantly correlated ($r^2 = 0.69$, $P < 0.01$) to the mean flow in the Sacramento River at Freeport in February (Figure 7). Catch per cubic meter reduced the variability in the relationship even though some of the data from earlier years could not be included (Figure 8).

Based on sampling upstream of the Delta, it appears many fall run juveniles from the American and Feather rivers migrate to the Delta as fry in both wet and dry years (Snider and others 1998; Sommer and others 2001, this volume). Fry, originating from the San Joaquin tributaries, also were apparent in the Delta during the spring in the wet years (Figure 9). Sampling has not been conducted early enough in the season in dry years to determine if many fry move downstream into the Delta from the San Joaquin basin to rear in the drier years.

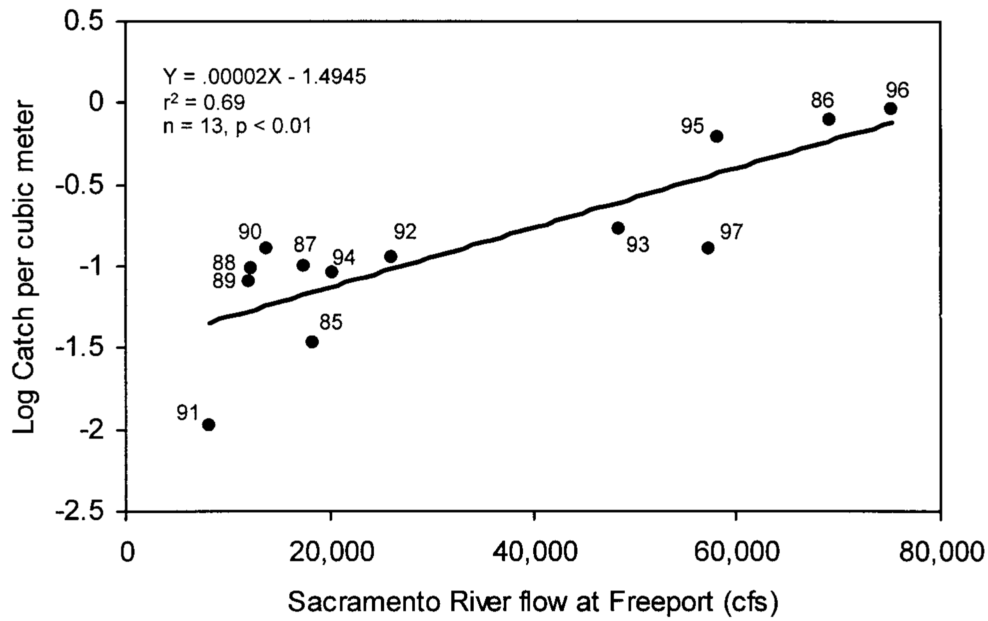

Figure 7 Catch per cubic meter of juvenile chinook salmon in the North Delta beach seine between January and March versus mean February flow on the Sacramento River at Freeport from 1985 to 1997

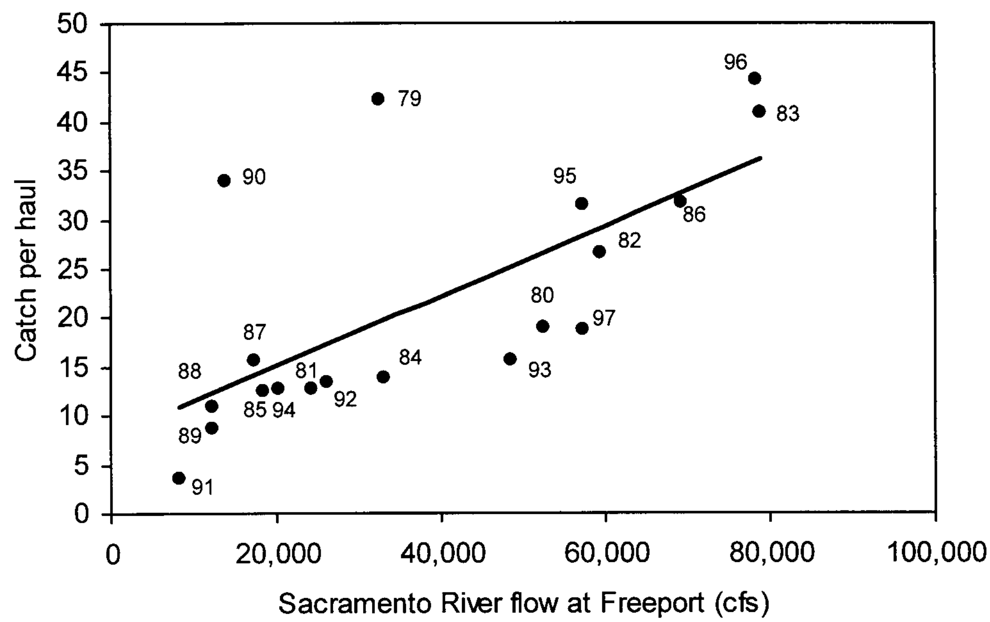

Figure 8 Catch per haul of juvenile chinook salmon in the North Delta beach seine between January and March versus mean February flow on the Sacramento River at Freeport from 1979 to 1997

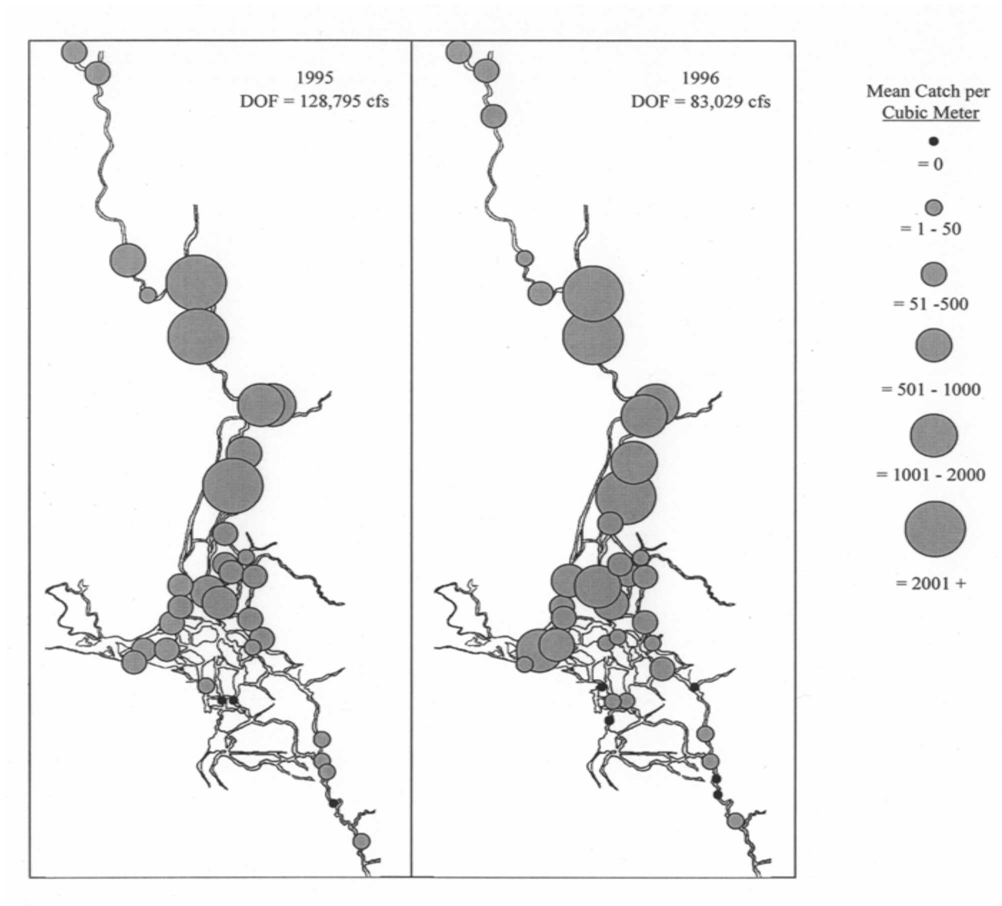

Figure 9 Mean monthly catch per cubic meter (x 1,000) of chinook salmon fry from beach seine sites and mean Delta outflow (DOF) between January and March in 1995 and 1996

Fry abundance during the spring in San Francisco Bay shows a similar effect of flow. We found that the average catch per cubic meter (plus 0.0001 and logged) in ten beach seine sites sampled in San Pablo and San Francisco bays (January through March) was positively correlated to the log of the mean daily Sacramento River flow at Freeport in February ($r^2 = 0.98$, $P < 0.01$) (Figure 10). Flow at Freeport was used, as most of the net flow moving from the Delta into the bay (Delta outflow) originates from the Sacramento River.

These results are consistent with Healy (1980) who observed increased chinook salmon fry catch during increased discharge in the Nanaimo River Estuary in British Columbia. Other studies have speculated that behavioral interactions and density dependent mechanisms were responsible for downstream migration (Healy 1991).

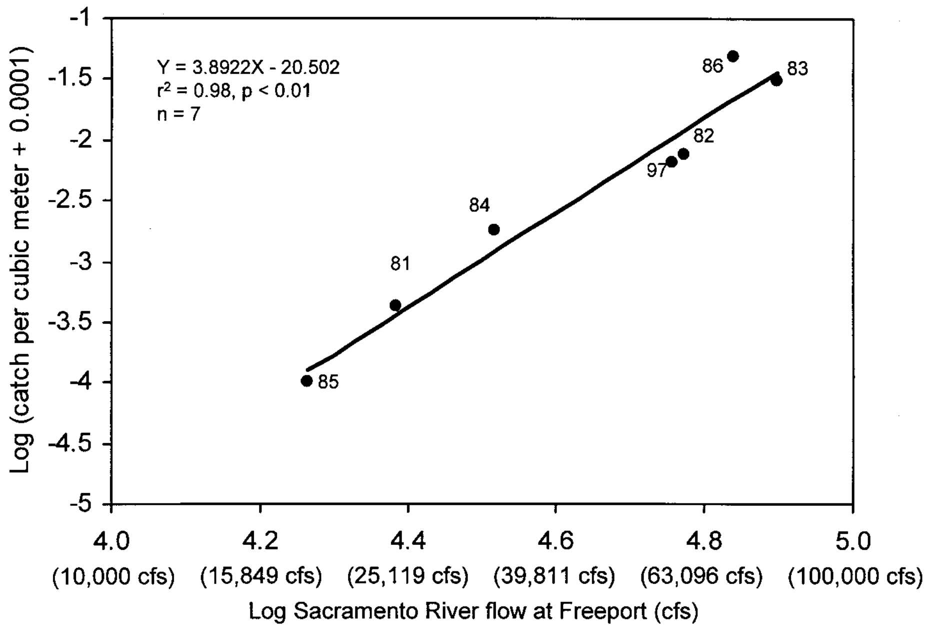

Figure 10 Log of catch of chinook fry per cubic meter (+ 0.0001) between January and March at beach seine sites in the San Francisco Bay versus log of mean flow at Freeport during February between 1981 and 1986 and in 1997. The equation without the 1986 outlier is $y = 3.6218x - 19.316$.

There were relatively few fry in the Delta during the other months of the year and likely reflected the lower abundance of the other races, lower Delta inflow, higher summer water temperatures and different life history strategies. Fry have been observed in the beach seining between April and July in some years; many were assumed to be late-fall run. They ranged in size between 30 and 53 mm. In addition, a nominal number of fry has been recovered in the Delta between November and January that ranged in size between 48 and 67 mm and were likely winter run. Overall, less than 300 fry have been observed in beach seining during the late spring and summer and late fall and winter between 1977 and 1997. In the earlier years, sampling was limited during the fall and winter months, but in recent years sampling frequency has generally been similar to that conducted in the spring.

Smolt Abundance

Methods

Since 1976, Kodiak or midwater trawls have been used near Sacramento and at Chipps Island (located near the city of Pittsburg) for a variety of purposes.

Initially, midwater trawling was conducted for approximately six weeks during the spring on the Sacramento River near Hood (1976–1981) and at Chipps Island (1976 and 1977) to recover marked fish released in those years (Kjelson and others 1982). Since 1978 at Chipps Island and 1988 at Sacramento, midwater trawling has been conducted between April and June to index the number of primarily fall-run smolts entering (Sacramento) and leaving (Chipps Island) the Delta (Figure 6).

Since 1992 at Sacramento and 1994 at Chipps Island, trawling has been conducted consistently between October and June and provides information on all races of juvenile salmon entering and leaving the Delta. Year-round trawling was conducted at Chipps Island in 1980 and at both locations in recent years (1996 and 1997). Starting in the fall of 1994, a Kodiak trawl replaced the midwater trawl at Sacramento during the fall and winter months to allow more intensive sampling of larger individuals from the less abundant races due to the larger net width and herding fashion of the Kodiak trawl (McLain 1998). The midwater trawling has continued at Sacramento between April and June to allow historical comparisons using the same gear.

Midwater trawling also was conducted in San Francisco Bay, near the Golden Gate Bridge (Figure 6) between 1983 and 1987. Sampling was conducted, primarily between April and July, to index the abundance of juvenile salmon migrating out of the bay during those months and to recover marked salmon released at Port Chicago in 1984, 1985, and 1986 (USFWS 1987). Only the survival information is presented in this report.

In general, 10 twenty-minute tows were done per sample day at each location, between three and seven days per week during the months sampling was conducted. Both the midwater trawl and Kodiak trawl fished the net at the surface. Occasionally, inclement weather, mechanical problems, or excessive fish catches required reducing tow times or the number of tows. All trawling at Sacramento was done in the middle of the channel facing upstream against the current within 1.5 km of the sample site. Trawling at Chipps Island also was done within 1.5 km from the sample site in both directions regardless of tide, and in three locations of the channel: north, south, and middle.

The midwater and Kodiak trawl nets at Sacramento, Chipps Island, and in San Francisco Bay varied in size and design. The midwater trawl net used at Sacramento had a mouth opening of 1.8 by 4.6 m (6 ft by 15 ft) (Figure 11a). The net tapered from the mouth to the cod end totaling 23.6 m (77.5 ft) to the beginning of the cod end. Net mesh varied from 102 mm (4 inches) to 6 mm (1/4 inch) at the cod end. Wings were constructed of 203-mm (8-inch) stretch mesh and attached to each of four corners of the net. Lead weights were attached to the bottom rib line of the net and floats attached to the top rib line. A metal depressor door was fastened to each bottom bridle line and an aluminum hydrofoil was fastened to each top bridle line. The midwater trawl at Chipps Island and in San Francisco Bay used a net with a mouth opening of 3.0 by 9.1 m (10 ft by 30 ft), was tapered from the mouth to the cod end, and totaled 25 m (82 ft) (Figure 11b). Net mesh and wings were similar to that used for the Sacramento midwater trawl. The Kodiak trawl net also was variable mesh with a fully expanded mouth opening of 1.8 by 7.6 m (6 ft by 25 ft) (Figure 11c). Net mesh varied from 51-mm (2-inch) stretch mesh to 6 mm (1/4 inch). A 1.8 m bar was attached to the front of each wing with lead and float lines on the bottom and top of the net respectively. The Kodiak trawl also incorporated a live box attached to the cod end of the net to avoid fish mortality. The live box consisted of perforated steel plating 6 mm (1/4 inch) in diameter.

Actual fishing dimensions of the nets varied and have been described in past reports (USFWS 1994). Based on these studies, the mean effective-fishing mouth size of the net at Sacramento was found to be 5.1 m^2 and 18.5 m^2 at Chipps Island. The estimated fishing net mouth size of the Kodiak trawl, based on these midwater trawl studies, was 12.5 m^2. The catch per cubic meter and mean amount of water sampled reported in this paper were based on these fishing mouth dimensions.

Cubic meters of water sampled with the trawls were estimated with a General Oceanics mechanical flowmeter (model 2030). Linear meters were calculated by multiplying meter rotations with the Standard Speed Rotor Constant (26,874) and dividing the result by a conversion factor (999999). The volume of water sampled was calculated by multiplying the number of linear meters traveled per tow by the mouth opening of the net.

Relative abundance was compared using average catch per cubic meter (C/m^3), where C/m^3 per tow equaled: catch per tow/net mouth area (m^2) x linear meters traveled through the water (m). Averages were calculated for each day, week and month. Each daily C/m^3 was calculated by averaging each C/m^3 per tow and dividing by the number of tows that day. Each weekly C/m^3 was calculated by summing the daily C/m^3 and dividing by the number of days sampled within the week. The monthly C/m^3 was the sum of weekly averages divided by the number of weeks sampled per month. Weeks were designated as Monday through Sunday and weeks which overlap months were split and included in their respective months.

Simple linear regression techniques were used to evaluate the relationships between C/m^3 and river flow. Mean C/m^3 between April and June at Sacramento was squared before regression analysis.

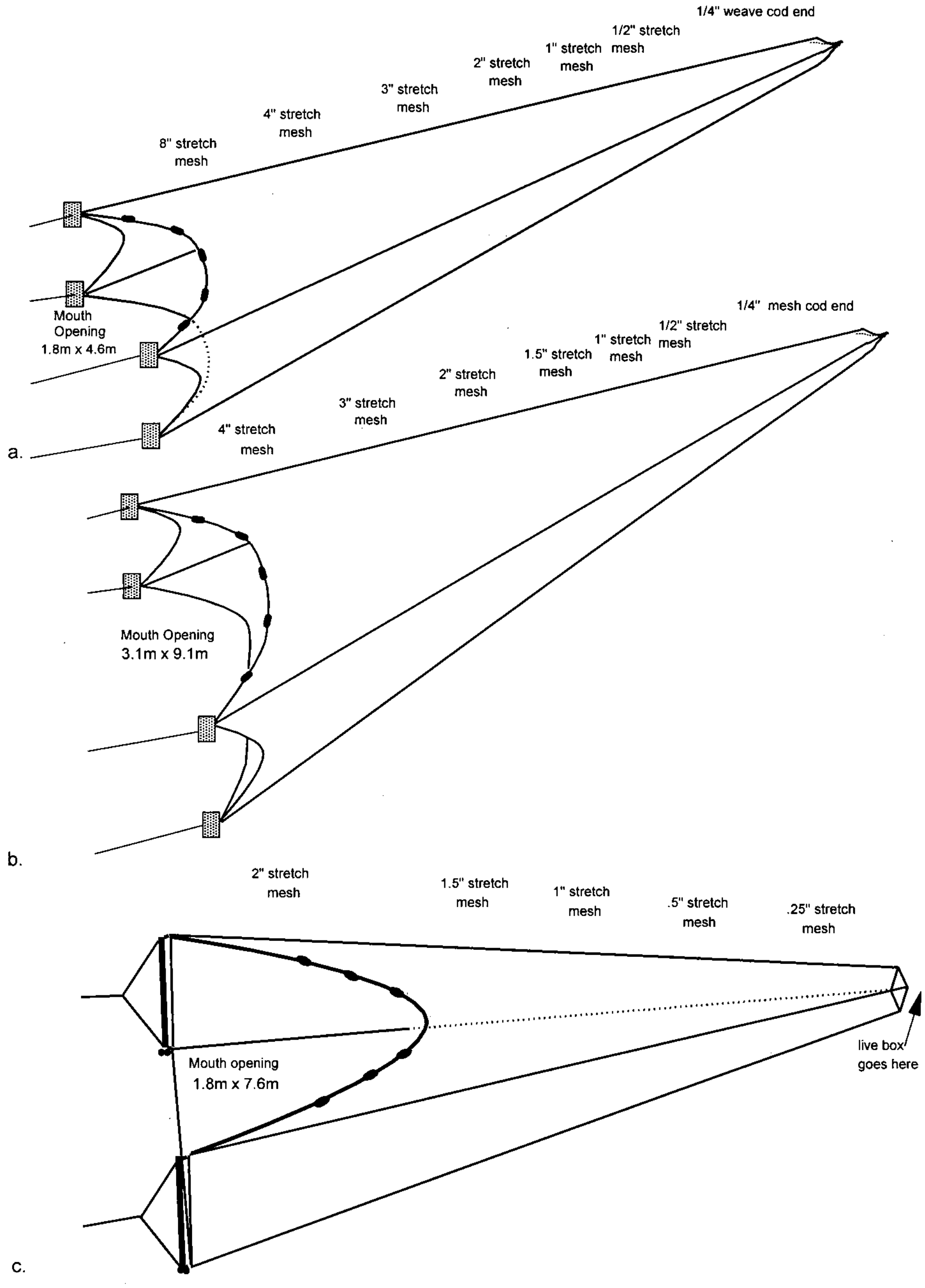

Figure 11 Schematic drawing of (a) midwater trawl net used at Sacramento, (b) midwater trawl net used at Chipps Island and in San Francisco Bay and (c) Kodiak trawl net used at Sacramento

Results and Discussion

The mean midwater trawl C/m^3 (squared) of unmarked smolts, primarily fall run, migrating past Sacramento between April and June was inversely and significantly (r^2 = 0.88, P < 0.01) related to mean Sacramento River flows in February (Figure 12). If this density measurement is a true index of abundance then it appears fewer smolts migrate into the Delta when flows are higher in the early spring (February).

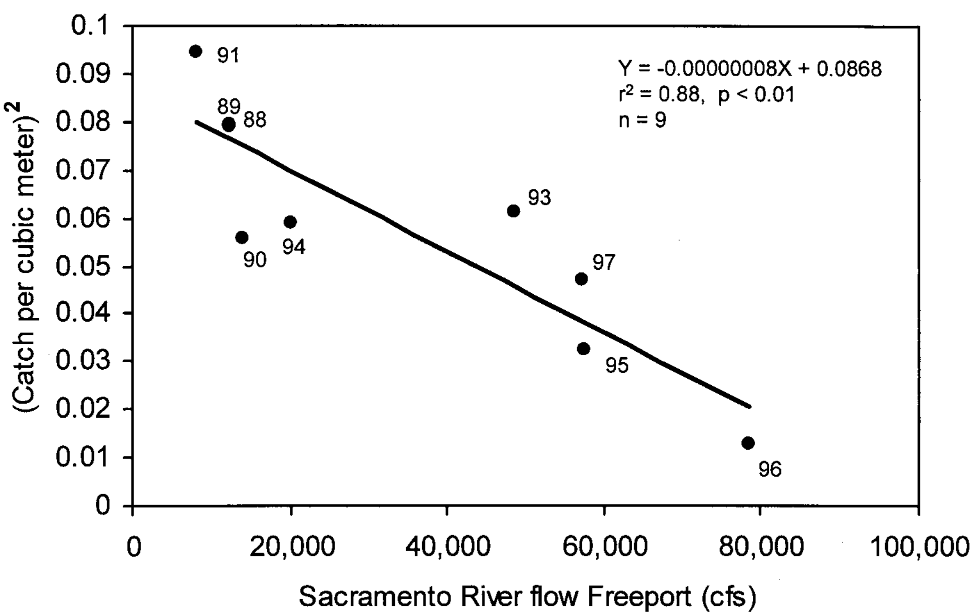

Figure 12 Mean catch of unmarked chinook salmon smolts per cubic meter (squared) in the midwater trawl at Sacramento between April and June of 1989 to 1997 versus mean daily flow (cfs) at Freeport on the Sacramento River during February. Data from 1992 were not included in the model because no sampling was done during April and late June in that year.

Catch of unmarked smolts in the midwater trawl at Chipps Island indicated that overall juvenile salmon production migrating from the Delta was greater in wet years. Mean catch per cubic meter between April and June at Chipps Island was positively correlated to flow at Rio Vista (r^2 = 0.78, P < 0.01), indicating that, overall, the density of juveniles leaving the Delta increases as flows increase (Figure 13). In addition, since many fry were observed downstream of Chipps Island in high flow years before April, the estimates of the juvenile production migrating past Chipps Island was underestimated in the high flow years. Stevens and Miller (1983) also found significant relationships between inflow and an index of abundance of fall run chinook in the Delta between April through June.

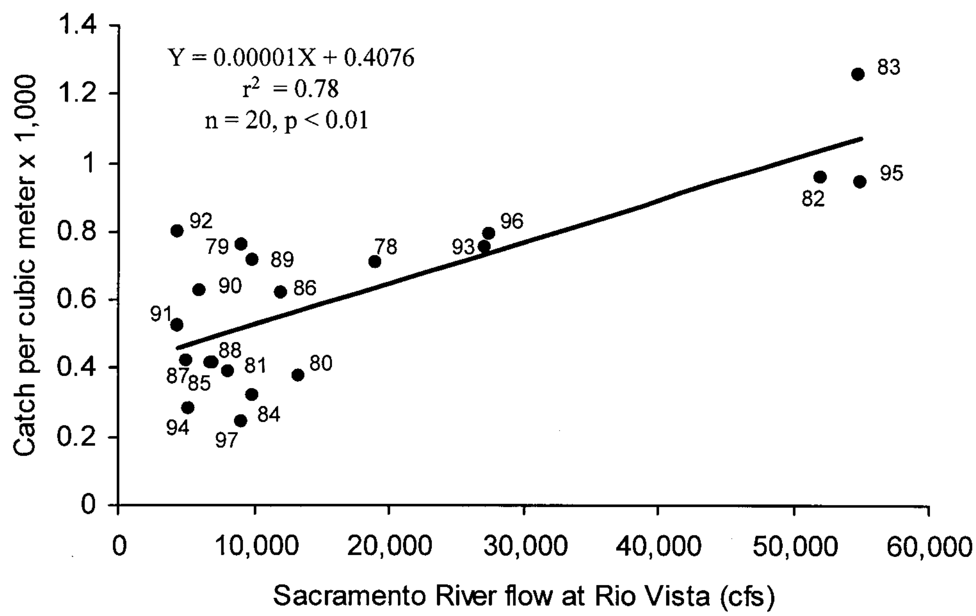

Figure 13 Mean catch of unmarked chinook salmon smolts per cubic meter (x 1,000) in the midwater trawl at Chipps Island between April and June from 1978 through 1997 versus mean daily Sacramento River flow (cfs) at Rio Vista between April and June

Catches at both Sacramento and Chipps Island include fall-run smolts released from Coleman National Fish Hatchery. Therefore, the Chipps Island abundance versus flow relationship incorporates flow effects on these hatchery fish as well as wild smolts. In recent years, about 12 million smolts have been released (Tom Nelson, personal communication, see "Notes"). Most other unmarked hatchery fish in the Central Valley are released downstream of Chipps Island.

Catches at Sacramento and Chipps Island during other months of the year indicated low abundance, until the December-January period when fall run fry enter the catches (Figure 14 and 15). Although, Figures 14 and 15 do not precisely show abundance, they show all unique lengths measured which illustrates this point.

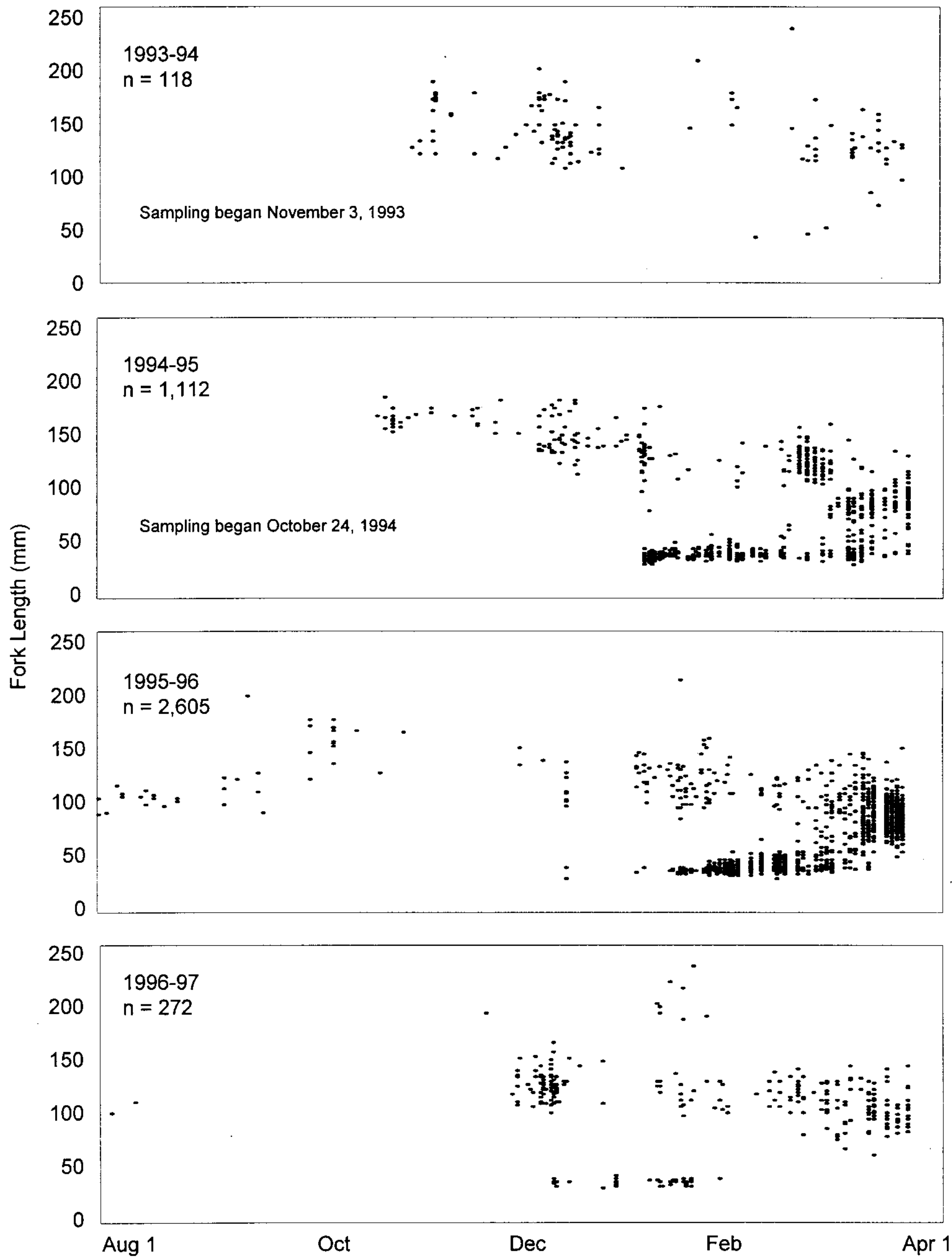

Figure 14 Measured juvenile chinook captured in the midwater trawl at Chipps Island near Pittsburg, California, between August 1 and March 31

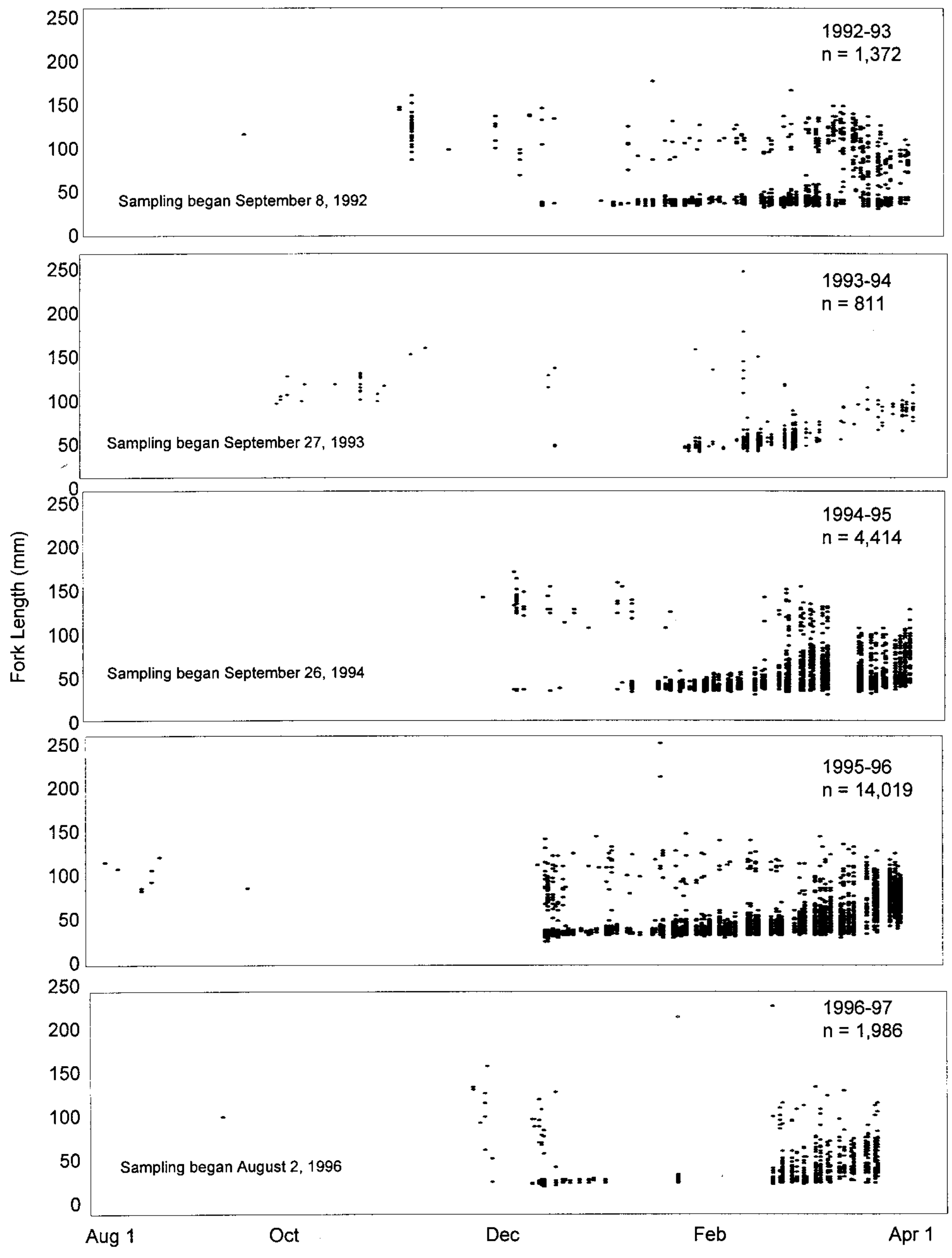

Figure 15 Measured juvenile chinook salmon captured in the midwater trawl and/or Kodiak trawl on the Sacramento River near Sacramento between August 1 and March 31

Fry Survival

Methods

Mark and recapture experiments with fry were conducted between 1980 and 1987 to (1) estimate survival in the upper Sacramento River, Delta and San Francisco Bay, under various river flows and (2) in later years, assess the impacts on survival of using existing Delta channels for water transport. Survival for fish released upstream in the Delta and in the bay was evaluated at various flows because river flows were anticipated to change with the operation of the proposed Peripheral Canal. The effects to juvenile salmon of using existing Delta channels for water transport were evaluated by estimating differential survival of marked fry released at locations in the North, Central and South Delta. Fry releases in the Delta were discontinued in 1988 to increase the number of marked smolts available for release.

Fry were obtained from Coleman National Fish Hatchery (Figure 4), adipose fin-clipped, and tagged in the snout of the fish with coded-wire half tags (CW½T). Recoveries of these marked fish were made in the beach seine, at the State and federal fish salvage facilities located at the respective pumping plant intake, and in the ocean fishery.

Ocean recovery rates are relative indices that were used to compare survival between locations within a year. The ocean recovery rate is the expanded number of recoveries in the ocean fishery divided by the number released (Kjelson and Brandes 1989). Catches in the ocean sport and commercial fishery were expanded based on the percentage of sampling conducted at the various ports (PSMFC 1998).

To compare survival between years, an estimate of absolute fry-to-smolt survival was obtained by comparing the recoveries in the ocean fishery of fry released in the Delta (or upstream) to those released at Port Chicago (or Benicia) in Suisun Bay (Kjelson and Brandes 1989). In some cases releases at Ryde were used as the downstream control group. We assume that the ratio between upstream and downstream groups factors out the smolt survival downstream of Suisun Bay from the upstream release group.

Ocean recovery rates for CW½T groups released on different days at the same location were averaged before analyses. Groups with different tag codes released at the same location on the same day were considered one group and recoveries were summed and divided by the total number released to represent the group. Two sample and student *t*-tests were used to test for significant differences between treatments at the 95% confidence level.

Results and Discussion

Ocean recovery rates indicated that relative survival was higher for fry released in the upper Sacramento River below Red Bluff Diversion Dam (RBDD) than for fry released in the North Delta, especially in the higher flow years (Figure 16). Those released in the bay had the lowest recovery rates in all years. The upper river release groups were recovered, on average, about five times greater than those released in the Delta in wetter years of 1980, 1982, and 1986 (Figure 16). We have defined the wetter years as those with mean February flows at "I" Street greater than 50,000 cfs. Although a dry year, 1987 also exhibited much greater survival upstream than in the Delta.

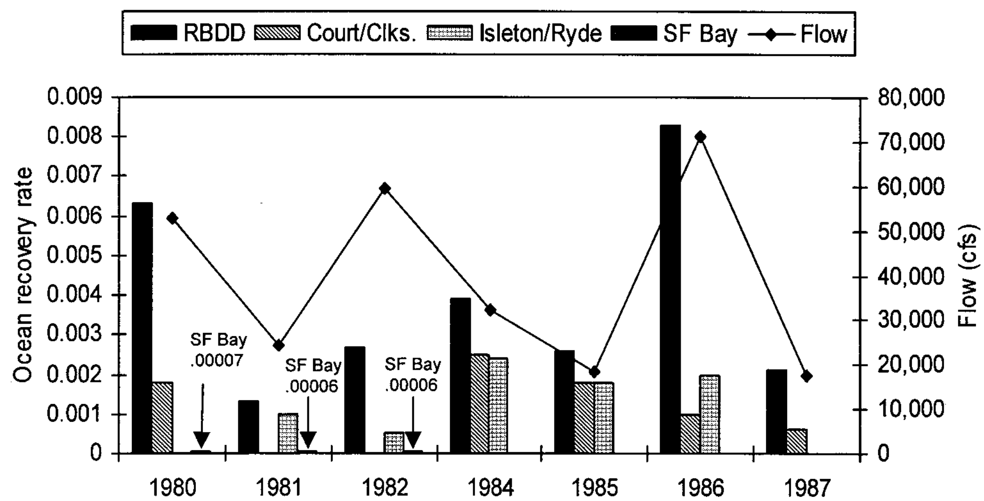

Figure 16 Ocean recovery rates of CW½T fry released in the upper Sacramento River below Red Bluff Diversion Dam (RBDD), in the Delta at Courtland or Clarksburg and Isleton or Ryde, and mean daily Sacramento River flow at "I" Street in February

Estimates of absolute survival provide additional support for the conclusion that survival is higher for upstream releases in the wet years. Absolute survivals of the RBDD release groups were significantly higher than the Delta release groups in wet years (two sample *t*-test, $t = 8.28$, $n = 3$, $P = 0.014$) (Table 1). In the drier years there was not a significant difference between fry released upstream and the Delta.

Table 1 Survival estimates for CW½T fry released below Red Bluff Diversion Dam in the Delta, mean daily Sacramento River flow at "I" Street during the month of February, and ocean recovery rates for smolts released at Port Chicago, Benicia or Ryde[a]

	Release location				
Year	*Red Bluff Diversion Dam*	*Courtland or Clarksburg*	*Isleton or Ryde*	*Port Chicago, Benicia, or Ryde*	*Mean daily Sacramento River flow at "I" Street (cfs)*
1980	0.29	0.08		0.022[b]	52,576
1981	0.05		0.04	0.028[b]	24,239
1982	0.39		0.07	0.009	59,432
1984	0.51	0.33	0.32	0.008[b]	32,949
1985	0.26	0.19	0.18	0.010[b]	18,376
1986	0.29	0.03	0.07	0.029[b]	69,306
1987	0.10	0.03		0.020[b]	17,404

[a] A Ryde release was used in 1987 because there were no groups released at Port Chicago or Benicia that year.

[b] Indicates Feather River Hatchery stock was used for the release. For all other releases, Coleman National Fish Hatchery stocks were used.

The observed wet year differences could be a result of increased survival of upstream fish or decreased survival in the Delta. The fact that Delta survival was not lower in wet years suggests that the trends are due to improved survival upstream. One hypothesis is that increased flows provide additional rearing habitat in the upper Sacramento River since there are large areas of floodplain (e.g. the Sutter and Yolo bypasses) that become accessible. Such habitat is not present along the Delta levees. Another explanation could be that some proportion of those released in the Delta moved downstream into the bay in the high flow years where observed survival was extremely poor making comparisons between those released in the Delta and those released upstream more difficult. Those released upstream also could have moved downstream into the Delta in the high flow years. Review of the recoveries by location in the beach seine survey indicated that some of those released upstream below Red Bluff Diversion Dam were recovered in the Delta soon afterwards, but recoveries were made in both dry and wet years (Table 2).

Table 2 CW½T fry released in the Delta and upper Sacramento River below Red Bluff Diversion Dam (Below RBDD) and recovered as fry (<70 mm) downstream of the Delta (Bay) and in the Delta, respectively, between 1980 and 1982[a]

Release site and date	*Recapture site (Delta or Bay)*	*Recapture date*
Clarksburg (Delta)		
26 Feb 1980	Crockett Marina (near Benicia) (Bay)	03 Mar 1980
07 Mar 1980	Montezuma Slough (Bay)	11 Mar 1980
Below RBDD		
12 Mar 1980	American River (near Sacramento) (Delta)	25 Mar 1980
	Brannon Island (near Rio Vista) (Delta)	02 Apr 1980
Isleton (Delta)		
12 Feb 1981	Montezuma Slough (2)	17 Feb 1981
	Montezuma Slough (2)	04 Mar 1981
04 Mar 1981	Montezuma Slough	17 Mar 1981
Below RBDD		
06 Feb 1981	Steamboat Slough (Delta)	12 Feb 1981
	Isleton (Delta)	26 Feb 1981
	Montezuma Slough (2)	04 Mar 1981
Isleton (Delta)		
02 Mar 1982	Antioch (near Chipps Island) (Bay)	30 Mar 1982
Below RBDD		
05 Feb 1982	Discovery Park (near Sacramento) (Delta)	09 Mar 1982
25 Feb 1982	Ryde (Delta)	09 Mar 1982
	Discovery Park	16 Mar 1982
	Discovery Park	30 Mar 1982

[a] No recoveries of fry released in the Delta or in the upper Sacramento River were made downstream of the Delta or in the Delta, respectively, between 1983 and 1987.

To evaluate growth as a potential mechanism for the higher survival observed upstream in these high flow years, we looked at growth rates of the CW½T fish released and recovered upstream and in the Delta in 1982, a high flow year. We did not find significant differences in growth between the two areas (using a student *t*-test to compare the slopes of the two lines) (Figure 17).

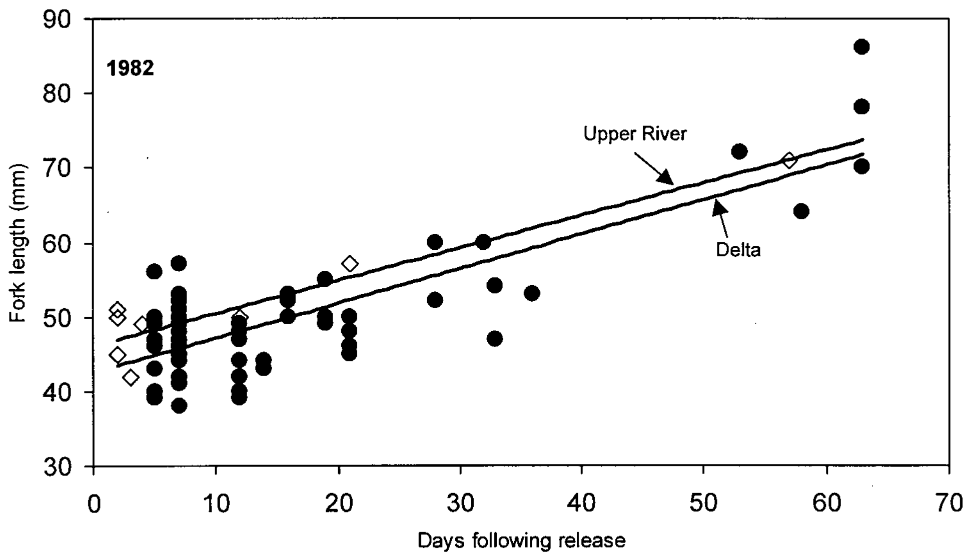

Figure 17 Growth curves for CW½T fry released and recaptured in the Delta (circles) and the upper Sacramento River (diamonds), between February 7 and April 28, 1982

Results, from additional CW½T fry released at various locations in the Delta between 1981 and 1985, indicated that in drier years survival was higher in the North Delta than in the Central Delta. Although not statistically significant, the ocean recovery rates were somewhat higher from CW½T fry released in the North Delta (Courtland, Ryde, or Isleton), relative to those released in Central Delta (at the mouth of Mokelumne River and in the North and South Forks of the Mokelumne) in the drier years (Figure 18). In the wetter years of 1982 and 1983, those released in the Central and South Delta (the mouth of the Mokelume River) appeared to survive at a similar rate as those released at Isleton (Figure 18). The lower Old River release even seemed to survive at a relatively high rate in 1983 (Figure 18). One mechanism for the lower survival of fry released in the Central Delta in dry years could be the greater effect of the pumping plants on hydrology in these years. In dry years (1981, 1984, 1985, and 1987), CW½T fry were recovered at the fish facilities, whereas in the wetter years they were not (1980, 1982, 1983 and 1986) (Appendix A).

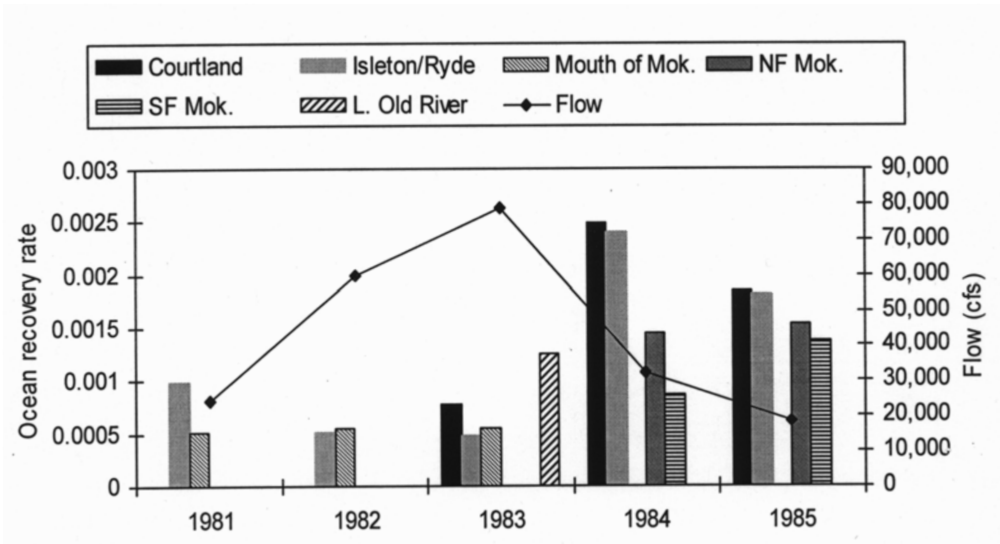

Figure 18 Ocean recovery rates for CW½T fry released at various locations in the Delta and mean daily Sacramento River flow at "I" Street in February

Smolt Survival

Methods

Mark and recapture studies also were conducted with fall run smolts starting in 1969. Survival through the Delta for smolts released near Sacramento was estimated between 1969 and 1971, 1976 and 1977, and 1978 and 1982 to document the importance of freshwater inflow on the survival of juvenile salmon migrating through the estuary (DFG 1976; Kjelson and others 1981, 1982). In 1983, the program was expanded to also examine the differential vulnerability to water project operations of marked smolts released at four locations in the Delta. These experiments were also used to evaluate the effect of movement into the Central Delta via the Delta Cross Channel and Georgiana Slough on the survival of juvenile salmon in the Delta. To separate the effects of flow from diversion into the Central Delta, experiments were conducted between 1987 and 1989 during low flows with the Delta Cross Channel gates open and/or closed. Prior to 1987, closure of the Delta Cross Channel gates only occurred in wet years. Between 1992 and 1997, survival was evaluated for fall-run smolts and late-fall-run yearlings released into Georgiana Slough in the Central Delta relative to those released on the mainstem Sacramento River. Late-fall-run yearlings were used as surrogates for winter-run juveniles to estimate the effects of diversion into the Central Delta on winter-run salmon.

Mark and recapture methodology also was used to evaluate survival in the San Joaquin Delta starting in 1985. Between 1985 and 1990, marked fish releases were made to evaluate the differential survival of smolts migrating through upper Old River relative to those continuing to migrate down the mainstem San Joaquin River. In 1992, 1994, and 1997, a temporary rock barrier was installed in upper Old River and marked smolts were released to determine if survival through the South Delta was increased with the barrier in place. In 1997, the rock barrier was changed to include two 48-inch culverts. In 1993, 1995, and 1996, the barrier was not installed because of high flows or lack of a permit, although survival through the South Delta was measured for comparison purposes. In addition, releases also were made in 1995 and 1996 to estimate the mortality associated with migration through upper Old River. Paired releases with smolts from both Feather River Hatchery and Merced River Fish Facility were made in 1996 and 1997 to address concerns that stock origin of the experimental fish had confounded previous results. In addition, physiological studies were conducted and subsets of fish were held in live cars to determine the potential cause of mortality or mortality differences between stocks if they were found. The role of exports was explored in 1989, 1990 and 1991 when releases were made at high, medium, and low exports.

Additional marked fish releases were made in the bay and upstream of the Delta. Survival through the bay was estimated to help develop outflow criteria to meet the needs of juvenile salmon migrating through San Pablo and San Francisco bays. Survival of smolts released from Coleman National Fish Hatchery into Battle Creek, at Merced River Fish Facility, and from the Feather River Hatchery released at the Feather River (Figure 4) has been measured in many years and provides an index of the survival of smolts migrating through the rivers and Delta.

For smolt and yearling mark and recapture experiments, hatchery fish were spray-dyed or fin-clipped and tagged with full sized coded-wire tags (CWT). Fall-run smolts used in the Delta experiments were obtained from Feather River Hatchery (FRH). Late-fall-run yearlings were obtained from Coleman National Fish Hatchery (CNFH). Hatchery smolts used in the San Joaquin Delta experiments originated from the Merced River Fish Facility (MRFF) between 1985 and 1987 and from the FRH between 1990 and 1995. In 1989, 1996, and 1997, both MRFF and FRH stocks were used. Smolts released at Jersey Point between 1989 and 1991, and 1994 and 1997 originated from FRH. In 1996 and 1997 releases also were made at Jersey Point with smolts from MRFF. Two groups of smolts released at Port Chicago and in San Francisco Bay in 1984 were from Nimbus Fish Hatchery. The location of the hatcheries is shown in Figure 4.

Water temperatures were measured in the transport truck (both at the hatchery and at the release site) and in the receiving water.

Recoveries of marked smolts and yearlings were made in the midwater trawl at Chipps Island, at the CVP and SWP fish salvage facilities, and as adults in the ocean fishery. (This report does not discuss inland adult recoveries.) Recoveries at the fish salvage facilities provided insight into the direct mortality of juvenile salmon within the Delta.

Sampling at the State and federal facilities generally occurred at ten-minute intervals every two hours, 24 hours per day, although the sampling protocol before 1985 was not as thorough or systematic. Marked salmon observed in the sampling were kept for tag recovery and were called unexpanded recoveries. To estimate the total number of marked salmon salvaged at the facilities (expanded salvage) those recovered in the sample are expanded by fraction of time sampled. (It should be noted that expanded salvage is not "loss." Loss would include mortality associated with pre-screen and screen efficiency losses.)

Relative and absolute survival were estimated using recoveries made at Chipps Island and in the ocean fishery. Survival indices to Chipps Island (relative survival) were estimated by dividing the number of fish recovered from each particular tag group by the number released, corrected for the fraction of time and channel width sampled using the midwater trawl at Chipps Island (Kjelson and Brandes 1989). Relative survival also was estimated using the recovery rate of marked fish as adults in the ocean fishery and was used to compare survival between locations within a year. Survival estimates (absolute survival) were obtained using the differential recovery rate of an upstream group relative to a downstream group, either at Chipps Island or in the ocean fishery and used to compare survival between years. This approach has the advantage of reducing variation due to differential gear or sampling efficiency between years. We have termed this absolute survival or a survival estimate, but it is more appropriately described as a standardized estimate of survival between two locations. The Chipps Island absolute survival estimates have the additional advantage of not incorporating the variability due to ocean residence and having the information available within months instead of years of release.

Several pieces of evidence indicate that our survival indices of hatchery fish do not have substantial bias. First, we show that smolt survival indices at Chipps Island were generally supported by similar trends of survival estimates using the ratio of ocean recovery rates. In addition, while recoveries at Chipps Island were relatively small, they seemed generally similar between separate tag codes from the same group (Appendix B). While these multiple tag codes within a group provided some assessment of the recapture variability both at Chipps Island and in the ocean fishery, true measurement of the variability in survival is not possible given the limits of releasing independent replicates each year. In addition, although in many years, especially on the San Joaquin River, survival is so low that determining true differences is problematic, we were able to detect large differences in survival between release locations, years and river basins.

Paired sample *t*-tests were used to test for significant differences with 95% confidence levels between survival indices of smolts released upstream and downstream of the Delta Cross Channel and Georgiana Slough with the cross channel gates open and closed. Simple linear regression analysis was used to explore the relationship between Georgiana Slough survival estimates and combined CVP and SWP exports. Regression analysis also was used to determine the relationship between survival estimates for smolts released at Dos Reis and river flow at Stockton.

Results and Discussion

Sacramento

Role of Flow, Temperature and Diversion into the Central Delta on Survival. Kjelson and others (1982) reported a relationship between estimated CWT salmon survival rates and river flow, which suggested that river flows influenced juvenile salmon survival during downstream migration through the Delta. In 1982, they reported that survival (based on adult recoveries in the ocean fishery) in the Delta appeared to be influenced by water temperature and/or river flow rate: smolt survival decreased as flow rates decreased and temperatures increased. For trawl recovery data, smolt survival was related to water temperature only during June (Kjelson and others 1982). Almost total mortality was observed using both methodologies in 1978 and 1981 when temperatures were about 23° C (Kjelson and others 1982).

Data gathered between 1982 and 1987, using marked smolts released near Sacramento, further supported these relationships. In presenting the "State Water Resources Control Board with the Needs of Chinook Salmon, *Oncorhynchus tshawytscha* in the Sacramento-San Joaquin Estuary," USFWS (1987) shared relationships of survival with flow and survival with temperature using both the trawl and ocean indices of Delta survival. Maximum survival was reached with calculated flows between 20,000 to 30,000 cfs at Rio Vista and with temperatures less than 17° C. It also was shown that survival of smolts released in the North Delta (Sacramento or Courtland) using differential ocean recovery rates was correlated with the percentage of water diverted into the Central Delta from the Sacramento River at Walnut Grove (USFWS 1987). Determining which factor was most important to the survival of juvenile salmon was not possible because water temperatures and the percentage of water diverted into the Central Delta were higher in dry years. Prior to 1987 the Delta Cross Channel gates were only closed when flows in the Sacramento River at Freeport were greater than about 25,000 cfs.

Data collected between 1987 and 1989, combined with the data collected in earlier years, showed that smolts released on the Sacramento River, upstream of the entrances to the Delta Cross Channel and Georgiana Slough (Courtland), survived at a significantly lower rate than those released downstream (Isleton or Ryde), with the cross channel gates open (paired *t*-test, $t = 4.11$, $n = 9$, $P = 0.003$) (Figure 19). The results of these studies indicated that smolts were diverted into the Central Delta via the Delta Cross Channel and Georgiana Slough and entering the interior Delta decreased their survival. In addition, the data also showed that survival was significantly less for smolts released upstream relative to those released downstream, when the Delta Cross Channel gates were closed (paired *t*-test, $t = 10.75$, $n = 4$, $P = 0.002$) (Figure 19), indicating that diversion into Georgiana Slough also negatively affects survival. Smolt survival information obtained from the ocean fishery showed generally the same trends but was more variable and not statistically significant (Figure 20).

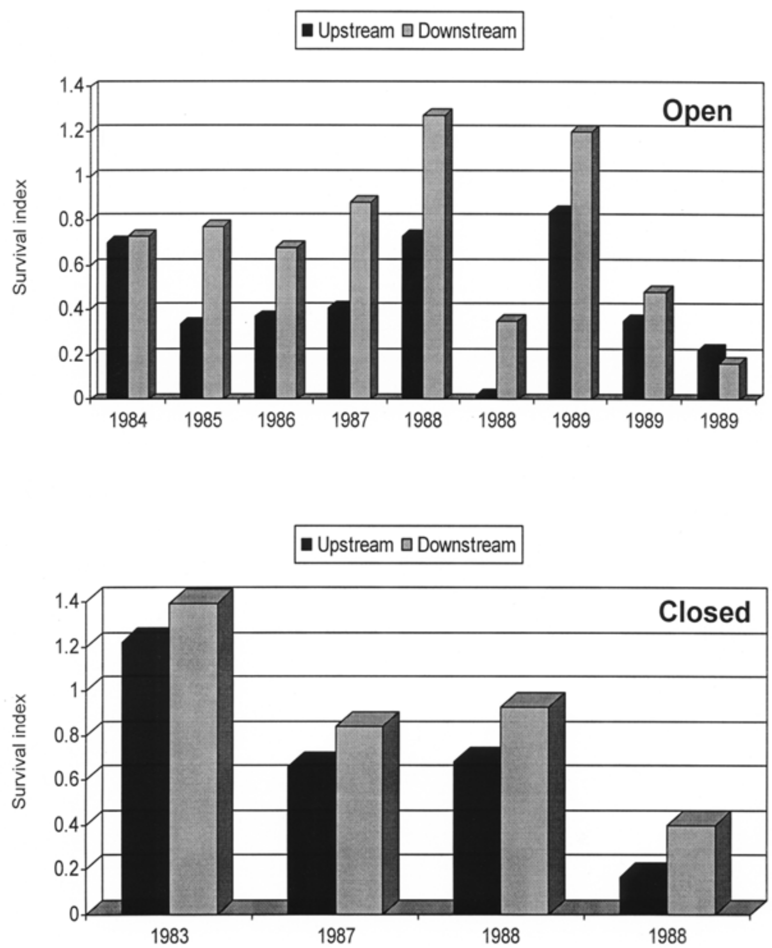

Figure 19 Survival indices of CWT fall run smolts released in the Sacramento River upstream (Courtland) and downstream (Ryde) of the Delta Cross Channel and Georgiana Slough with the gates open and closed

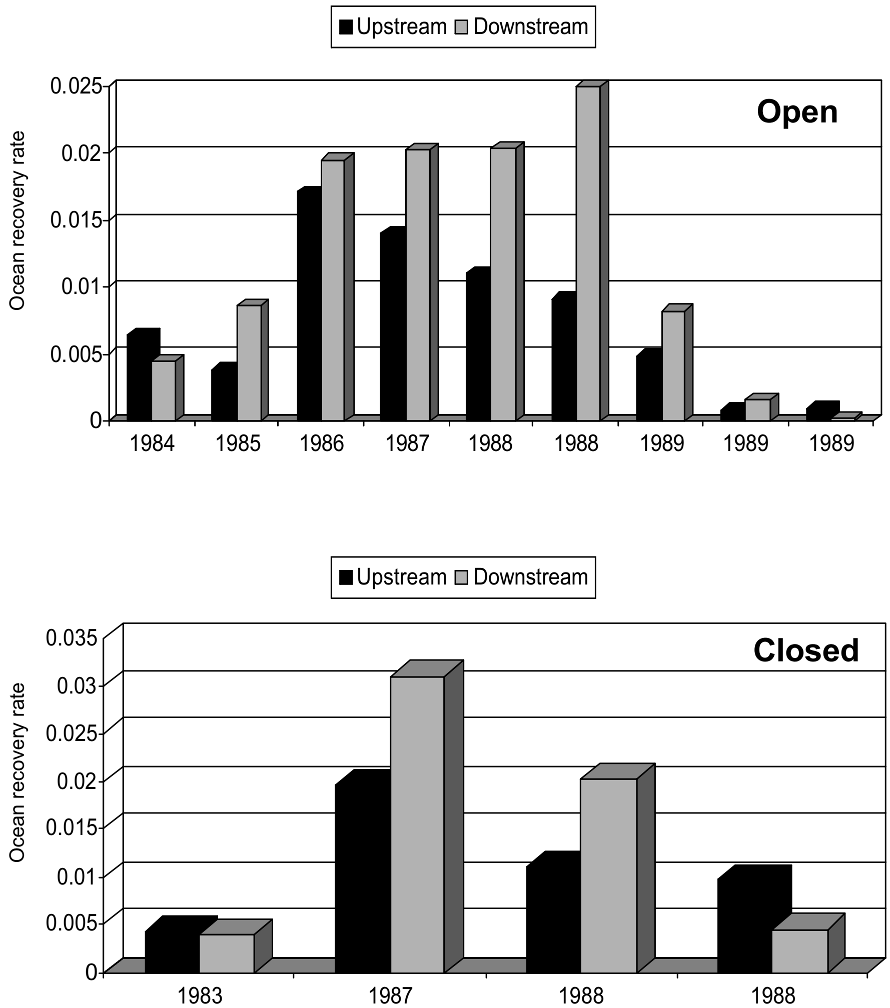

Figure 20 Recovery rates in the ocean fishery for CWT smolts released in the Sacramento River upstream (Courtland) and downstream (Ryde) of the Delta Cross Channel with the gates open and closed

The hypothesis that diversion into the Central Delta reduces juvenile salmon survival is further supported by the results of coded wire tagged, fall-run groups released into Georgiana Slough and in the main-stem Sacramento River at Ryde. The smolt survival indices and ocean recovery rates obtained from the two release locations indicated that fall run smolts survived at a significantly higher rate when released at Ryde rather than into Georgiana Slough) (Figure 21). (Paired t-tests were done for smolt survival indices (t = 3.14, n = 7, P = 0.019) and ocean recovery rates (t = 4.19, n = 7, P = 0.005).

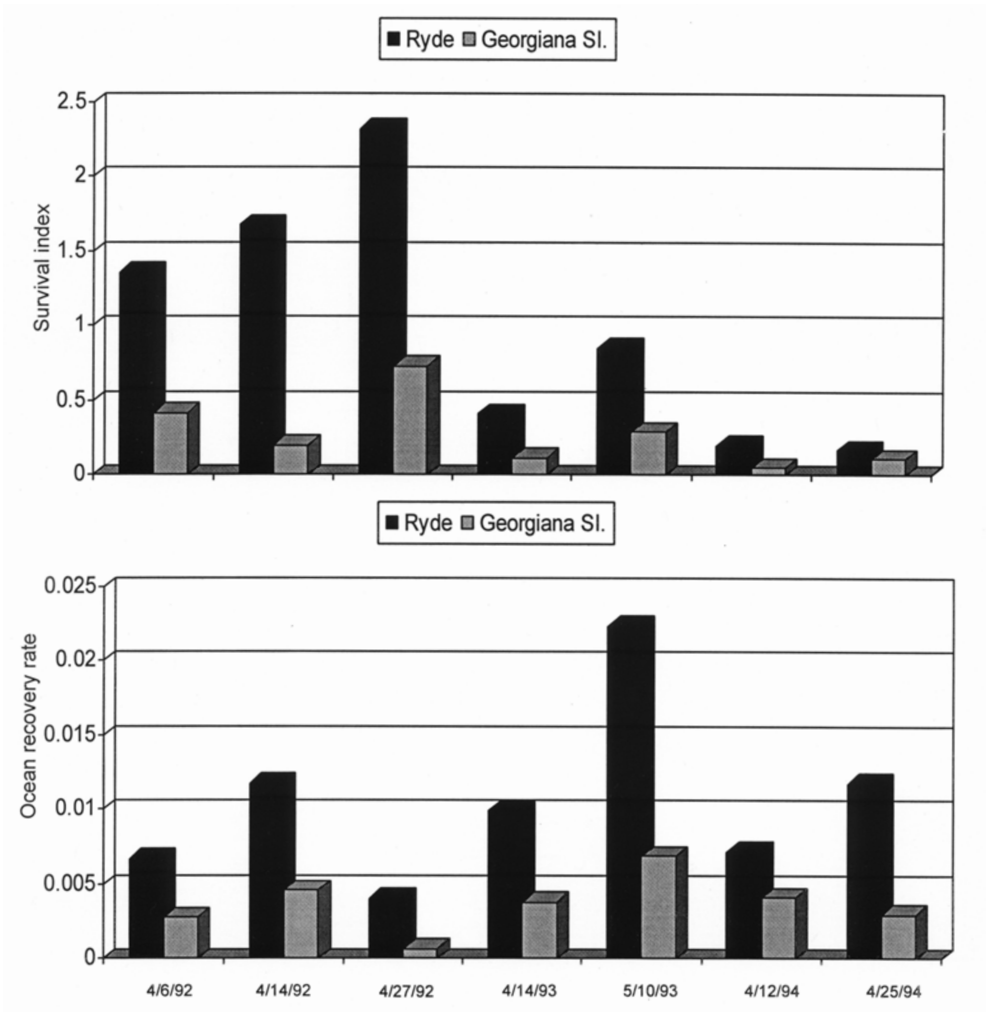

Figure 21 Survival indices to Chipps Island and ocean recovery rates for CWT fall-run smolts released at Ryde and in Georgiana Slough between 1992 and 1994

Between 1993 and 1998, studies using late-fall run juveniles were conducted to determine if survival also was higher for CWT late-fall yearlings released at Ryde than for those released into Georgiana Slough. Late-fall are larger and migrate through the Delta during the winter months when water temperatures are cooler. Despite the cooler temperatures and larger size of the fish relative to fall run, the results with late-fall yearlings were similar to those obtained with fall run smolts. Results indicated that the survival indices to Chipps Island and ocean recovery rates were significantly greater for fish released at Ryde than for those released into Georgiana Slough (Figure 22). Paired *t*-tests were done for smolt survival indices (t = 3.60, n = 6, P = 0.015) and ocean recovery rates (t = 3.16, n = 4, P = 0.050). Although the ratios between the groups released at Ryde versus those released into Georgiana Slough were similar for the fall and late-fall experiments, it is likely that true survival was less for the fall run groups which were smaller at release and experienced higher water temperatures. These data infer that once fish are diverted into the Central Delta via Georgiana Slough, high relative mortality occurs even for winter run juveniles migrating through the Delta in the late fall and winter months—a period when environmental conditions should be less stressful.

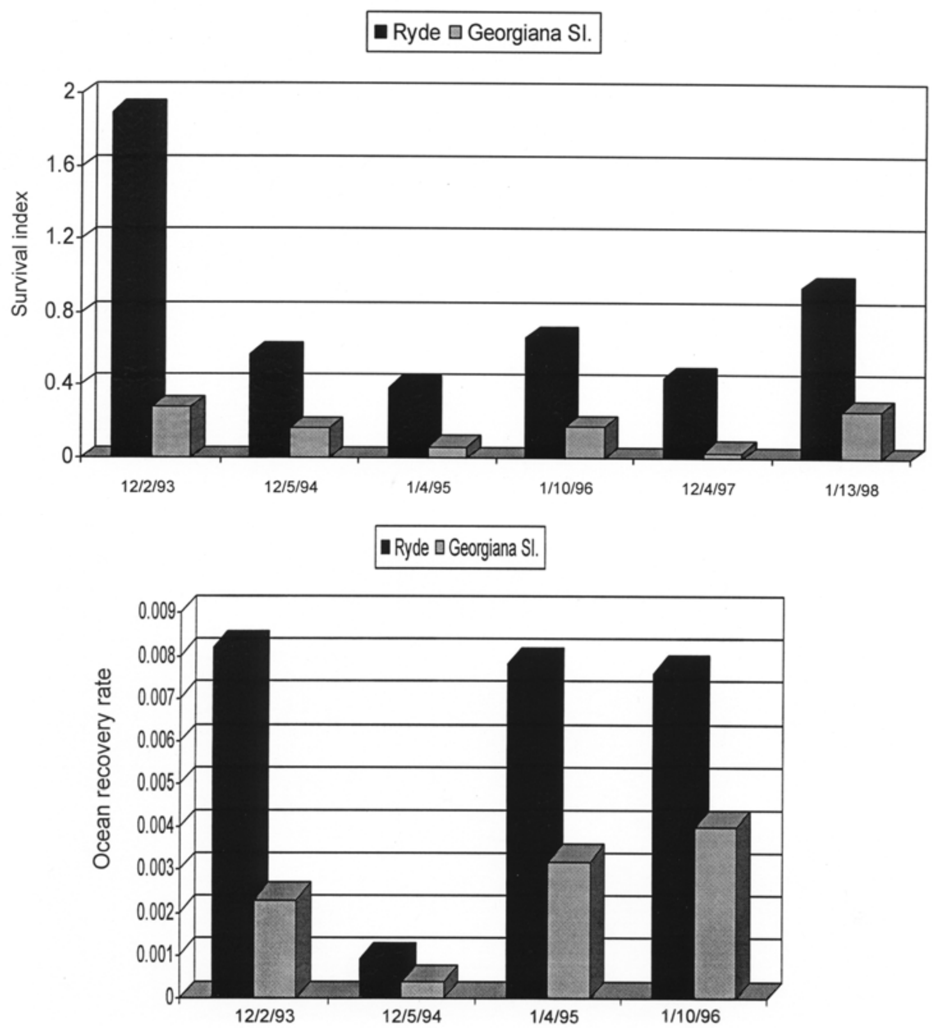

Figure 22 Survival indices to Chipps Island and ocean recovery rates for CWT late-fall-run juveniles released at Ryde/Isleton and in Georgiana Slough

Results from survival studies conducted to determine the relative vulnerability of juvenile salmon to project exports seem consistent with our hypothesis that diversion into the Central Delta is detrimental for juvenile salmon. Coded wire tagged smolts released in the North Delta (at Isleton or Ryde) appeared to have survived at higher rate than those released in the Central or South Delta (at the mouth, North and South Forks of the Mokelumne River and Lower Old River) in the drier years of 1985 and 1986 (Figure 23). This result is similar to that observed with fry released in the Central Delta relative to those released in the North Delta in the drier years.

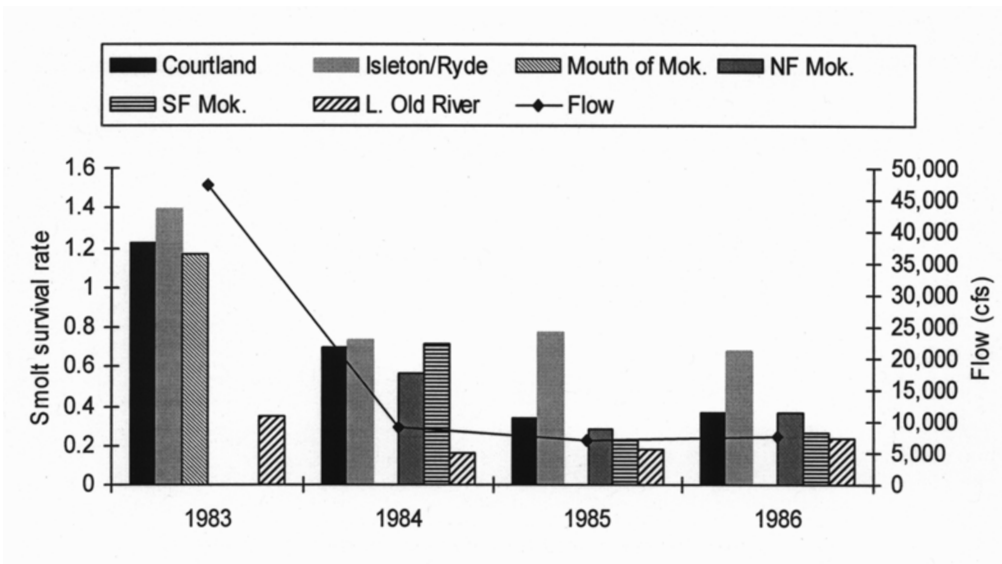

Figure 23 Survival indices of CWT smolts released at various sites in the Delta and mean Sacramento River flow (cfs) at Rio Vista. Flow at Rio Vista was the average during the recovery period of the Courtland releases at Chipps Island.

Although, we have found that diversion into the Central Delta increases juvenile salmon mortality, we have not been able to clearly separate the effects of flow and temperature from diversion impacts. The fact that relative mortality in the Central Delta appears to increase in the drier years, would indicate that there are combined effects. Two separate and independent models constructed using these coded wire tag data have found that temperature is likely the most important factor to fall run smolt survival in the Delta (Newman and Rice 1997; Kjelson and others 1989). Diversion into the central Delta via the Delta Cross Channel gates was also considered important in these models. Sacramento River flow was considered important in the Newman and Rice model (Newman and Rice 1997), but so was salinity (which was inversely correlated to Sacramento River flow) making interpretation difficult. In the Kjelson and others (1989) model Sacramento River flow was tied to the percent of water diverted into the Central Delta.

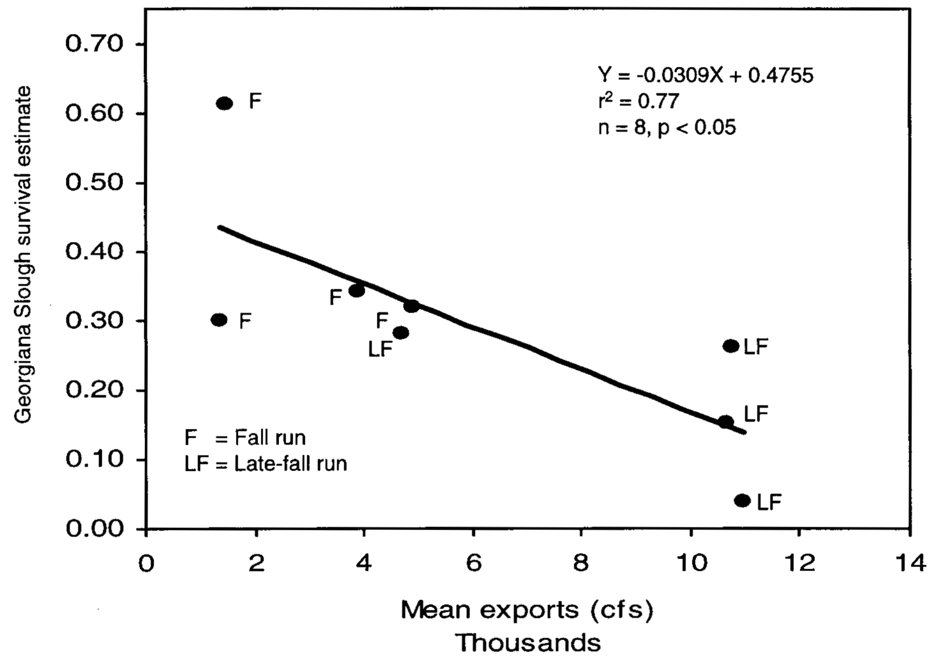

Figure 24 Estimate of survival to Chipps Island for CWT fall-run smolts and late-fall-run yearlings released into Georgiana Slough relative to those released at Ryde with the cross channel gates closed versus combined CVP+SWP exports from release date to 14 days later (fall run) or 17 days later (late-fall run).

Why survival in the Central Delta is lower than that on the main-stem Sacramento River has been hypothesized to be related to the amount of net lower San Joaquin river flow (QWEST), exports or just the longer route to the western Delta of smolts migrating through the central Delta. The survival index to Chipps Island, of fall run smolts and late-fall run yearlings released into Georgiana Slough, does not appear to be related to QWEST. However, the estimate of survival of the Georgiana Slough groups relative to the Ryde groups, for both the fall and late-fall run groups released when the cross channel gates were closed, may be related to exports, although there were large outliers in the relationship which transforming failed to resolve (Figure 24) (r^2= 0.77, $P <$ 0.05). A longer route through the Delta would expose the fish to various mortality factors for a longer period of time. However, the difference in distance, assuming the most direct routes for both groups, is only 37% greater for the Georgiana Slough group (White 1998). The Ryde groups survived between 1.5 and 22 times that observed for the Georgiana Slough groups (Table 3). Differences of between 2 and 7 times are observed in the ocean recovery rate data but some of the most recent releases have not yet been recovered in the ocean fishery (Table 4). These data would infer that the increased distance alone would not account for the differences in survival between the two groups, and exports may contribute, at least in part, to the observed differences.

Table 3 Survival indices to Chipps Island for fall-run smolts and late-fall-run yearlings released at Ryde and Georgiana Slough between 1992 and 1998 and the ratio of survival between the two paired groups

Date	*Ryde*	*Georgiana Slough*	*Ryde:Georgiana Slough ratio*
Fall run			
06 Apr 1992	1.36	0.41	3.3
14 Apr 1992	2.15[a]	0.71	3.0
27 Apr 1992	1.67	0.20	8.4
14 Apr 1993	0.41	0.13	3.2
10 May 1993	0.86	0.29	3.0
12 Apr 1994	0.20	0.05	3.7
25 Apr 1994	0.18	0.12	1.5
Mean			3.7
Late-fall run			
02 Dec 1993	1.91	0.28	6.8
05 Dec 1994	0.58	0.16	3.6
04 Jan 1995	0.39	0.06	6.5
10 Jan 1996	0.66	0.17	3.9
04 Dec 1997	0.67	0.03	22.3
13 Jan 1998	0.94	0.26	3.6
Mean			7.8

[a] The survival index and ocean recovery rate for the 1992 release made at Ryde has been corrected to account for 10,500 marked fish inadvertently released at Georgiana Slough instead of Ryde.

Table 4 Ocean recovery rates for fall-run and late-fall-run yearlings released at Ryde and Georgiana Slough between 1992 and 1996 and the ratio of survival between the two paired groups

Date	*Ryde*	*Georgiana Slough*	*Ryde:Georgiana Slough ratio*
Fall run			
06 Apr 1992	0.0067	0.0028	2.4
14 Apr 1992	0.0107[a]	0.0046	2.3[a]
27 Apr 1992	0.0041	0.0006	6.8
14 Apr 1993	0.0099	0.0039	2.5
10 May 1993	0.0224	0.0069	3.2
12 Apr 1994	0.0074	0.0042	1.8
25 Apr 1994	0.0118	0.0030	3.9
Mean			3.3
Late-fall run			
02 Dec 1993	0.0082[b]	0.0023	3.6
05 Dec 1994	0.0009	0.0004	2.3
04 Jan 1995	0.0078	0.0033	2.4
10 Jan 1996	0.0076	0.0040	1.9
Mean			2.6

[a] The survival index and ocean recovery rate for the 1992 release made at Ryde has been corrected to account for 10,500 marked fish inadvertently released at Georgiana Slough instead of Ryde.

[b] Actual release made at Isleton, about five miles downstream of Ryde.

San Joaquin

Impacts of Migration Through Upper Old River and the Use of a Barrier in Upper Old River. Studies using marked fish released into upper Old River and on the San Joaquin River at Dos Reis found that smolts survived at a higher rate if they migrated to Chipps Island via the main-stem San Joaquin River instead of through upper Old River. Inter-annual survival rates at these two locations were highly variable and a significant difference was not found. Although not statistically significant, the survival difference is shown using both survival indices to Chipps Island and ocean recovery rates (Figure 25), suggesting that any wild smolts diverted into upper Old River have greater mortality than those migrating down the main-stem San Joaquin River.

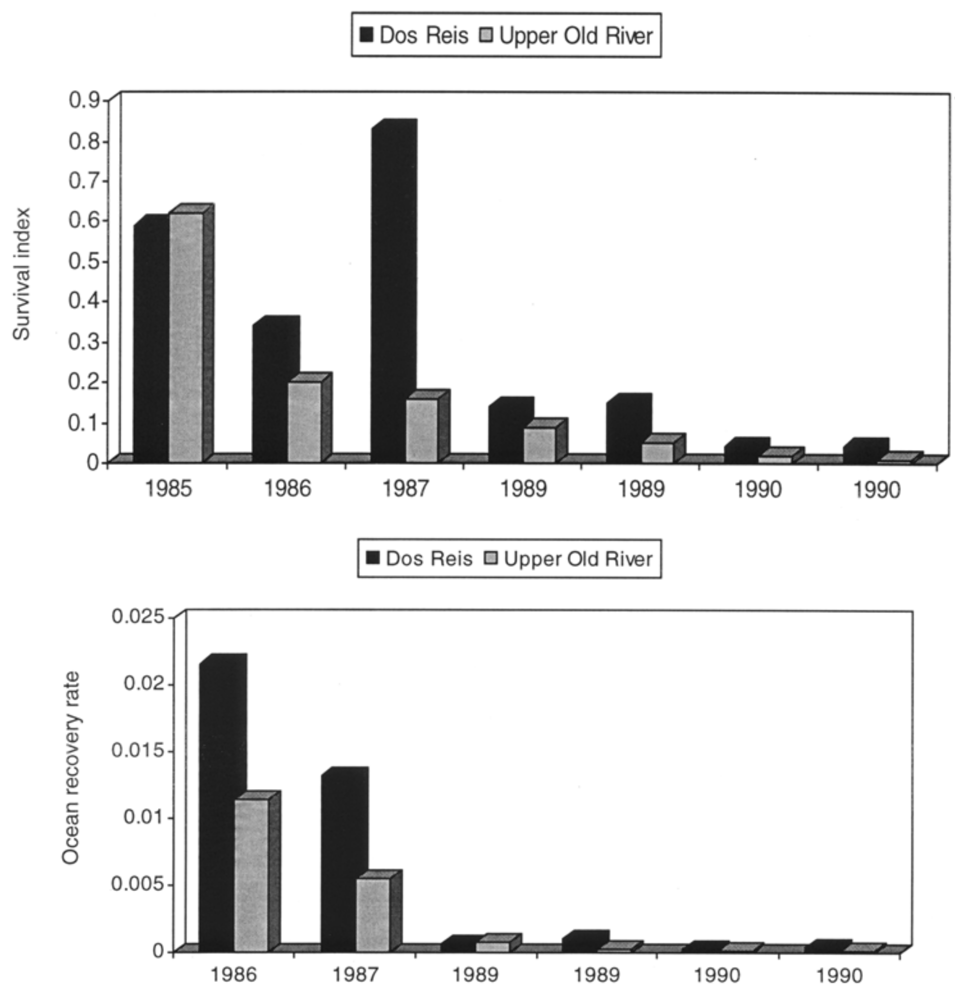

Figure 25 Smolt survival indices and ocean recovery rates of smolts released at Dos Reis on the mainstem San Joaquin River and into upper Old River. Ocean recovery rates are not available for spray-dyed smolts released in 1985.

Table 5 Results of studies comparing survival indices of Feather River Hatchery CWT juvenile chinook salmon from Mossdale to Chipps Island before and after the barrier at Old River was constructed in 1992

Date	*Water temperature (°F)*	*Survival*
Before barrier was constructed		
07 April 1992	64	0.17
13 April 1992	63	0.12
Mean	—	0.15
After barrier was constructed		
24 April 1992	69	0.08
04 May 1992	71	0.01
12 May 1992	72	0.02
Mean	—	0.04

Table 6 Results of studies comparing survival indices of Feather River Hatchery CWT juvenile chinook salmon from Mossdale to Chipps Island before and after the barrier at Old River was constructed in 1994

Date	*Water temperature (°F)*	*Survival*
Before barrier was constructed		
11 April 1994	63	0
After barrier was constructed		
26 April 1994	60	0.04
02 May 1994	66	0
09 May 1994	68	0.02
Mean	—	0.02

In 1992 and 1994, studies were conducted to evaluate the benefits to smolt survival of a full temporary rock barrier at the head of Old River. The study design included releasing CWT groups at Mossdale with and without the barrier in place. Due to logistical considerations, the without barrier scenario was the first experimental condition tested. In 1992, results showed survival indices to be less with the barrier in place than without counter to our hypothesis and earlier information. It is likely that the higher temperatures which occurred in the later part of the experimental period during the time the barrier was in place reduced the survival such that the benefits of the barrier were not observed (Table 5) (DWR 1992). Results in 1994 showed that smolt survival indices for all releases were extremely low and differences between the barrier-in and barrier-out groups were not large (Table 6) (DWR 1995). Neither the 1992 nor 1994 testing was adequate to confirm benefits to smolt survival of a barrier in upper Old River.

Table 7 Release temperatures, average fish size at release, average flow at Vernalis, average Delta exports, and survival indices for Delta CWT releases in 1993, 1995, and 1996[a]

Release date	*Release location*	*Temperature at release (°F)*	*Average size at release (mm FL)*	*Average flow at Vernalis (cfs)*	*Average Delta exports (cfs)*	*Survival index*
6 Apr 1993	Mossdale	63	59	3,293	6,968	0.04
28 Apr 1993	Mossdale	64	71	4,598	1,518	0.07
4 May 1993	Mossdale	61	72	4,349	1,516	0.07
12 May 1993	Mossdale	65	75	3,167	1,533	0.07
17 Apr 1995	Mossdale	57	70	20,558	3,915	0.22
17 Apr 1995	Dos Reis	57	70	20,698	3,924	0.15
5 May 1995	Mossdale	62	75–76	22,772	4,527	0.12
5 May 1995	Dos Reis	63	76	22,397	5,194	0.39
17 May 1995	Mossdale	63	76–79	23,269	4,700	0.07
17 May 1995	Dos Reis	65	77	23,012	4,993	0.16
15 April 1996	Mossdale	59.5	78	6,613	1,687	0.02
30 April 1996	Mossdale	64	81	6,296	1,571	0.01
1 May 1996	Dos Reis	63	83–84	7,714	1,566	0.02

[a] Average flows at Sacramento and Vernalis and average export values are from dayflow. Average flows at Vernalis are from date of release to last day of recovery, or for 14 days after release if no recoveries were made at Chipps Island (survival = zero). Average exports are for 14 days after release. In 1993, they were from release date to last recovery date at Chipps Island. All releases are from Feather River Hatchery stock.

Survival indices were low in 1993 and 1996, and somewhat higher in 1995, for smolts released at Mossdale, without a barrier at the head of upper Old River. Survival indices to Chipps Island ranged between 0.01 and 0.07 in 1993 and 1996 and between 0.07 to 0.22 in 1995. Complementary releases made at Dos Reis in 1995 and 1996 to estimate loss through Old River, indicated that survival was generally higher at Dos Reis than for releases made at Mossdale, suggesting that even in the higher flow years diversion into upper Old River reduces survival (Table 7).

In 1997 all releases at Mossdale were made with the barrier in place, to allow multiple measurements of survival to be generated with the barrier in place. Two 48-inch culverts included in the barrier in 1997 allowed approximately 300 cfs of water to flow from the San Joaquin River into upper Old River. Releases made at Dos Reis, relative to those released at Mossdale, were designed to evaluate the effects on smolt survival of the culverts in the barrier.

Table 8 Release temperatures, average fish size at release, average flow at Vernalis, average Delta exports, and survival indices for Delta CWT releases in 1997 with the head of Old River barrier in place[a]

Release date	*Release location*	*Temperature at release (°F)*	*Average size at release (mm FL)*	*Average flow at Vernalis (cfs)*	*Average Delta exports (cfs)*	*Survival Index*
28 Apr 1997	Mossdale	61	100	5,287	2,353	0.19
29 Apr 1997	Dos Reis	60	97	5,286	2,287	0.19

[a] Average flows at Vernalis and average export values are from dayflow. Average flows at Vernalis are from date of release to last day of recovery, or for 14 days after release if no recoveries were made at Chipps Island (survival = zero). Average exports are for 14 days after release. All releases are from Feather River Hatchery.

Survival indices to Chipps Island of the Feather River smolts released at Dos Reis and Mossdale in 1997 were similar indicating that no difference in survival attributable to the culverts was detected (Table 8). This would suggest that the impact of the culverts was minimal to smolts passing between Mossdale and Dos Reis.

Several pieces of evidence support our conclusion that the barrier improved smolt survival through the Delta in 1997. First, the similarity between the Mossdale and Dos Reis groups provides evidence that the barrier improved survival in 1997. Without a barrier we would have expected the Mossdale group to survive at a lower rate than those released at Dos Reis. Second, the smolt survival index, to Chipps Island for smolts released at Mossdale in 1997, was relatively high compared to past releases made at Mossdale since 1992 (Table 9). Third, the survival index to Chipps Island from smolts released at Mossdale was higher relative to past years of smolts released in the San Joaquin tributaries. In past years, survival of fish released at Mossdale was similar to that observed for fish released in the tributaries. For instance in 1996, the survival indices, to Chipps Island, of smolts released at Mossdale was 0.01 and 0.02, whereas for releases made on the upper Merced and Tuolumne it was 0.01 and 0.04, respectively - the same general magnitude (Table 9). Similarly in 1995, the survival index of smolts released at Mossdale was 0.22, and the groups released in the upper reaches of the tributaries survived at a rate of 0.15 and 0.25. Again, in the same general magnitude. In contrast, in 1997 the survival index from CWT fish released at Mossdale was 0.19 and the survival indices for upper reaches of the tributaries were 0.04, indicating that survival through the South Delta was higher relative to that in the tributaries in 1997, when the barrier was in place. Fourth, the survival index from the release made at Mossdale was closer to that of smolts released at Sacramento in 1997 than it had been in previous years. All of these data support our conclusion that the barrier improved survival in 1997.

Although it seems probable that the barrier increased survival in 1997, survival indices in the San Joaquin Delta still appeared low relative to earlier experiments conducted in 1985 and 1986 (Table 9). The use of non-basin, hatchery fish (those from FRH) or the affect of differences in water temperature between the hatchery truck and release site were hypothesized as possible causes. In both 1996 and 1997, paired releases were made at Dos Reis and Jersey Point with smolts from both FRH and MRFF to assess the potential affect of different stocks on the results of past experiments. Results showed that the survival estimate to Chipps Island, of the Dos Reis group relative to the Jersey Point group, was higher for the MRFF group in both 1996 and 1997 (Table 10). In 1997, smolts from FRH were significantly larger (average 88 mm fork length) and heavier than Merced River stock (average 74 mm fork length). However by standardizing survival, bias associated with recapture efficiency of the different sized fish between stocks should be factored out as long as sizes within a stock were similar, which they were in this case. Results from physiological tests conducted in 1996 and 1997, on subsets of fish (approximately 30) from paired groups released at Dos Reis, indicated there were no physiological reasons for the differences in survival between the two stocks (MRFF and FRH). In 1996 pathologists determined that the Merced stock was at an early infection stage of PKX, a myxosporean parasite, but it should not have affected their survival through the Delta, but could be a factor in adult survival of this stock (True 1996). Physiological tests conducted included those for internal parasites and bacterium and various other analyses (organosomatic analyses, ATPase assay, triglyceride level analyses and stress glucose response analyses). An additional group of 12 was used to assess osmoregulatory ability. In 1996 these tests were made on fish at release, while in 1997 they were made on fish that had been held in live cars for 48 hours.

Table 9 Survival indices of Merced Fish Facility, Feather River Hatchery, and Tuolumne River Fish Facility smolts released in the San Joaquin Delta and tributaries between 1982 and 1997

	Release sites									
Year	*Dos Reis*	*Mossdale w/o HORB*[a]	*Mossdale w/o HORB*[a]	*Upper Old River*	*Upper Merced*[b]	*Lower Merced*[b]	*Upper Tuolumne*[b]	*Lower Tuolumne*[b]	*Upper Stanislaus*[b]	*Lower Stanislaus*[b]
1997	0.19[a] 0.14[b]	–	0.19	–	0.04	0.14	0.04	0.17	–	–
1997		–	–	–	0	0.01	–	–	–	–
1996	0.02[a] 0.09[b]	0.01		–	0.01	0.01	0.04	0.07	–	–
1996		0.02	–	–	–	–	–	–	–	–
1995	0.15[a]	0.22	–	–	0.15	0.20	0.25	0.22	–	–
1995	0.39[a]	0.12	–	–	–	–	–	–	–	–
1995	0.16[a]	0.07	–	–	–	–	–	–	–	–
1994	–	0.00	0.02	–	0.06	0.02	0.03	0.04	–	–
1994	–	–	0.04	–	–	–	–	–	–	–
1994	–	–	0	–	–	–	–	–	–	–
1993	–	0.04	–	–	–	–	–	–	–	–
1993	–	0.07	–	–	–	–	–	–	–	–
1993	–	0.07	–	–	–	–	–	–	–	–
1993	–	0.07	–	–	–	–	–	–	–	–
1992	–	0.18	0.08	–	–	–	–	–	–	–
1992	–	0.12	0.01	–	–	–	–	–	–	–
1992	–	–	0.02	–	–	–	–	–	–	–
1991	0.16[a]	–	–	–	–	–	–	–	–	–
1990	0.04[a]	–	–	0.02[a]	–	–	0.04	0.01[c]	–	–
1990	0.04[a]		–	0.01[a]	–	–	–	–	–	–
1989	0.14[a]	–	–	0.09[a]	–	0.05	–	–	0.05	0.21
1989	0.15[b]	–	–	0.05[b]	–	–	–	–	–	0
1988	–	–	–	–	–	–	–	–	0.07	0.09
1987	0.83[a,d]	–	–	0.16[b]	–	–	0.05	0.18	–	–
1986	0.34[b]	–	–	0.2[b]	–	–	0.40	0.27	0.34	0.56
1985	0.59[b,e]	–	–	0.62[b]	–	–	–	–	–	–
1984	–	–	–	–	–	–	–	–	–	–
1983	–	–	–	–	–	–	–	–	–	–
1982	0.6[b,f]	–	–	–	0.62	–	–	–	–	–

[a] Stock source: Feather River Hatchery.
[b] Stock source: Merced River Fish Facility.
[c] Stock source: TRFF.
[d] Release temperature of 70 °F.
[e] Spray-dyed fish.
[f] May be biased low due to the lack of sampling at Chipps Island during the first week after release.

Table 10 Ratio of survival indices (absolute smolt survival) of smolts released at Dos Reis and Jersey Point and recovered at Chipps Island using Feather River Hatchery and Merced River Fish Facility stock in 1996 and 1997

Release date	*Hatchery stock*	*Release site*	*Survival index to Chipps Island*	*Absolute smolt survival*
01 May 1996	Feather River	Dos Reis	0.02	0.06
03 May 1996	Feather River	Jersey Point	0.35	
01 May 1996	Merced River FF	Dos Reis	0.10	0.14
03 May 1996	Merced River FF	Jersey Point	0.72	
29 Apr 1997	Feather River	Dos Reis	0.19	0.18
02 May 1997	Feather River	Jersey Point	1.03	
29 Apr 1997	Merced River FF	Dos Reis	0.14	0.27
02 May 1997	Merced River FF	Jersey Point	0.51	
08 May 1997	Merced River FF	Dos Reis	0.12	0.30
12 May 1997	Merced River FF	Jersey Point	0.40	

To address the concern that temperature shock reduced the survival of smolts released in the South Delta, smolts were held in live cars in 1996 and 1997. Approximately 200 fish from the paired Dos Reis releases in 1996 were held in live cages for 48 hours to assess immediate and short term mortality within and between groups. In 1997, this was expanded to include all release sites. Sub-samples of the 200 fish (25) were closely evaluated immediately after each release and after they had been held for 48 hours to assess their condition. Fish were evaluated based on eye condition, body color, fin condition, scale loss and gill color. All fish looked healthy both immediately after release and after 48 hours. Only minor mortality (6 dead fish) was observed, of which most (4) was attributed to one location in one year. Mortality (less than 1%) was observed at the release site for this group, which was released on May 12, 1997, at Jersey Point (Brandes 1996; Brandes and Pierce 1998). Considering that most of the fish were healthy after being held for 48 hours in the live cars, it did not appear that acute temperature shock or any other factor at the release site caused mortality within the holding period. Increased predation as a result of reduced avoidance to predators due to temperature stress or other factors can not be assessed holding fish in live cars.

The Role of Flow on Survival. To separate the role of flow in the San Joaquin River from the impacts of diversion into upper Old River, survival estimates of smolts released at Dos Reis relative to those released at Jersey Point were plotted against river flow at Stockton (Figure 26). The relationship between survival and river flow was statistically significant (r^2 = 0.65, P < 0.01), using stock from both Feather River Hatchery and Merced River Fish Facility. In 1989, a release was made at Dos Reis with Merced River stock. Since there was no corresponding Jersey Point release using Merced stock, a Feather River stock was used instead. Although the intercept changed slightly (0.0581), the slope of the relationship did not change when the data point was deleted from the regression (r^2 = 0.82, P < 0.01). If smolts from Dos Reis survive at a higher rate because of increased flows at Stockton, the barrier may have served as the mechanism to increase the flows. It could be that survival is improved via the barrier because of the shorter migration path, but also because it increases the flows down the main-stem San Joaquin River.

The relative importance of flow and the barrier to smolt survival through the Delta between Mossdale and Jersey Point is shown in Figure 27. The rock barrier cannot presently be installed at Vernalis flows of greater than 7000 cfs. To put the improvement in survival resulting from the barrier in perspective, survival indices were compared between 1996 and 1995 and 1996 and 1997. In 1995, the high flows, without a barrier, increased survival by about 16 times that of 1996. The barrier in 1997 improved the 1996 survival index about 4.5 times. The barrier improves survival at flows of less than 7000 cfs but flows greater than 10,000 cfs appear to improve survival even further (Figure 27).

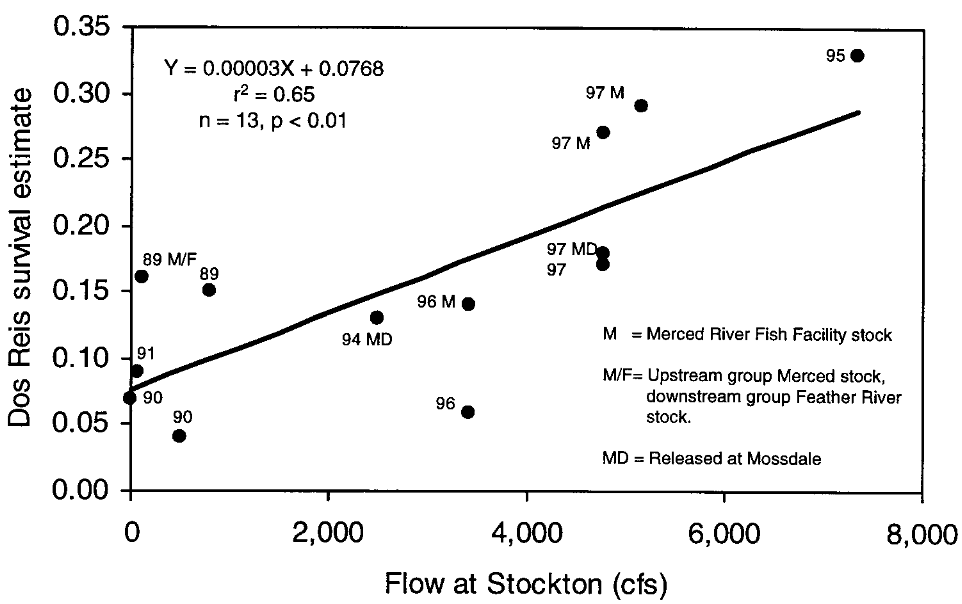

Figure 26 Estimate of survival between Dos Reis and Jersey Point or Mossdale and Jersey Point with the barrier in place using CWT smolts from Feather River Hatchery and Merced River Fish Facility

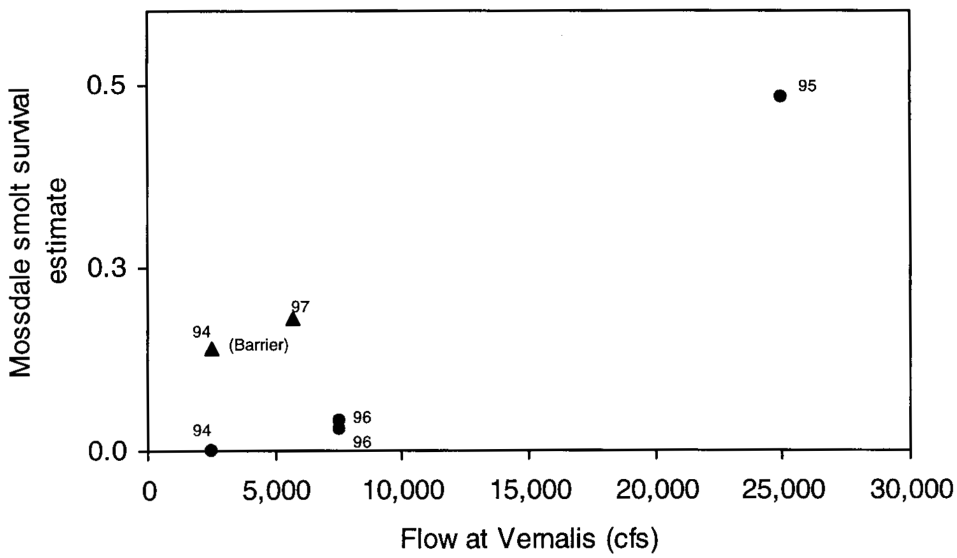

Figure 27 Absolute smolt survival for smolts released at Mossdale in relation to those released at Jersey Point versus flow (cfs) at Vernalis

The Role of Exports and Direct Entrainment on Survival. To determine if exports influenced the survival of smolts in the San Joaquin Delta, experiments were conducted in 1989, 1990 and 1991 at medium/high and low export levels. Results were mixed showing in 1989 and 1990 that survival estimates between Dos Reis and Jersey Point were higher with higher exports whereas in 1991 between Stockton and the mouth of the Mokelumne River (Tables 11 and 12) survival was shown to be lower (0.008 compared to 0.15) when exports were higher. One potential bias in the 1989 and 1990 data is that as mentioned earlier, smolts released at Dos Reis in 1989 were from the Merced River Fish Facility while those released at Jersey Point were from Feather River hatchery. Using different stocks to estimate smolt survival between two locations may introduce bias. In addition, results in 1989 and 1990 also showed that survival indices of the upper Old River groups relative to the Jersey Point groups were also higher during the higher export period, but overall still about half that of the survival of smolts released at Dos Reis (Table 11).

Table 11 Survival indices of smolts released at Dos Reis on the mainstem San Joaquin River, upper Old River, and Jersey Point based on Chipps Island recoveries[a]

Year	*Flow at Vernalis (cfs)[b]*	*CVP + SWP exports (cfs)[c]*	*Dos Reis*	*Upper Old River*	*Jersey Pt.*	*Dos Reis-Jersey Pt. ratio*	*Upper Old River:Jersey Pt. ratio*
1989	2,274	10,247	0.14	0.09	0.88	0.16	0.10
1989	2,289	1,797	0.14	0.05	0.96	0.14	0.05
1990	1,290	9,618	0.04	0.02	0.61	0.06	0.03
1990	1,665	2,462	0.04	0.01	1.05	0.04	0.01

[a] The ratio of survival indices between Dos Reis to Jersey Point and upper Old River to Jersey Point are included to compare absolute survival between years.

[b] Flows at Vernalis are ten-day averages in cubic feet per second after the Dos Reis groups were released.

[c] Exports are daily averages in cubic feet per second five days after release of upper Old River groups.

Contrary to the mixed results between survival and exports, direct entrainment losses at the fish facilities has been identified as a cause of juvenile salmon mortality in the Delta. Kjelson (1981) reported that records of salmon observed in salvage and respective spring export rates between 1959 and 1967 and 1968 to 1979 indicated that as exports increased more downstream migrating salmon are observed in the salvage. In USFWS Exhibit 31 (1987), it was reported that on average only 0.36% of the CWT smolts, released in the Sacramento River (above the Walnut Grove diversion) or in the forks of the Mokelumne River, were estimated to have been salvaged (expanded salvage) at the export facilities in the south Delta. These percentages are small, even when further expanded for screen efficiency and predation losses in Clifton Court Forebay, relative to the indirect mortality in the Delta that would occur to juveniles drawn off their normal migration path and exposed to other mortality factors for a longer period of time.

Table 12 Survival indices for CWT chinook released at various locations along the San Joaquin and Mokelumne rivers in the Delta in April and May 1991[a]

Month (mean exports) and release site	*River mile*	*Temp. (°F)*	*Survival index to Chipps Island*	*Survival rate per mile [a]*
April (4,283 cfs)				
Dos Reis	50	60	0.16	
Dos Reis to Stockton				0.06
Stockton	39	59	0.25	
Stockton to Empire Tract				0.05
Empire Tract	29	61	0.54	
Empire Tract to mouth of Mokelumne River				0.03
Mouth of the Mokelumne River	19	61	1.56	
Stockton to the mouth of Mokelumne River				0.008
Mouth of the Mokelumne River to Jersey Point				0.13
Jersey Point	12	63	1.70	
May (2,613 cfs)				
Stockton		65	0.19	
Stockton to the mouth of Mokelumne River				0.015
Mouth of the Mokelumne River		64.5	0.640	
Mouth of the Mokelumne River to Jersey Point				0.05
Jersey Point		61	1.69	

[a] Survival rate per mile and river miles to Chipps Island also are included for the reaches between Stockton and the mouth of the Mokelumne River and between the mouth of the Mokelumne River and Jersey Point.

Recoveries at the fish salvage facilities were much greater from releases made in the South Delta than in the North Delta. Many marked fish were observed at the fish facilities when they were released into upper Old River (average 19%). Smolts released at Dos Reis on the main-stem San Joaquin River had a lower salvage rate (averaged 3%) (USFWS 1990). These differences in salvage may, in part, account for the lower survival observed for the upper Old River group.

The number of marked fish recovered at the fish facilities from releases made in the San Joaquin Delta seems to be related to release location, whether or not there is a barrier in place and the rate of exports. In 1991, the greatest number of fish recovered at the fish facilities was from Dos Reis, Stockton and Empire Tract groups. The fewest recoveries were from the Mokelumne release groups and those released at Jersey Point (Table 13) (USFWS 1992b). Recoveries at the fish facilities from releases made at Mossdale were greatest when there was no barrier at the head of Old River (Table 14). This is further illustrated by the greater recoveries at both the CVP and SWP of smolts released at Mossdale relative to those released at Dos Reis (Table 15). In 1997, the number of expanded recoveries from two Dos Reis groups and the Mossdale group, were similar with the barrier in place (Table 16).

Table 13 Expanded fish facility recoveries during high (April) and low (May) export levels during spring 1991

				Expanded fish facility recoveries	
Release location	*Release date*	*Number released*	*Mean daily exports*[a]	*CVP*	*SWP*
Dos Reis	15 April	102,999	4,283	5,472	2,526
Stockton	16 April	99,341	4,283	338	2,635
Empire Tract	17 April	95,602	4,283	131	1,401
L. Mokelumne	18 April	47,289	4,283	0	276
Jersey Point	19 April	52,139	4,283	20	274
Stockton	06 May	99,820	2,613	52	64
L. Mokelumne	09 May	45,706	2,613	22	13
Jersey Point	13 May	49,184	2,613	6	0

[a] Mean daily exports (CVP and SWP combined) for April (16 April to 6 May) and May (6 May to 30 May) are the mean between the release date and final capture.

Table 14 Expanded SWP and CVP fish facility recoveries for fish released at Mossdale with and without the head of Old River barrier in place in 1992 and 1994

			Expanded fish facility recoveries	
Release date	*Barrier status*	*Number released*	*SWP*	*CVP*
07 April 1992	No barrier	107,103	71	5,380
13 April 1992	No barrier	103,712	106	3,385
11 April 1994	No barrier	51,084	100	648
04 May 1992	Barrier	99,717	8	28
12 May 1992	Barrier	105,385	6	0
26 April 1994	Barrier	50,259	0	0
02 May 1994	Barrier	51,632	24	12
09 May 1994	Barrier	53,880	13	0

Table 15 Expanded SWP and CVP fish facility recoveries for fish released at Dos Reis and Mossdale without the upper Old River barrier in place in 1995 and 1996

			Expanded fish facility recoveries	
Release location	*Release date*	*Number released*	*SWP*	*CVP*
Mossdale	17 April 1995	100,969	36	2,732
Dos Reis	17 April 1995	50,848	0	1
Mossdale	05 May 1995	102,562	74	1,859
Dos Reis	05 May 1995	52,097	0	0
Mossdale	17 May 1995	104,125	128	1,452
Dos Reis	17 May 1995	51,665	0	24
Mossdale	30 April 1996	99,656	24	110
Dos Reis	01 May 1996	206,780	0	0

In 1989 and 1990 expanded recoveries at the fish salvage facilities for both CWT groups released in upper Old River and Dos Reis during the high export were greater than those during the low export experiments (USFWS 1990) (Table 17). In 1991, it was observed that there were 25 times more marked fish recovered at the fish facilities from the Stockton group during the period of higher exports, than the releases made during the lower export period (USFWS 1992b) (Table 13). These pieces of information indicate that direct mortality is higher when exports are higher.

Table 16 Expanded SWP and CVP fish facility recoveries for fish released at Dos Reis and Mossdale in 1997 with the upper Old River barrier in place using Feather River Hatchery or Merced River Fish Facility stock

				Expanded fish facility recoveries	
Release location	*Stock*	*Release date*	*Number released*	*SWP*	*CVP*
Mossdale	Feather River Hatchery	28 April	48,774	34	204
Dos Reis	Feather River Hatchery	29 April	49,830	31	96
Dos Reis	Merced River Fish Facility	29 April	102,480	130	288

Table 17 Expanded SWP and CVP fish facility recoveries for smolts released in the San Joaquin River at Dos Reis and into upper Old River in 1989 and 1990 and mean daily exports five days after release of the upper Old River group

				Expanded fish facility recoveries	
Release location	*Release date*	*CVP + SWP mean daily exports (cfs)*	*Number released*	*SWP*	*CVP*
Dos Reis	20 Apr 1989	10,247	52,962	2,286	428
Upper Old River	21 Apr 1989	10,247	51,972	2,916	658
Dos Reis	02 May 1989	1,797	75,983	344	84
Upper Old River	03 May 1989	1,797	74,309	215	1,256
Dos Reis	16 Apr 1990	9,618	105,742	1,044	722
Upper Old River	17 Apr 1990	9,618	106,269	1,729	948
Dos Reis	02 May 1990	2,462	103,533	96	54
Upper Old River	03 May 1990	2,462	103,595	920	426

Bay Survival. In 1984, 1985 and 1986 smolts were released at Port Chicago in Suisun Bay and in San Francisco Bay near the Golden Gate Bridge to estimate survival through the Bay. The survival indices of marked fish released at Port Chicago and recovered in the midwater trawl at the Golden Gate were highly variable and ranged from 0.75 to 2.39 (Table 18). The extreme tidal fluctuations in San Francisco Bay most likely had a significant effect on the variability of the indices. Survival estimates through the Bay, from Port Chicago to the Golden Gate measured using the differential ocean recovery rates from the two release groups, showed survival ranged between 0.76 and 0.84 in the three years (Table 18). Delta outflows were low, and ranging from 6,690 cfs to 13,507 cfs, and did not appear to effect survival rates through the Bay. Since survival was observed to be relatively high through the Bay in the three years measured, CWT experiments in the Bay were discontinued to free up marked fish for use in the Delta where survival had been shown to be less and the need for information greater.

Table 18 San Francisco Bay (Golden Gate Bridge) tag summary, survival calculations and expanded ocean recoveries

Tag code	*Release site (stock)*	*Release date*	*Number released*	*Size (mm)*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Ocean recoveries*
6-62-51	Port Chicago (FRH)	06/02/86	47,995	75	06/05/86	06/18/86	15	0.75	1,382
6-62-52	Fort Baker (FRH)	06/03/86	49,583	73	---	---	0		1,807
6-62-45	Port Chicago (FRH)	05/13/85	48,143	76	05/17/85	05/29/85	22	1.54	465
6-62-44	Fort Baker (FRH)	05/14/85	47,158	N/A	---	---	0		537
6-54-51	Port Chicago (NFH)	07/23/84	50,114	N/A	07/26/84	07/31/84	36	2.39	1,159
6-54-52	Fort Baker (NFH)	07/25/84	48,677	N/A	---	---	0		1,461

Annual Indices of Survival. The survival indices to Chipps Island and survival estimates using differential ocean recovery rates, of smolts released near Sacramento, in the upper Sacramento River and in the San Joaquin tributaries, allows survival through the Delta and upstream to be compared between years.

Survival indices to Chipps Island of hatchery smolts released near Sacramento were compared to those released upstream in Battle Creek in Figure 28. The survival indices to Chipps Island from releases made into Battle Creek would include survival in the Delta as well as that in the upper river. Survival appeared to be relatively high between Battle Creek and Chipps Island in 1984 and 1993. Smolt survival through the Delta appeared highest in 1982 and 1983.

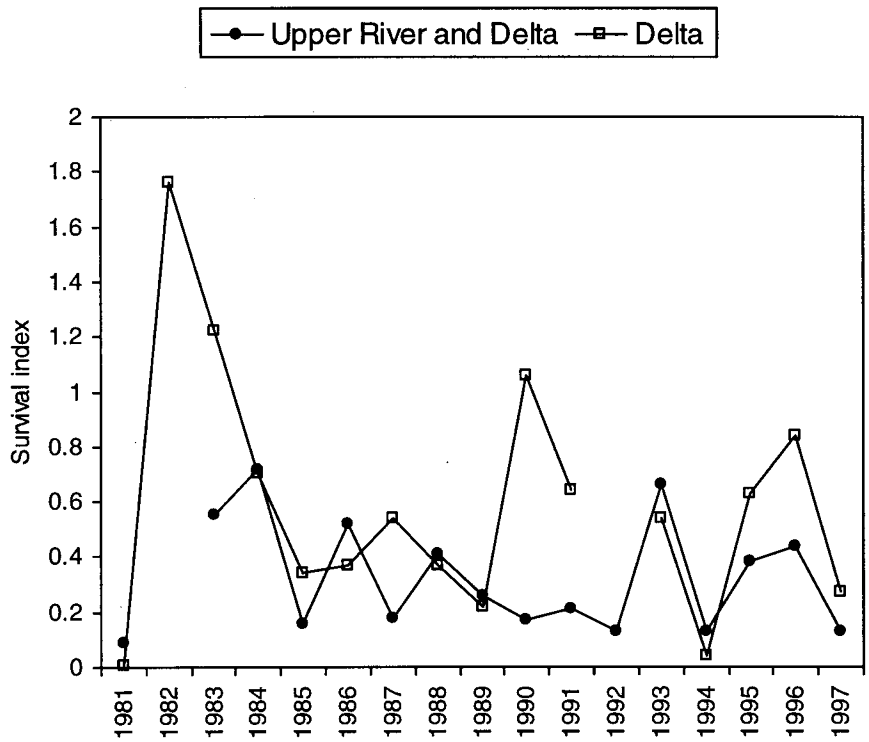

Figure 28 Survival indices of smolts released in the upper river (Battle Creek) and those released in the northern Delta (Courtland, Sacramento, Miller Park, Discovery Park) between 1981 and 1997. No release upstream in 1982 or at Sacramento in 1992.

Survival estimates using ocean recovery rates of smolts released at Battle Creek, relative to those released at Princeton, Knights Landing or Sacramento, were compared to the survival estimates of fish released at Sacramento, relative to those released at Port Chicago/Benicia, to allow upriver survival estimates to be separated from those in the Delta (Figure 29). These data show that survival was greatest upstream in 1987 and 1990, contrary to the conclusions based on Chipps Island survival indices. Variability in the ocean recovery rates or the poor survival of the downstream groups relative to the upstream groups likely account for the ratios of greater than 1.0 observed for several of the groups. Both sets of survival indices/estimates provide a rough estimate of the survival of smolts migrating through the River and Delta over time.

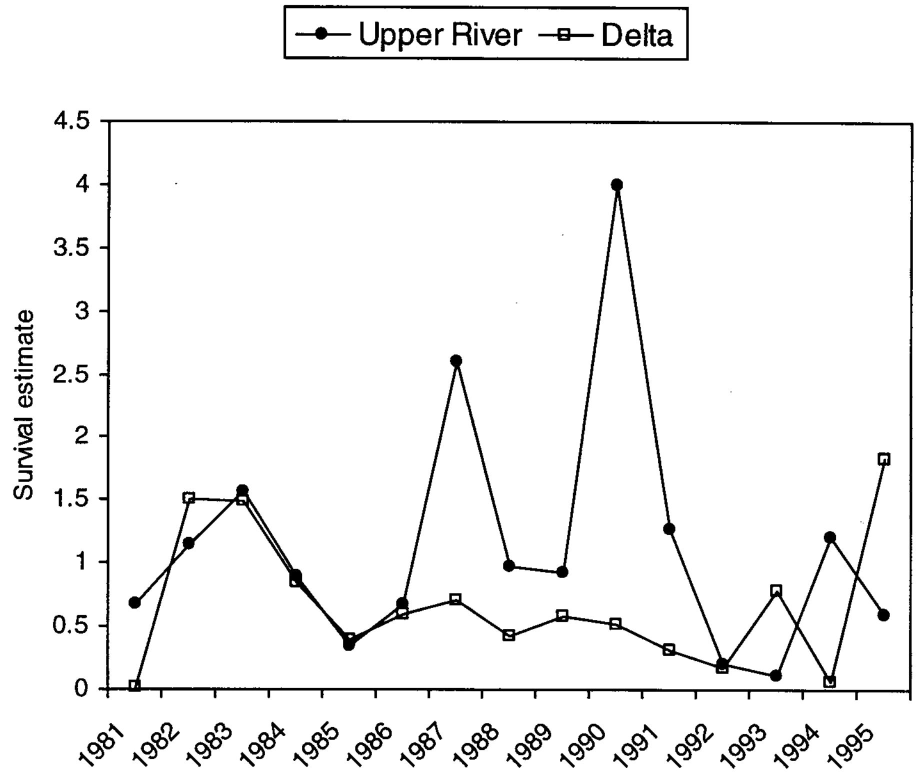

Figure 29 Estimates of survival in the upper river and Delta. A Ryde release was used as a downstream control in 1987 because a release was not made at Port Chicago or Benicia that year. In 1992, Princeton was used for the Delta survival estimate.

Marked releases have been made at sites in the San Joaquin tributaries during many years since 1982 and similar upstream and Delta comparisons were made between years. The survival indices from releases made in the lower reach of the tributaries would provide an index of survival through the lower San Joaquin River and Delta. Survival indices to Chipps Island from releases made in the upstream reaches of the tributaries would include both tributary and Delta survival. In many years (1986, 1988, 1994, 1995, and 1996) survival to Chipps Island from the upper reaches of the tributaries were similar to that from the releases made in the lower reaches indicating that most of the mortality occurred in the San Joaquin River main-stem and Delta (Figure 30). In other years, such as in 1987, 1989 and 1997, survival from releases made in the upper reaches of the tributaries was much less than that in the lower reaches, indicating that mortality in the tributaries was higher relative to that in the Delta and San Joaquin River.

Survival for smolts released in the lower reaches of the San Joaquin River tributaries also can be compared to that for smolts released near Sacramento. Survival is generally, substantially higher for smolts released at Sacramento than for those released in the lower tributaries of the San Joaquin River. Exceptions were in 1986, 1994 and 1997 when survival through the Delta from both basins was similar (Figure 30).

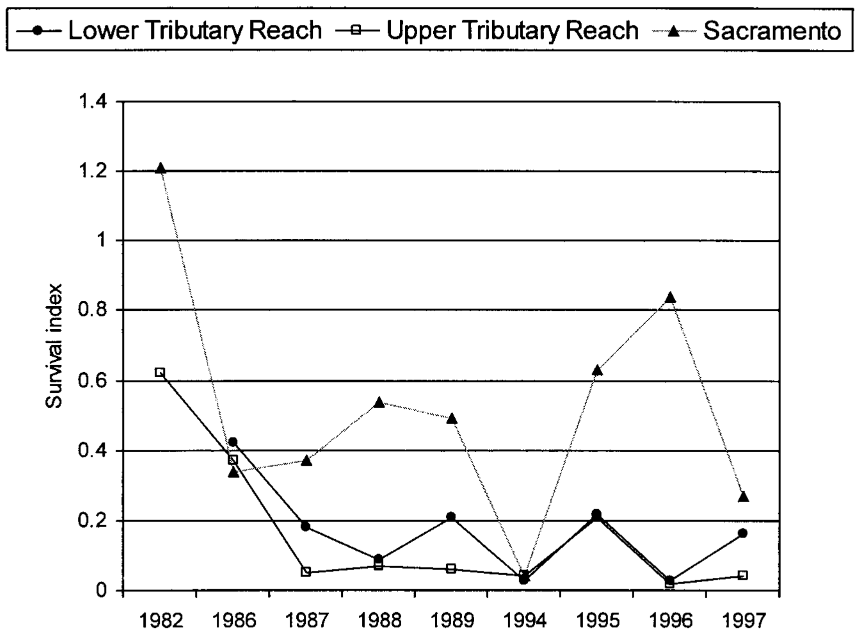

Figure 30 Survival indices for CWT smolts released at sites in the lower (L. Trib.) and upper (U. Trib.) reaches of the San Joaquin tributaries and near Sacramento (Sac.)

Summary and Recommendations

Analyses of the lower river and Delta beach seine data and the trawl data at Sacramento and Chipps Island, indicates that many juveniles enter the Delta as fry in wet years and that overall, juvenile production leaving the Delta is higher in wet years. The increase in juvenile production in wet years could be partially due to survival increases of fry upstream. Increased river flows appeared to increase fry survival upstream, but likely caused a greater proportion of them to migrate to the estuary where fry survival appears lower than upriver in the higher flow years. The survival of marked fry and smolts in the Central Delta appeared lower than in the North Delta, especially in the drier years. Both fry and smolts in the Central Delta may be more vulnerable to exports than those released in the North Delta in the drier years.

Studies using marked smolts in the Sacramento Delta indicated that migration into the Central Delta via the Delta Cross Channel or Georgiana Slough negatively affected the survival of juveniles migrating through the Delta not only in the spring, but in the winter months as well. Migration through upper Old River in the south Delta also appeared to negatively affect the survival of smolts originating from the San Joaquin basin. Direct losses, as indexed using expanded salvage recoveries, due to export pumping were generally low for smolts migrating through the Delta on the Sacramento River. Direct losses were higher for marked fish released in the San Joaquin Delta, with the greatest salvage from smolts released in upper Old River. Salvage also was higher for releases made at the same location when exports were increased. These long-term studies have helped identify actions that could improve juvenile salmon survival through the Delta.

Long-term systematic releases to measure survival through the Delta can be used as the basis for future modeling to further define ways to improve survival. Some models have been developed from CWT data generated from the Sacramento Delta (Newman and Rice 1997; Kjelson and others 1989). Additional models using this data are in the process of being generated. In such a complex system, it will take consistent releases over many years to refine models that will further define the factors important to juvenile salmon abundance and survival and identify additional ways to improve survival through the Delta.

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Notes

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Appendix A:
Unexpanded Fish Facility Recoveries for Coded Wire Half Tagged Fry Released in the Sacramento-San Joaquin Delta

Table A-1 Unexpanded fish facility recoveries for CW1/2T fry released in the Sacramento-San Joaquin Delta[a]

Year	Tag code	Release site (stock)[b]	Release date	Number released	Size (mm)	Unexpanded recoveries CVP	Unexpanded recoveries SWP[c]
1987	H6-7-7	Below RBDD (CNFH)	13-Mar-87	52,977	52	0	1
1987	B5-4-13	Battle Creek (CNFH)	12-Mar-87	51,075	51	1	0
1986	H6-7-6	Courtland (NFH)	05-Mar-87	48,733	50	4	3
1986	H6-7-5	Below RBDD (CNFH)	19-Mar-86	51,426	50	0	0
1986	H5-7-7	Battle Creek (CNFH)	18-Mar-86	51,371	50	0	0
1986	H6-6-7	Courtland (CNFH)	27-Feb-86	50,961	45	0	0
1986	H6-7-3	Courtland (CNFH)	10-Mar-86	53,831	50	0	0
1986	H6-7-2	Ryde (CNFH)	14-Mar-86	52,635	47	0	0
1986	H6-7-4	Ryde (CNFH)	12-Mar-86	52,748	53	0	0
1985	H6-5-5	Below RBDD (CNFH)	14-Feb-85	49,155	47	0	2
1985	H6-6-5	Below RBDD (CNFH)	14-Mar-85	52,313	48	0	0
1985	H6-5-6	Courtland (CNFH)	19-Feb-85	51,201	48	0	0
1985	H6-6-4	Courtland (CNFH)	07-Mar-85	51,985	46	0	(3) 6
1985	H6-6-1	South Fork Mokelumne (CNFH)	26-Feb-85	50,052	48	2	(2) 1
1985	H6-6-2	North Fork Mokelumne (CNFH)	28-Feb-85	51,145	46	0	(1) 3
1985	H6-5-7	Ryde (CNFH)	21-Feb-85	49,183	47	0	0
1985	H6-6-3	Ryde (CNFH)	05-Mar-85	50,550	47	1	(2) 8
1984	H6-4-4	Below RBDD (CNFH)	01-Mar-84	43,883	45	1	0
1984	H6-5-4	Below RBDD (CNFH)	24-Mar-84	47,855	50	0	0
1984	H6-4-5	Courtland (CNFH)	05-Mar-84	48,460	45	0	0
1984	H6-5-3	Courtland (CNFH)	21-Mar-84	48,157	48	0	0
1984	H6-4-6	Ryde (CNFH)	08-Mar-84	45,465	49	4	0
1984	H6-5-2	Ryde (CNFH)	19-Mar-84	46,767	49	4	0
1984	H6-5-1	South Fork Mokelumne (CNFH)	14-Mar-84	45,036	49	3	0
1984	H6-4-7	North Fork Mokelumne (CNFH)	12-Mar-84	42,165	50	5	0
1983	H6-3-3	Isleton (FRH)	04-Mar-83	45,775	44	0	0
1983	H6-4-2	Isleton (FRH)	29-Mar-83	47,518	49	0	0
1983	H6-3-4	Courtland (FRH)	09-Mar-83	48,541	47	0	0
1983	H6-4-3	Courtland (FRH)	31-Mar-83	48,501	51	0	0
1983	H6-3-5	Mouth of Mokelumne (FRH)	14-Mar-83	45,960	N/A	0	0

[a] In some cases, average size was calculated from number of fish per pound using a conversion table (Source: USFWS 1982, Table I-6).

[b] CNFH = Coleman National Fish Hatchery, FRH = Feather River Hatchery.

[c] Salvage numbers in parentheses have an unknown location (either CVP or SWP).

Table A-1 Unexpanded fish facility recoveries for CW1/2T fry released in the Sacramento-San Joaquin Delta[a] (Continued)

						Unexpanded recoveries	
Year	*Tag code*	*Release site (stock)[b]*	*Release date*	*Number released*	*Size (mm)*	*CVP*	*SWP[c]*
1983	H6-4-1	Mouth of Mokelumne (FRH)	24-Mar-83	47,367	48	0	0
1983	H6-3-6	Lower Old River (FRH)	17-Mar-83	47,677	49	0	0
1983	H6-3-7	Lower Old River (FRH)	22-Mar-83	48,580	48	0	0
1982	H6-2-2	Below RBDD (CNFH)	05-Feb-82	41,753	44	0	0
1982	H6-2-6	Below RBDD (CNFH)	25-Feb-82	43,673	44	0	0
1982	H6-2-3	Isleton (CNFH)	11-Feb-82	43,248	44	0	0
1982	H6-2-7	Isleton (CNFH)	02-Mar-82	40,508	45	0	0
1982	H6-2-4	Mouth of Mokelumne (CNFH)	17-Feb-82	43,849	43	0	0
1982	H6-3-2	Mouth of Mokelumne (CNFH)	10-Mar-82	41,470	44	0	0
1982	H6-2-5	Berkeley (CNFH)	22-Feb-82	40,699	44	0	0
1982	H6-3-1	Berkeley (CNFH)	08-Mar-82	39,321	44	0	0
1981	H6-1-1	Below RBDD (CNFH)	06-Feb-81	35,905	41	0	0
1981	H6-1-5	Below RBDD (CNFH)	28-Feb-81	47,019	40	0	0
1981	H6-1-4	Berkeley (CNFH)	25-Feb-81	49,705	44	0	0
1981	H6-2-1	Berkeley (CNFH)	08-Mar-81	36,901	43	0	, 0
1981	H6-1-3	Mouth of Mokelumne (CNFH)	20-Feb-81	45,193	44	2	0
1981	H6-1-7	Mouth of Mokelumne (CNFH)	06-Mar-81	45,796	43	2	0
1981	H6-1-2	Isleton (CNFH)	12-Feb-81	40,916	45	3	0
1981	H6-1-6	Isleton (CNFH)	04-Mar-81	45,949	43	0	0
1981	H5-2-4	Berkeley (CNFH)		21,939	46	0	0
1981	H5-2-5	Berkeley (CNFH)		20,788	46	0	0
1981		**Total**	**28-Feb-80**	**42,727**			
1981	H5-2-6	Clarksburg (CNFH)		22,121	50	0	0
1981	H5-2-7	Clarksburg (CNFH)		21,624	50	0	0
1981		**Total**	**28-Feb-80**	**43,745**			
1981	H5-3-3	Clarksburg (CNFH)		23,908	46	0	0
1981	H5-3-4	Clarksburg (CNFH)		22,829	44	0	0
1981		**Total**	**31-Mar-80**	**46,737**			

[a] In some cases, average size was calculated from number of fish per pound using a conversion table (Source: USFWS 1982, Table I-6).

[b] CNFH = Coleman National Fish Hatchery, FRH = Feather River Hatchery.

[c] Salvage numbers in parentheses have an unknown location (either CVP or SWP).

Appendix B:
Chipps Island Tag Summary and Survival Calculations for Coded Wire Tagged Fish Groups with Multiple Tag Codes

Table B-1 1997 Sacramento-San Joaquin Estuary, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-1-6-2-11	West Sacramento (FRH)		25,641	22-Apr-97	07-May-97	14	0.52	
6-1-6-2-12	West Sacramento (FRH)		25,032	22-Apr-97	08-May-97	9	0.34	
	Total	15-Apr-97	50,673	22-Apr-97	08-May-97	23		0.43
6-1-6-3-2	Mossdale (w/ barrier) (FRH)		23,701	03-May-97	07-May-97	2	0.08	
6-1-6-3-3	Mossdale (w/ barrier) (FRH)		25,073	05-May-97	18-May-97	8	0.31	
	Total	28-Apr-97	48,774	03-May-97	18-May-97	10		0.19
6-1-6-3-4	Dos Reis (FRH)		25,084	06-May-97	11-May-97	7	0.27	
6-1-6-3-5	Dos Reis (FRH)		24,746	06-May-97	11-May-97	3	0.12	
	Total	29-Apr-97	49,830	06-May-97	11-May-97	10		0.19
6-25-45	Dos Reis (MRFF)		49,005	08-May-97	16-May-97	9	0.18	
6-25-46	Dos Reis (MRFF)		53,475	10-May-97	15-May-97	7	0.13	
	Total	29-Apr-97	102,480	08-May-97	16-May-97	16		0.15
6-1-6-2-13	West Sacramento (FRH)		25,829	05-May-97	15-May-97	15	0.55	
6-1-6-2-14	West Sacramento (FRH)		26,315	07-May-97	10-May-97	7	0.25	
	Total	01-May-97	52,144	05-May-97	15-May-97	22		0.40
6-1-6-2-7	Jersey Point (FRH)		24,815	03-May-97	10-May-97	27	1.03	
6-1-6-2-8	Jersey Point (FRH)		25,049	04-May-97	11-May-97	28	1.05	
	Total	02-May-97	49,864	03-May-97	11-May-97	55		1.03
6-1-6-2-9	West Sacramento (FRH)		25,152	---	---	0		
6-1-6-2-10	West Sacramento (FRH)		25,069	21-May-97	21-May-97	1	0.04	
	Total	15-May-97	50,221	21-May-97	21-May-97	1		0.02

[a] FRH = Feather River Hatchery, MRFF = Merced River Fish Facility.

Table B-2 1997 Upper San Joaquin River Tributaries, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-1-11-5-11	Upper Merced (MRFF)		26,045	06-May-97	06-May-97	1	0.04	
6-1-11-5-12	Upper Merced (MRFF)		27,683	06-May-97	08-May-97	3	0.10	
6-1-11-5-13	Upper Merced (MRFF)		31,930	09-May-97	09-May-97	1	0.03	
6-1-11-6-12	Upper Merced (MRFF)		24,880	---	---	0		
	Total	20-Apr-97	110,538	06-May-97	09-May-97	5		0.04
6-1-11-5-15	Lower Merced (MRFF)		24,398	04-May-97	14-May-97	6	0.23	
6-1-11-6-1	Lower Merced (MRFF)		29,011	04-May-97	09-May-97	3	0.10	
6-1-11-6-2	Lower Merced (MRFF)		25,761	03-May-97	12-May-97	7	0.25	
6-1-11-6-3	Lower Merced (MRFF)		25,317	---	---	0		
	Total	22-Apr-97	104,487	03-May-97	14-May-97	16		0.14
6-1-11-6-7	Upper Tuolumne (MRFF)		31,112	18-May-97	18-May-97	1	0.04	
6-1-11-6-8	Upper Tuolumne (MRFF)		29,947	---	---	0		
6-1-11-6-9	Upper Tuolumne (MRFF)		24,551	24-May-97	24-May-97	1	0.04	
6-1-11-6-10	Upper Tuolumne (MRFF)		7,897	18-May-97	18-May-97	1	0.14	
	Total	22-Apr-97	93,507	18-May-97	24-May-97	3		0.036
6-1-11-6-4	Lower Tuolumne (MRFF)		25,241	11-May-97	18-May-97	6	0.23	
6-1-11-6-5	Lower Tuolumne (MRFF)		25,692	11-May-97	18-May-97	2	0.07	
6-1-11-6-6	Lower Tuolumne (MRFF)		21,531	08-May-97	21-May-97	4	0.19	
	Total	23-Apr-97	72,464	08-May-97	21-May-97	12		0.17
6-1-11-6-14	Lower Merced (MRFF)		33,064	---	---	0		
6-1-11-6-15	Lower Merced (MRFF)		28,294	28-May-97	28-May-97	1	0.03	
6-1-11-7-1	Lower Merced (MRFF)		24,943	---	---	0		
6-1-11-7-2	Lower Merced (MRFF)		5,856	---	---	0		
	Total	14-May-97	92,157	28-May-97	28-May-97	1		0.01

[a] MRFF = Merced River Fish Facility.

Table B-3 1996 Sacramento-San Joaquin Estuary, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-01-06-01-14	Mossdale (FRH)		49,024	---	---	0		
6-01-06-01-15	Mossdale (FRH)		51,718	25-Apr-96	27-Apr-96	2	0.04	
	Total	15-Apr-96	100,742	25-Apr-96	27-Apr-96	2		0.02
6-01-06-02-01	Mossdale (FRH)		50,462	07-May-96	07-May-96	1	0.02	
6-01-06-02-05	Mossdale (FRH)		49,194	---	---	0		
	Total	30-Apr-96	99,656	07-May-96	07-May-96	1		0.01
6-01-06-02-03	Dos Reis (FRH)		49,868	09-May-96	23-May-96	2	0.04	
6-01-06-01-10	Dos Reis (FRH)		48,770	11-May-96	11-May-96	1	0.02	
	Total	01-May-96	98,819	09-May-96	23-May-96	2		0.02
6-01-11-04-12	Dos Reis (MRFF)		25,530	08-May-96	10-May-96	2	0.07	
6-01-11-04-13	Dos Reis (MRFF)		28,079	05-May-96	07-May-96	2	0.07	
6-01-11-04-14	Dos Reis (MRFF)		18,459	06-May-96	06-May-96	1	0.05	
6-01-11-04-15	Dos Reis (MRFF)		35,893	08-May-96	12-May-96	5	0.13	
	Total	01-May-96	107,961	05-May-96	12-May-96	10		0.09

[a] FRH = Feather River Hatchery, MRFF = Merced River Fish Facility.

Table B-4 1996 Upper San Joaquin River Tributaries, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-01-11-04-08	Upper Merced (MRFF)		21,011	---	---	0		
6-01-11-04-09	Upper Merced (MRFF)		21,069	---	---	0		
6-01-11-04-10	Upper Merced (MRFF)		22,638	08-May-96	08-May-96	1	0.04	
6-01-11-04-11	Upper Merced (MRFF)		21,693	---	---	0		
	Total	25-Apr-96	86,411	08-May-96	08-May-96	1		0.01
6-01-11-05-03	Lower Merced (MRFF)		21,705	---	---	0		
6-01-11-05-04	Lower Merced (MRFF)		22,019	05-May-96	05-May-96	1	0.04	
6-01-11-05-05	Lower Merced (MRFF)		20,613	---	---	0		
	Total	26-Apr-96	64,337	05-May-96	05-May-96	1		0.01
6-01-11-05-06	Upper Tuolumne (MRFF)		21,601	---	---	0		
6-01-11-05-07	Upper Tuolumne (MRFF)		22,861	02-May-96	06-May-96	2	0.08	
6-01-11-05-08	Upper Tuolumne (MRFF)	26-Apr-96	22,984	06-May-96	06-May-96	1	0.04	
	Total		67,446	02-May-96	06-May-96	3		0.04
6-01-11-05-09	Upper Tuolumne (MRFF)		22,789	02-May-96	02-May-96	1	0.04	
6-01-11-05-10	Upper Tuolumne (MRFF)		27,819	01-May-96	08-May-96	3	0.10	
	Total	27-Apr-96	50,608	01-May-96	08-May-96	4		0.07

[a] MRFF = Merced River Fish Facility.

Table B-5 1995 Sacramento-San Joaquin Estuary, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-1-14-5-1	Mossdale (FRH)		50,849	25-Apr-95	24-May-95	10	0.19	
6-1-14-4-14	Mossdale (FRH)		50,120	26-Apr-95	17-May-95	10	0.19	
	Total	17-Apr-95	100,969	25-Apr-95	24-May-95	20		0.19
6-31-50	Mossdale (FRH)		52,297	12-May-95	24-May-95	10	0.19	
6-31-51	Mossdale (FRH)		50,265	12-May-95	02-Jun-95	3	0.06	
	Total	05-May-95	102,562	12-May-95	02-Jun-95	13		0.12
6-1-14-5-4	Mossdale (FRH)		52,703	29-May-95	29-May-95	1	0.02	
6-31-48	Mossdale (FRH)		51,422	21-May-95	29-May-95	7	0.13	
	Total	17-May-95	104,125	21-May-95	29-May-95	8		0.07

[a] FRH = Feather River Hatchery.

Table B-6 1995 Upper San Joaquin River and Tributaries, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-1-11-4-1	Upper Merced (MRFF)		28,349	08-May-95	29-May-95	5	0.17	
6-1-11-4-2	Upper Merced (MRFF)		27,961	21-May-95	13-Jun-95	3	0.10	
6-1-11-4-3	Upper Merced (MRFF)		26,839	28-May-95	12-Jun-95	4	0.14	
6-1-11-4-4	Upper Merced (MRFF)		28,138	23-May-95	06-Jun-95	6	0.20	
	Total	03-May-95	111,287	08-May-95	13-Jun-95	18		0.16
6-1-11-4-5	Lower Merced (MRFF)		27,318	21-May-95	03-Jun-95	7	0.24	
6-1-11-4-6	Lower Merced (MRFF)		27,643	21-May-95	09-Jun-95	4	0.14	
6-1-11-4-7	Lower Merced (MRFF)		28,054	20-May-95	29-May-95	7	0.23	
	Total	04-May-95	83,015	20-May-95	09-Jun-95	18		0.20
6-1-11-3-11	Upper Tuolumne (MRFF)		28,068	31-May-95	13-Jun-95	8	0.27	
6-1-11-3-12	Upper Tuolumne (MRFF)		27,132	21-May-95	25-Jun-95	6	0.22	
6-1-11-3-13	Upper Tuolumne (MRFF)		28,347	29-May-95	14-Jun-95	8	0.27	
	Total	04-May-95	83,547	21-May-95	25-Jun-95	22		0.26

[a] MRFF = Merced River Fish Facility.

Table B-7 1994 Upper San Joaquin River and Tributaries, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-1-11-2-10	Upper Merced (MRFF)		28,315	01-May-94	02-May-94	2	0.07	
6-1-11-2-11	Upper Merced (MRFF)		25,328	01-May-94	01-May-94	1	0.04	
6-1-11-2-12	Upper Merced (MRFF)		28,532	01-May-94	08-May-94	2	0.07	
6-1-11-2-13	Upper Merced (MRFF)		17,390	15-May-94	15-May-94	1	0.05	
	Total	22-Apr-94	99,565	01-May-94	15-May-94	6		0.06
6-1-11-2-14	Lower Merced (MRFF)		35,017	---	---	0		
6-1-11-2-15	Lower Merced (MRFF)		23,324	01-May-94	03-May-94	2	0.08	
6-1-11-3-1	Lower Merced (MRFF)		23,750	---	---	0		
	Total	22-Apr-94	82,091	01-May-94	03-May-94	2		0.02
6-1-11-3-2	Upper Tuolumne (MRFF)		58,859	05-May-94	14-May-94	2	0.03	
6-1-11-3-3	Upper Tuolumne (MRFF)		4,281	12-May-94	12-May-94	1	0.22	
6-1-11-3-4	Upper Tuolumne (MRFF)		20,274	---	---	0		
	Total	23-Apr-94	83,414	05-May-94	14-May-94	3		0.03
6-1-11-3-5	Lower Tuolumne (MRFF)		36,429	06-May-94	06-May-94	1	0.03	
6-1-11-3-6	Lower Tuolumne (MRFF)		13,626	08-May-94	08-May-94	1	0.07	
	Total	24-Apr-94	50,055	06-May-94	08-May-94	2		0.04

[a] MRFF = Merced River Fish Facility.

Table B-8 1992 Sacramento-San Joaquin Estuary, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-1-14-2-12	Mossdale (FRH)		54,073	13-Apr-92	05-May-92	9	0.16	
6-1-14-2-13	Mossdale (FRH)		53,030	13-Apr-92	01-May-92	11	0.20	
	Total	07-Apr-92	107,103	13-Apr-92	05-May-92	20		0.18
6-1-14-2-14	Mossdale (FRH)		53,754	16-Apr-92	27-Apr-92	10	0.17	
6-1-14-2-15	Mossdale (FRH)		49,958	21-Apr-92	01-May-92	3	0.06	
	Total	13-Apr-92	103,712	16-Apr-92	01-May-92	13		0.12
6-1-14-3-3	Mossdale (w/barrier) (FRH)		53,294	03-May-92	06-May-92	7	0.12	
6-1-14-3-4	Mossdale (w/barrier) (FRH)		51,445	04-May-92	19-May-92	2	0.04	
	Total	24-Apr-92	104,739	03-May-92	19-May-92	9		0.08
6-31-31	Mossdale (w/barrier) (FRH)		51,262	16-May-92	16-May-92	1	0.02	
6-31-32	Mossdale (w/barrier) (FRH)		48,455	---	---	0		
	Total	04-May-92	99,717	16-May-92	16-May-92	1	0.01	0.01
6-31-33	Mossdale (w/barrier) (FRH)		52,454	---	---	0		
6-31-34	Mossdale (w/barrier) (FRH)		52,931	21-May-92	23-May-92	2	0.04	
	Total	12-May-92	105,385	21-May-92	23-May-92	2		0.02

[a] FRH = Feather River Hatchery, w/barrier = with barrier in upper Old River.

Table B-9 1991 Upper Sacramento River, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
5-18-45	Princeton (CNFH)		12,474	14-May-91	19-May-91	4	0.30	
5-18-47	Princeton (CNFH)		18,713	11-May-91	21-May-91	10	0.50	
5-18-48	Princeton (CNFH)		20,792	10-May-91	30-May-91	10	0.46	
	Total	03-May-91	51,979	10-May-91	30-May-91	24		0.44

[a] CNFH = Coleman National Fish Hatchery.

Table B-10 1991 Sacramento-San Joaquin Estuary, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-1-14-1-14	Dos Reis (FRH)		52,097	23-Apr-91	11-May-91	8	0.15	
6-1-14-1-15	Dos Reis (FRH)		50,902	23-Apr-91	02-May-91	9	0.17	
	Total	15-Apr-91	102,999	23-Apr-91	11-May-91	17		0.16
6-1-14-2-1	Buckley Cove (FRH)		51,128	24-Apr-91	06-May-91	15	0.28	
6-1-14-2-2	Buckley Cove (FRH)		48,213	25-Apr-91	02-May-91	11	0.21	
	Total	16-Apr-91	99,341	24-Apr-91	06-May-91	26		0.24
6-1-14-2-3	Empire Tract (FRH)		48,255	24-Apr-91	09-May-91	25	0.48	
6-1-14-2-4	Empire Tract (FRH)		47,347	24-Apr-91	12-May-91	29	0.58	
	Total	17-Apr-91	95,602	24-Apr-91	12-May-91	54		0.54
6-1-14-2-7	Sacramento (Miller Park) (FRH)		51,392	01-May-91	06-May-91	34	0.62	
6-1-14-2-8	Sacramento (Miller Park) (FRH)		51,272	30-Apr-91	09-May-91	50	0.91	
	Total	25-Apr-91	102,664	30-Apr-91	09-May-91	84		0.77
6-1-14-2-9	Sacramento (Miller Park) (FRH)		53,430	27-Apr-91	16-May-91	21	0.37	
6-31-24	Sacramento (Miller Park) (FRH)		51,086	04-May-91	10-May-91	34	0.64	
	Total	29-Apr-91	104,516	27-Apr-91	16-May-91	55		0.50
6-31-25	Buckley Cove (FRH)		49,393	11-May-91	30-May-91	7	0.13	
6-31-26	Buckley Cove (FRH)		50,427	11-May-91	16-May-91	13	0.24	
	Total	06-May-91	99,820	11-May-91	30-May-91	20		0.19

[a] FRH = Feather River Hatchery.

Table B-11 1990 Sacramento-San Joaquin Estuary, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-1-14-1-8	Dos Reis (FRH)		53,254	26-Apr-90	13-May-90	2	0.04	
6-1-14-1-7	Dos Reis (FRH)		52,488	12-May-90	15-May-90	2	0.04	
	Total	16-Apr-90	105,742	26-Apr-90	15-May-90	4		0.04
6-1-14-1-6	Upper Old River (FRH)		52,954	---	---	0		
6-1-14-1-5	Upper Old River (FRH)		53,313	24-Apr-90	01-May-90	2	0.041	
	Total	17-Apr-90	106,267	24-Apr-90	01-May-90	2		0.02
6-1-14-1-12	Upper Old River (FRH)		51,521	16-May-90	16-May-90	1	0.02	
6-1-14-1-13	Upper Old River (FRH)		52,074	---	---	0		
	Total	03-May-90	103,595	16-May-90	16-May-90	1		0.01

[a] FRH = Feather River Hatchery.

Table B-12 1990 Upper San Joaquin River and Tributaries, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-1-11-1-14	Upper Tuolumne (MRFF)		24,134	12-May-90	12-May-90	1	0.04	
6-1-11-1-15	Upper Tuolumne (MRFF)		24,259	16-May-90	16-May-90	1	0.04	
6-1-11-2-1	Upper Tuolumne (MRFF)		23,494	12-May-90	12-May-90	1	0.04	
6-1-11-2-2	Upper Tuolumne (MRFF)		21,766	08-May-90	08-May-90	1	0.04	
	Total	30-Apr-90	93,653	08-May-90	16-May-90	4		0.04
6-1-11-2-3	Lower Tuolumne (TRFF)		27,263	12-May-90	12-May-90	1	0.03	
6-1-11-2-4	Lower Tuolumne (TRFF)		26,067	---	---	0		
6-1-11-2-5	Lower Tuolumne (TRFF)		24,905	---	---	0		
	Total	01-May-90	78,235	12-May-90	12-May-90	1		0.01

[a] MRFF = Merced River Fish Facility, TRFF = Tuolumne River Fish Facility.

Table B-13 1989 Sacramento-San Joaquin Estuary, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-1-11-1-11	Jersey Point (FRH)		27,758	29-Apr-89	15-May-89	24	0.81	
6-1-11-1-12	Jersey Point (FRH)		29,058	29-Apr-89	12-May-89	29	0.94	
	Total	24-Apr-89	56,816	29-Apr-89	15-May-89	53		0.88
6-1-11-1-7	Dos Reis (MRFF)		25,089	10-May-89	30-May-89	3	0.12	
6-1-11-1-8	Dos Reis (MRFF)		25,631	08-May-89	24-May-89	7	0.26	
6-1-11-1-13	Dos Reis (MRFF)		25,353	10-May-89	10-May-89	1	0.04	
	Total	02-May-89	76,073	08-May-89	30-May-89	11		0.15
6-1-11-1-4	Upper Old River (MRFF)		25,087	08-May-89	08-May-89	1	0.04	
6-1-11-1-5	Upper Old River (MRFF)		24,472	09-May-89	09-May-89	1	0.04	
6-1-11-1-6	Upper Old River (MRFF)		24,782	08-May-89	15-May-89	2	0.08	
	Total	03-May-89	74,341	08-May-89	15-May-89	4		0.05
6-1-11-1-9	Jersey Point (FRH)		27,525	08-May-89	25-May-89	33	1.13	
6-1-11-1-10	Jersey Point (FRH)		28,708	08-May-89	22-May-89	25	0.82	
	Total	05-May-89	56,233	08-May-89	25-May-89	58		1.0
6-31-15	Sacramento (Miller Park) (FRH)		44,695	17-Jun-89	19-Jun-89	11	0.23	
6-31-17	Sacramento (Miller Park) (FRH)		49,909	17-Jun-89	19-Jun-89	9	0.17	
	Total	14-Jun-89	94,604	17-Jun-89	19-Jun-89	20		0.20

[a] FRH = Feather River Hatchery, MRFF = Merced River Fish Facility.

Table B-14 1989 Upper San Joaquin River and Tributaries, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
B6-14-9	Upper Stanislaus (MRFF)		52,445	29-Apr-89	11-May-89	3	0.05	
B6-14-10	Upper Stanislaus (MRFF)		51,506	30-Apr-89	16-May-89	4	0.07	
	Total	20-Apr-89	103,951	29-Apr-89	16-May-89	7		0.06
B6-1-1	Lower Stanislaus (MRFF)		25,525	24-Apr-89	02-May-89	11	0.40	
B6-14-11	Lower Stanislaus (MRFF)		48,695	24-Apr-89	27-Apr-89	6	0.12	
	Total	19-Apr-89	74,220	24-Apr-89	2-May-89	17		0.21
6-1-11-1-1	Lower Merced (MRFF)		25,357	03-May-89	10-May-89	3	0.11	
6-1-11-1-2	Lower Merced (MRFF)		25,276	15-May-89	15-May-89	1	0.04	
6-1-11-1-3	Lower Merced (MRFF)		23,832	---	---	0		
	Total	21-Apr-89	74,465	03-May-89	15-May-89	4		0.05

[a] MRFF = Merced River Fish Facility.

Table B-15 1988 Sacramento-San Joaquin Estuary Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
B6-14-2	Courtland (FRH)		51,388	07-May-88	21-May-88	71	0.65	
B6-14-3	Courtland (FRH)		55,861	07-May-88	25-May-88	83	0.70	
	Total	03-May-88	107,249	07-May-88	25-May-88	154		0.68
B6-14-6	Sacramento (Miller Park) (FRH)		51,005	08-May-88	23-May-88	77	0.71	
B6-14-7	Sacramento (Miller Park) (FRH)		51,731	09-May-88	21-May-88	65	0.59	
	Total	05-May-88	102,736	08-May-88	23-May-88	142		0.65
B6-14-4	Courtland (FRH)		51,274	08-May-88	27-May-88	67	0.67	
B6-14-5	Courtland (FRH)		51,206	10-May-88	21-May-88	80	0.73	
	Total	06-May-88	102,480	08-May-88	27-May-88	147		0.73
6-62-59	Courtland (FRH)		54,997	23-Jun-88	29-Jun-88	25	0.21	
6-62-60	Courtland (FRH)		51,904	23-Jun-88	03-Jul-88	14	0.13	
	Total	21-Jun-88	106,901	23-Jun-88	03-Jul-88	39		0.17
6-62-61	Sacramento (Miller Park) (FRH)		49,245	26-Jun-88	07-Jul-88	7[b]	0.08	
6-62-62	Sacramento (Miller Park) (FRH)		48,647	26-Jun-88	03-Jul-88	7[b]	0.07	
	Total	23-Jun-88	97,892	26-Jun-88	07-Jul-88	14		0.08

[a] FRH = Feather River Hatchery.

[b] Total number recovered for both tag code 6-62-61 and 6-62-62 is reduced by 1, as they were recorded as being recovered at Chipps Island on the day of release.

Table B-16 1988 Upper San Joaquin River and Tributaries Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
B6-11-5	Upper Stanislaus (MRFF)		36,769	04-May-88	11-May-88	6	0.08	
B6-11-6	Upper Stanislaus (MRFF)		34,906	12-May-88	21-May-88	5	0.07	
	Total	26-Apr-88	71,675	04-May-88	21-May-88	11		0.07
B6-11-3	Lower Stanislaus (MRFF)		35,249	03-May-88	19-May-88	6	0.08	
B6-11-4	Lower Stanislaus (MRFF)		33,539	07-May-88	22-May-88	7	0.10	
	Total	26-Apr-88	68,788	03-May-88	22-May-88	13		0.09

[a] MRFF = Merced River Fish Facility.

Table B-17 1987 Sacramento San Joaquin Estuary, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-45-3	Upper Old River (MRFF)		31,099	30-Apr-87	06-May-87	8	0.23	
6-45-4	Upper Old River (MRFF)		29,253	30-Apr-87	05-May-87	5	0.16	
6-45-5	Upper Old River (MRFF)		30,600	30-Apr-87	03-May-87	3	0.07	
	Total	27-Apr-87	90,952	30-Apr-87	06-May-87	16		0.16
6-45-6	Dos Reis (MRFF)		30,919	05-May-87	13-May-87	30	0.93	
6-45-7	Dos Reis (MRFF)		31,634	05-May-87	20-May-87	22	0.66	
6-45-8	Dos Reis (MRFF)		30,059	05-May-87	12-May-87	28	0.89	
	Total	27-Apr-87	92,612	05-May-87	20-May-87	80		0.83
6-62-53	Courtland (FRH)		49,781	01-May-87	12-May-87	32	0.60	
6-62-54	Courtland (FRH)		50,521	01-May-87	14-May-87	39	0.72	
	Total	28-Apr-87	100,302	01-May-87	14-May-87	71		0.66
6-62-56	Courtland (FRH)		49,083	04-May-87	15-May-87	20	0.39	
6-62-57	Courtland (FRH)		51,836	05-May-87	22-May-87	23	0.42	
	Total	01-May-87	100,919	04-May-87	22-May-87	43		0.41

[a] MRFF = Merced River Fish Facility, FRH = Feather River Hatchery.

Table B-18 1987 Upper San Joaquin River and Tributaries, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-46-60	Upper Tuolumne (MRFF)		29,959	25-Apr-87	01-May-87	2	0.06	
6-46-61	Upper Tuolumne (MRFF)		30,601	---	---	0		
6-46-62	Upper Tuolumne (MRFF)		29,040	28-Apr-87	30-Apr-87	3	0.10	
	Total	16-Apr-87	89,600	25-Apr-87	01-May-87	5		0.05
6-45-1	Lower Tuolumne (MRFF)		31,866	22-Apr-87	04-May-87	5	0.14	
6-45-2	Lower Tuolumne (MRFF)		30,936	22-Apr-87	05-May-87	9	0.27	
6-46-63	Lower Tuolumne (MRFF)		30,709	26-Apr-87	05-May-87	4	0.12	
	Total	16-Apr-87	93,511	22-Apr-87	05-May-87	18		0.18

[a] MRFF = Merced River Fish Facility.

Table B-19 1986 Upper Sacramento River and Tributaries, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
H5-4-2	Battle Creek (CNFH)		24,933	21-May-86	26-May-86	11	0.41	
H5-4-3	Battle Creek (CNFH)		28,659	21-May-86	27-May-86	19	0.62	
	Total	13-May-86	53,592	21-May-86	27-May-86	30		0.52
H5-4-4	Below RBDD (CNFH)		26,900	21-May-86	31-May-86	9	0.31	
H5-4-5	Below RBDD (CNFH)		27,606	20-May-86	01-Jun-86	17	0.58	
	Total	13-May-86	54,506	20-May-86	01-Jun-86	26		0.45
H5-4-6	Princeton (CNFH)		23,669	23-May-86	27-May-86	3	0.12	
H5-4-7	Princeton (CNFH)		22,719	19-May-86	22-May-86	7	0.29	
	Total	14-May-86	56,388	19-May-86	27-May-86	10		0.17

[a] CNFH = Coleman National Fish Hatchery.

Table B-20 1986 Sacramento-San Joaquin Estuary, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-46-58	Dos Reis (MRFF)		47,954	02-Jun-86	08-Jun-86	13	0.25	
B6-11-1	Dos Reis (MRFF)		47,641	02-Jun-86	07-Jun-86	22	0.43	
	Total	29-May-86	95,595	02-Jun-86	08-Jun-86	35		0.34
6-46-59	Upper Old River (MRFF)		49,434	01-Jun-86	06-Jun-86	10	0.19	
B6-11-2	Upper Old River (MRFF)		50,747	01-Jun-86	03-Jun-86	11	0.20	
	Total	30-May-86	100,181	01-Jun-86	06-Jun-86	21		0.20

[a] MRFF = Merced River Fish Facility.

Table B-21 1986 Upper San Joaquin River and Tributaries, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-46-54	Upper Tuolumne (MRFF)		49,630	25-Apr-86	27-May-86	17	0.38	
6-46-55	Upper Tuolumne (MRFF)		49,518	23-Apr-86	21-May-86	18	0.43	
	Total	14-Apr-86	99,148	23-Apr-86	27-May-86	35		0.40
6-46-56	Lower Tuolumne (MRFF)		51,300	23-Apr-86	7-May-86	10	0.31	
6-46-57	Lower Tuolumne (MRFF)		52,174	25-Apr-86	10-May-86	10	0.26	
	Total	14-Apr-86	103,474	23-Apr-86	10-May-86	20		0.27
6-46-48	Upper Stanislaus (MRFF)		31,120	03-May-86	16-Jun-86	17	0.55	
6-46-49	Upper Stanislaus (MRFF)		31,148	05-May-86	20-May-86	11	0.33	
6-46-50	Upper Stanislaus (MRFF)		24,751	07-May-86	07-Jun-86	4	0.15	
6-46-53	Upper Stanislaus (MRFF)		21,254	08-May-86	11-Jun-86	5	0.22	
	Total	28-Apr-86	108,273	03-May-86	16-Jun-86	37		0.34
6-46-45	Lower Stanislaus (MRFF)		31,491	05-May-86	15-May-86	16	0.48	
6-46-46	Lower Stanislaus (MRFF)		31,310	05-May-86	25-May-86	18	0.54	
6-46-47	Lower Stanislaus (MRFF)		30,530	03-May-86	18-May-86	20	0.66	
6-46-52	Lower Stanislaus (MRFF)		12,768	05-May-86	18-May-86	6	0.44	
	Total	29-Apr-86	106,169	03-May-86	25-May-86	60		0.56

[a] MRFF = Merced River Fish Facility.

Table B-22 1985 Upper Sacramento River and Tributaries, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
5-39-4	Battle Creek (CNFH)		11,484	21-May-85	23-May-85	2	0.16	
5-40-4	Battle Creek (CNFH)		10,698	22-May-85	25-May-85	2	0.17	
5-41-4	Battle Creek (CNFH)		10,330	21-May-85	23-May-85	3	0.27	
H5-1-5	Battle Creek (CNFH)		22,558	20-May-85	22-May-85	3	0.12	
5-6-16	Battle Creek (CNFH)		10,209	24-May-85	24-May-85	1	0.09	
	Total	14-May-85	65,279	20-May-85	25-May-85	11		0.16
5-9-47	Below RBDD (CNFH)		21,871	21-May-85	24-May-85	2	0.09	
5-42-4	Below RBDD (CNFH)		10,610	21-May-85	31-May-85	5	0.44	
5-43-4	Below RBDD (CNFH)		9,756	22-May-85	23-May-85	3	0.29	
H5-1-6	Below RBDD (CNFH)		23,378	22-May-85	24-May-85	9	0.36	
	Total	14-May-85	65,615	21-May-85	31-May-85	19		0.27
5-9-48	Princeton (CNFH)		21,943	21-May-85	24-May-85	3	0.13	
5-9-49	Princeton (CNFH)		20,460	21-May-85	22-May-85	3	0.14	
H5-1-7	Princeton (CNFH)		23,519	20-May-85	22-May-85	3	0.12	
	Total	15-May-85	65,922	20-May-85	24-May-85	9		0.13

[a] CNFH = Coleman National Fish Hatchery.

Table B-23 1985 Sacramento-San Joaquin Estuary, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-62-38	Courtland (FRH)		54,457	14-May-85	25-May-85	23	0.40	
6-62-39	Courtland (FRH)		14,731	14-May-85	25-May-85	2	0.13	
6-62-40	Courtland (FRH)		10,887	14-May-85	25-May-85	3	0.26	
6-62-41	Courtland (FRH)		20,551	14-May-85	25-May-85	9	0.41	
	Total	10-May-85	100,626	14-May-85	25-May-85	37		0.34

[a] FRH = Feather River Hatchery.

Table B-24 1984 Upper Sacramento River and Tributaries, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-60-42	Battle Creek (CNFH)		50,742	16-May-84	23-May-84	19	0.77	
6-60-43	Battle Creek (CNFH)		49,479	16-May-84	23-May-84	16	0.66	
	Total	09-May-84	100,221	16-May-84	23-May-84	35		0.72
6-60-40	Below RBDD (CNFH)		51,948	15-May-84	23-May-84	29	1.06	
6-60-41	Below RBDD (CNFH)		50,921	15-May-84	23-May-84	29	1.08	
	Total	09-May-84	102,869	15-May-84	23-May-84	58		1.07
6-60-38	Knights Landing (CNFH)		49,400	13-May-84	23-May-84	19	0.85	
6-60-39	Knights Landing (CNFH)		49,351	15-May-84	23-May-84	17	0.65	
	Total	09-May-84	98,751	13-May-84	23-May-84	36		0.81

[a] CNFH = Coleman National Fish Hatchery.

Table B-25 1984 Sacramento-San Joaquin Estuary, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-62-28	South Fork Mokelumne (FRH)		41,371	16-Jun-84	26-Jun-84	25	0.72	
6-42-8	South Fork Mokelumne (FRH)		14,916	17-Jun-84	22-Jun-84	9	0.66	
	Total	12-Jun-84	56,287	16-Jun-84	26-Jun-84	34		0.72
6-62-29	Ryde (FRH)		44,818	16-Jun-84	26-Jun-84	30	0.66	
6-42-9	Ryde (FRH)		15,180	17-Jun-84	28-Jun-84	8	0.62	
	Total	13-Jun-84	59,998	16-Jun-84	28-Jun-84	38		0.73

[a] FRH = Feather River Hatchery.

Table B-26 1983 Upper Sacramento River and Tributaries, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-60-36	Battle Creek (CNFH)		44,382	07-Jun-83	24-Jun-83	15	0.65	
6-60-37	Battle Creek (CNFH)		43,508	07-Jun-83	17-Jun-83	10	0.34	
	Total	02-Jun-83	87,890	07-Jun-83	24-Jun-83	25		0.55
6-60-34	Below RBDD (CNFH)		44,498	07-Jun-83	15-Jun-83	16	0.51	
6-60-35	Below RBDD (CNFH)		45,343	07-Jun-83	21-Jun-83	10	0.40	
	Total	02-Jun-83	89,841	07-Jun-83	21-Jun-83	26		0.52
6-60-32	Knights Landing (CNFH)		45,986	05-Jun-83	15-Jun-83	45	1.26	
6-60-33	Knights Landing (CNFH)		46,099	05-Jun-83	21-Jun-83	31	1.10	
	Total	02-Jun-83	92,085	05-Jun-83	21-Jun-83	76		1.34

[a] CNFH = Coleman National Fish Hatchery.

Table B-27 1982 Upper Sacramento River and Tributaries, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-60-26	Battle Creek (CNFH)		42,964	13-May-82	07-Jun-82	37	1.65	
6-60-27	Battle Creek (CNFH)		41,738	13-May-82	24-May-82	27	0.76	
	Total	05-May-82	84,702	13-May-82	07-Jun-82	64		1.45
6-60-28	Below RBDD (CNFH)		44,308	13-May-82	15-Jun-82	34	1.24	
6-60-29	Below RBDD (CNFH)		43,817	10-May-82	24-May-82	35	1.06	
	Total	05-May-82	88,125	10-May-82	15-Jun-82	69		1.25
6-60-30	Knights Landing (CNFH)		44,735	10-May-82	24-May-82	50	1.48	
6-60-31	Knights Landing (CNFH)		44,540	10-May-82	24-May-82	41	1.22	
	Total	05-May-82	89,275	10-May-82	24-May-82	91		1.35

[a] CNFH = Coleman National Fish Hatchery.

Table B-28 1981 Upper Sacramento River and Tributaries, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-60-20	Knights Landing (CNFH)		43,059	28-May-81	28-May-81	3	0.08	
6-60-21	Knights Landing (CNFH)		43,562	28-May-81	04-Jun-81	2	0.14	
	Total	18-May-81	86,621	28-May-81	04-Jun-81	5		0.18

[a] CNFH = Coleman National Fish Hatchery.

Table B-29 1981 Sacramento-San Joaquin Estuary, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*	*Survival index*	*Group survival*
6-62-14	Discovery Park (FRH)		71,932	10-Jun-81	10-Jun-81	1	0.02	
6-62-17	Discovery Park (FRH)		68,318	---	---	0	0	
	Total	04-Jun-81	140,249	10-Jun-81	10-Jun-81	1		0.01

[a] FRH = Feather River Hatchery.

Table B-30 1980 Upper Sacramento River and Tributaries, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*
H5-3-1	Below RBDD (CNFH)		25,618	---	---	0
H5-3-2	Below RBDD (CNFH)		22,560	---	---	0
	Total	28-Feb-80	48,178			
H5-3-5	Below RBDD (CNFH)		21,786	15-May-80	15-May-80	1
H5-3-6	Below RBDD (CNFH)		21,836	---	---	0
	Total	31-Mar-80	43,622			

[a] CNFH = Coleman National Fish Hatchery.

Table B-31 1980 Sacramento-San Joaquin Estuary, Fall-run Releases

Tag code	*Release site (stock)*[a]	*Date released*	*Number released*	*First day recovered*	*Last day recovered*	*Number recovered*
H5-2-4	Berkeley (CNFH)		21,939	---	---	0
H5-2-5	Berkeley (CNFH)		20,788	---	---	0
	Total	28-Feb-80	42,727			
H5-2-6	Clarksburg (CNFH)		22,121	---	---	0
H5-2-7	Clarksburg (CNFH)		21,624	---	---	0
	Total	28-Feb-80	43,745			
H5-3-3	Clarksburg (CNFH)		23,908	17-Apr-80	01-May-80	2
H5-3-4	Clarksburg (CNFH)		22,829	24-Apr-80	01-May-80	2
	Total	31-Mar-80	46,737			

[a] CNFH = Coleman National Fish Hatchery.