# BIOLOGICAL ASSESSMENT

## Effects of
## Central Valley Project and State Water Project
## Delta Operations on
## Winter-Run Chinook Salmon

By

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# CONCLUSIONS

Delta operations of the Central Valley Project and State Water Project have not been a major factor in the decline of the winter run of Central Valley Chinook salmon stocks. This conclusion is based on three facts:

- There is no correlation between detrended cohort abundance and Delta pumping during the period when the cohort migrated through the Delta toward the ocean.
- There is no correlation between an index of survival (recruits per spawner) and such Delta conditions during outmigration as total pumping, percent of inflow diverted, and numbers of days of reverse flow.
- Perhaps most important, the decline occurred during one of the wettest periods in this century. During winters of wet years, Delta Cross Channel gates are closed, flows in the Sacramento and San Joaquin rivers are high, and total pumping is a small fraction of the inflow.

Delta operations do result in the take of winter-run Chinook salmon. Take occurs due to juvenile salmon being diverted off the mainstem through the Delta Cross Channel, perhaps due to flow reversals in the lower San Joaquin River, and due to direct losses associated with CVP/SWP diversions in the southern Delta.

At this time it is not possible to quantify the take caused by either the direct or the indirect effects of Delta operations. This conclusion is due to uncertainties in:

- The application of models derived from studies of survival of fall-run hatchery juveniles planted at various locations in the Delta. The models do consistently indicate that temperature may be the most important factor in calculations of survival indices.
- The use of DFG's system of classifying Chinook salmon by race, knowing the fish's length and time of capture. The system is innovative and exhibits considerable biological insight, but it appears to greatly overestimate the numbers of winter-run salmon captured or salvaged in the Delta. It does appear appropriate for use in the upper river.
- The loss rate of salmon moving across Clifton Court Forebay to the fish protective facilities. Based on temperature alone, and its effects on predator feeding rates, the loss rates should be lower in the winter, when winter-run juveniles are moving through the Delta.

# CONTENTS

## Tables

## Figures

# INTRODUCTION

This report describes results of analyses to assess the impacts of existing Delta operations of the Central Valley Project and State Water Project on the Sacramento River winter run of Chinook salmon, *Oncorhynchus tshawytscha*. The report provides the basis for formal Section 7 consultations and resulting biological opinion regarding Delta operations of the U.S. Bureau of Reclamation and California Department of Water Resources Delta. A second winter-run biological assessment focusing on the USBR's Sacramento and Trinity operations has been released by the USBR (USBR, October 1992).

For purposes of these analyses, existing project operations cover the ranges of flows and exports experienced within the past several years. Principal facilities included in these analyses are CVP fish protective and pumping facilities at Tracy, SWP fish protective and pumping at Byron, CVP Delta Cross Channel gates at Walnut Grove, Montezuma Slough salinity control gates, the CVP's Contra Costa Canal, the SWP's North Bay Aqueduct's pumping and fish protective facilities in Barker Slough, and DWR's South Delta Temporary Barriers Project.

The report covers existing operations and evaluates operational scenarios developed by USBR and DWR staff for the CVP-OCAP (CVP-Operations Criteria and Procedures). The goal of the Section 7 process is to obtain a long-term incidental winter-run take permit which encompasses expected CVP/SWP operations using existing facilities. Once this permit is obtained, DWR expects to enter consultation regarding future SWP facilities such as the Kern Fan ground water storage element.

Although the assessment is primarily for fulfilling the requirements of the federal Endangered Species Act, it is also intended for use by the California Department of Fish and Game pursuant to the State act. By informal interagency agreement in June 1991, the State and federal government combined the two consultation processes with the expectation that conditions in the State and federal biological opinions would be identical.

The report contains sections describing the biology of the winter-run salmon, a summary of out-of-Delta factors influencing its distribution and abundance, project operations and facilities in the Delta, means of identifying winter-run salmon, timing winter-run movement through the Delta, and analysis of Delta impacts.

As will become apparent in the report, our knowledge of winter-run distribution and abundance in the Delta and factors controlling survival is severely limited. There are essentially no published analyses of winter-run Chinook salmon migration through the Delta and factors influencing survival of either adults or juveniles through this migratory corridor. The available data and hypotheses are examined to help ensure they provide the best available scientific information related to this race of Chinook salmon.

# BIOLOGY AND LIFE HISTORY OF WINTER-RUN CHINOOK SALMON

The following descriptions of Chinook salmon biology and specific features of winter-run biology are designed to provide a common starting point. More information is in a 1991 USBR publication, *Guide to Upper Sacramento River Chinook Salmon Life History* (Vogel and Marine 1991).

## Chinook Salmon Basic Life Cycle

The Chinook salmon, or King salmon as it is sometimes referred to in California, has the broadest geographic range of any of the Pacific salmon species. Runs of Chinook salmon are found throughout the northern Pacific Ocean and tributary drainages around the Pacific Rim from northern Japan to southern California. In spite of its wide distribution, the Chinook salmon is the least abundant of Pacific salmon species. As a species, the Chinook salmon is distinguished by its highly variable life history, and many rivers have more than one distinct stock identifiable by its life history patterns.

The life span of Chinook salmon may range from 2 to 7 years. Chinook salmon spend from 1-1/2 to 5 years in the ocean before maturing and returning to natal streams to spawn. Both life span and the timing of spawning migrations are primarily genetically controlled.

Chinook salmon eggs are laid in nests, referred to as redds, excavated by the female in uncompacted gravels. Suitable gravel beds selected by female Chinook salmon consist mainly of gravel ranging from 1 to 6 inches in diameter. Optimal survival of eggs and pre-emergent fry occurs when the largest fraction of the redd is composed of the small to midsize gravel. The female seeks out gravel beds with water depths and velocities sufficient for spawning activities and egg incubation. Depths for spawning range from shallow riffle areas (0.5 to 2 feet deep) to deep runs or glides (5 feet to over 20 feet deep). Spawning depth is a function of physiological requirements, available habitat, and specific preferential differences between stocks of salmon, probably under genetic influence. For instance, some winter-run Chinook salmon have been observed to spawn on gravels in deeper water than the other three Sacramento River salmon runs. Preferred spawning velocities are generally in the range of 1.5 to 2.5 feet per second just above the surface of the gravel bed. As the female lays the eggs in the redd, one or more male salmon fertilize the eggs. The female subsequently buries the eggs in the redd by displacing gravels upstream of the redd onto the eggs.

Eggs hatch after a variable incubation period that is dependent on water temperature, generally about 40 to 60 days. Based on literature from other streams, maximum survival of incubating eggs and pre-emergent fry occurs at water temperatures between 40 and 56° Fahrenheit. The newly hatched larvae, or pre-emergent fry, remain in the redd and absorb the yolk stored in their yolk-sacs to grow into fry. This period of larval incubation lasts about 2 to 4 weeks, depending on water temperatures. The fry then wiggle out of the redds, up into the water above. The fry seek out shallow, near-shore areas with slow current and vegetative and/or boulder cover nearby, where they begin to feed on drifting insects and crustaceans. As they grow, the juvenile salmon (about 50 to 75 millimeters fork length) move into deeper, swifter water for rearing, but continue to remain near boulders, fallen trees, and other such cover to reduce chances of being preyed upon and to minimize energy expenditure.

Juvenile salmon may emigrate downstream toward the estuary at any time from immediately after emerging from the redd to after spending more than a year in fresh water. The length of juvenile residence time in fresh water and estuaries varies between salmon runs and depends on a variety of factors, including season of emergence, streamflow, turbidity, water temperature, and interactions with other species. There are two general types of Chinook salmon life history strategies, the "stream" and "ocean" types (see for example Taylor 1990). Stream-type juveniles remain in the river for one or more years before migrating to the ocean. Ocean-type juveniles typically move to the ocean during their first few months of life. In general, stream types are found north of the Columbia River and in streams that have long migratory routes (*eg* the Snake River in Idaho). Although California races more typically follow the "ocean" pattern, some fall, late-fall, and spring-run juveniles may outmigrate as age 1 smolts. Winter-run salmon apparently all migrate during the first few months after emergence (Frank Fisher, personal communication).

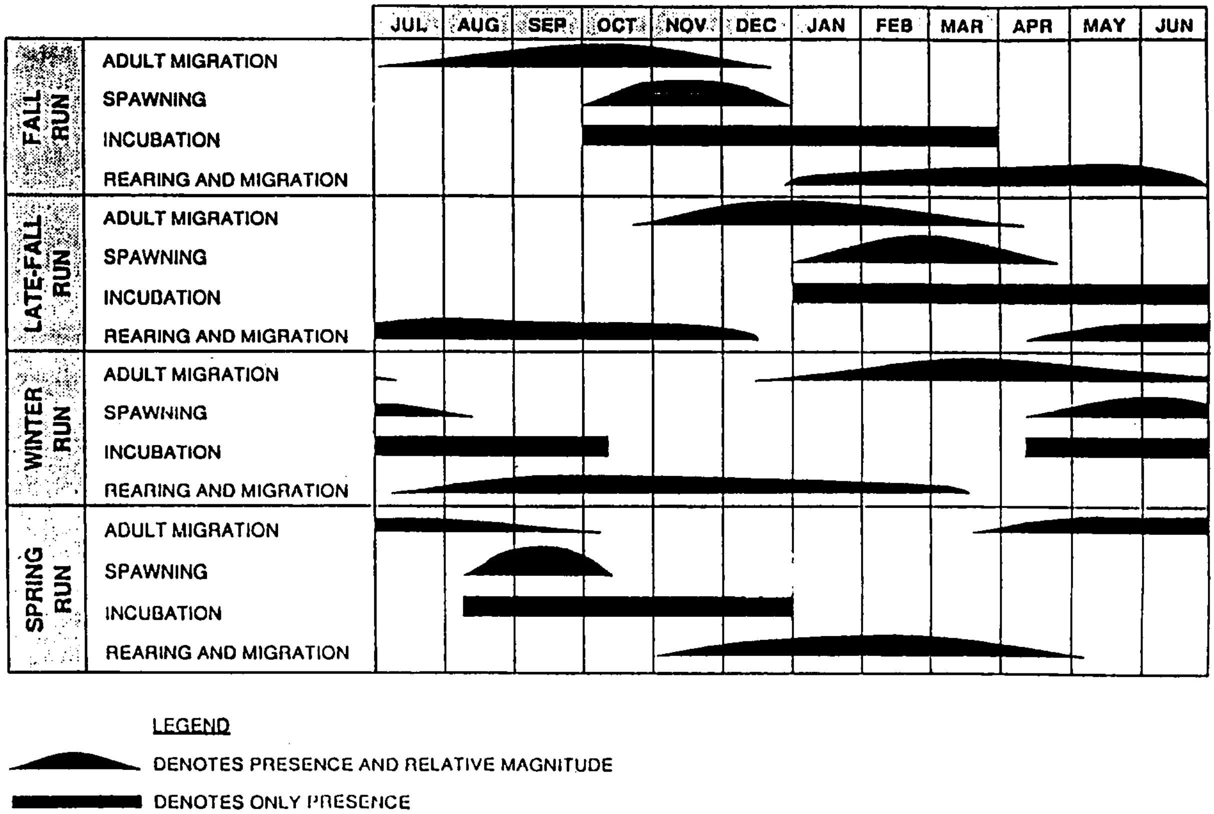
## Life History Strategies Distinguishing the Four Runs of Sacramento River Chinook Salmon

The Sacramento River is unique among Pacific Coast streams in that it possesses four Chinook runs (fall, late-fall, winter, and spring) and spawning occurs virtually year-round. Each of the freshwater life stages (*ie*, spawning adult, egg and larva, fry, and juvenile) may be found in the upper river every month of the year. This is due to a variety of factors, including the remarkable adaptability of the Chinook salmon, the historically diverse habitat available in the Sacramento River Basin including spring-fed streams that remain cool all summer, and the moderate California climate that provides for nearly year-round ice-free streams throughout many drainages (Vogel and Marine 1991).

Figure 1 illustrates the general timing of each run of Sacramento River Chinook salmon at and upstream of Red Bluff for the freshwater life stages during the course of a year. Actual timing of each life stage varies somewhat from year to year and is primarily a function of weather, streamflow, and water temperature. For example, the onset and peak of spawning for each run can vary by 2 to 3 weeks from year to year (Richard Painter, DFGame, personal communication).

Sacramento River Chinook salmon runs are designated by the season during which they enter the river to begin upstream spawning migration. Although migrating and spawning adults from adjacent runs may be found in the river at the same time, each run has

Figure 1
LIFE HISTORY CHARACTERISTICS OF SACRAMENTO RIVER CHINOOK SALMON
AT AND UPSTREAM OF RED BLUFF
(U.S. Bureau of Reclamation)




a fairly discrete period of spawning (some overlap does occur, particularly between the fall and spring runs). There is a consensus among fishery scientists that a "genetically pure" mainstem spawning population of Sacramento River spring-run salmon no longer exists, due to the broad overlap in spawning periods of the fall and spring runs. The fall run and spring run have likely crossbred to become one protracted late-summer through fall spawning run in the mainstem. The only remaining genetically pure spring-run stocks in the upper Sacramento River Basin are believed to be those using the tributary spawning habitats (*eg*, Mill Creek and Deer Creek).

The Sacramento River winter Chinook salmon run has been defined as a separate species according to a provision in the Endangered Species Act of 1973. That provision states:

> "The term species includes any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature" (ESA of 1973, as amended by PL 95-632).

Anecdotal evidence has indicated a winter run may have been sporadically present in the Calaveras River. Data are not available to determine if observed spawners were strays from the Sacramento River and if egg deposition resulted in juvenile production.

## Winter-Run Chinook Salmon Life Cycle

The winter run life cycle is characterized by a series of discrete events in fresh and salt water. For convenience, the following discussion starts with the adults leaving the ocean.

### Adult Spawning Migration

Winter-run Chinook salmon first begin appearing in the Sacramento-San Joaquin Delta during early winter (Skinner 1972), with the first upstream migrants arriving at the upper reaches of the river during December. Since the closing of Shasta and Keswick Dams on the upper Sacramento River in 1946 and 1951, respectively, the upstream movement of the salmon migration has been restricted. Keswick Dam is about 302 river miles upstream of San Francisco Bay (Figure 2). Due to the lack of fish passage facilities and the configuration of Keswick Dam, there is no way for salmon to migrate past the dam. There are, however, facilities to collect adults as they congregate at the dam for transport to Coleman National Fish Hatchery near Anderson, California, where they can be used for artificial propagation.

The first adult arrivals to the upper Sacramento River, and those following through the winter months, migrate to and hold in deep pools prior to initiating spawning activities. Based on past fish counts at Red Bluff Diversion Dam (Figure 2) on the upper Sacramento River, the peak migration of winter-run Chinook to the upper river reaches usually occurs during March (Figure 1), but this can vary depending on the run timing, streamflows, and operations of the diversion dam. Spawning migration usually starts to decline in April, but in some years is substantial during the spring months. During dry years, a greater proportion of the spawning population arrives in the river upstream of the diversion dam by April as compared to wet years. The upstream migration subsides substantially during May and continues to decline until July, when the migration is complete (Vogel and Marine, 1991).

Hallock and Fisher (1985) found that most winter-run Chinook return as 3-year-olds (67 percent) with the remainder returning as 2-year-olds (25 percent) and 4-year-olds (8 percent).

### Spawning Activity

The timing of spawning activity for winter-run Chinook is fairly well established, and incubation periods can be reasonably calculated from knowledge of egg development in hatcheries. A small portion of winter-run Chinook spawning activity may begin as early as mid-April, and in most years the first eggs are in redds by the end of April. Spawning

Figure 2
CENTRAL VALLEY LOCATION MAP

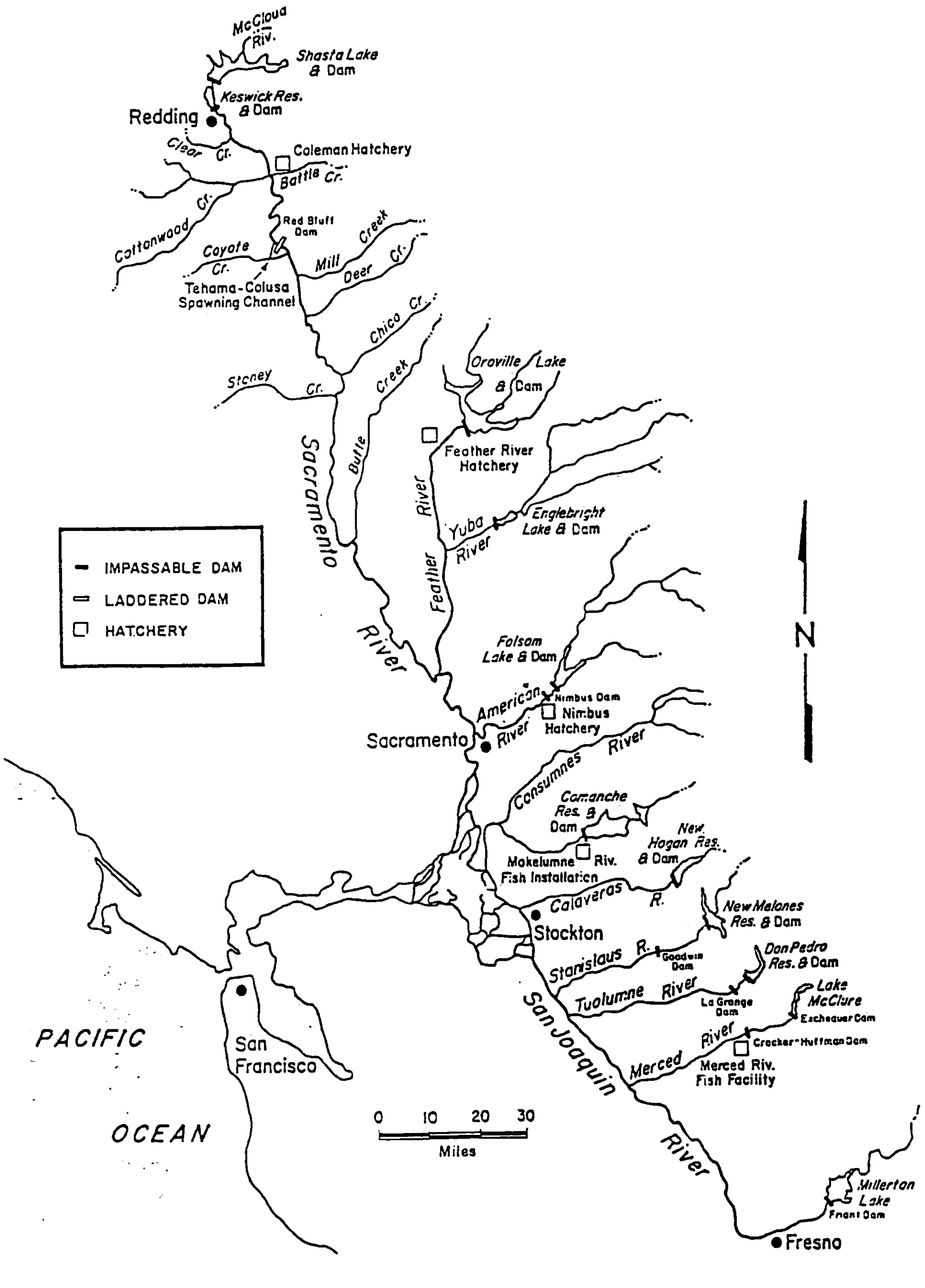


Figure 3
RELATIVE PROPORTIONS OF EACH LIFE STAGE PRESENT IN THE UPPER SACRAMENTO RIVER FOR EACH RUN OF SACRAMENTO RIVER CHINOOK SALMON DURING A REPRESENTATIVE WET YEAR (1983) AND A DRY YEAR (1985) FOR THE MONTH OF AUGUST

(Hydrologic and water temperature data for 1983 and 1985 are presented in Appendix B, Figures 1 and 2.)

| | Run | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Fall | | Late Fall | | Winter | | Spring | |
| | Wet (1983) | Dry (1985) | Wet (1983) | Dry (1985) | Wet (1983) | Dry (1985) | Wet (1983) | Dry (1985) |
| Cumulative percent of spawning migration passing RBDD by mid-month | 5 | 20 | | | 100 | 100 | 40 | 75 |
| Cumulative percent having spawned by mid-month | | | | | 100 | 100 | <5 | <5 |
| Relative percent of year's brood as incubating eggs and larvae | | | | | 25 | 5 | <5 | <5 |
| Relative percent of year's brood having reach fry life stage | | | | | 75 | 95 | | |
| Relative percent of year's brood having reached juvenile life stage | | | 100 | 100 | 0 | 0 | | |
| Estimated cumulative percent of year's brood emigrating from upper river by mid-month | | | 50-90 | 40-60 | 5-10 | <5 | | |

activity increases through May and reaches its peak during June. The majority of the winter-run eggs are incubating in redds by the end of June (Figure 3). By the end of July, winter-run spawning activity is declining and continues to do so through August, when spawning is completed (Vogel and Marine, 1991).

The fecundity of winter-run Chinook salmon varies, but based on samples taken at Coleman National Fish Hatchery, a typical female has about 3,400 eggs (Hallock and Fisher, 1985).

Although spawning may occur in the mainstem between Keswick and Red Bluff Diversion Dam (and even below) in many years, because of ambient warming at Shasta releases, habitat in the first few miles below Keswick is most suitable for egg incubation. In 1992, for example, most spawning occurred above Cottonwood Creek where cold-water releases from Shasta Reservoir should have allowed excellent survival from eggs to emergence.

## Fry Emergence and Juvenile Outmigration

The timing and dynamics of the rearing and downstream migration periods of winter-run Chinook are not well understood. This circumstance is due to the paucity and limitations on data regarding juveniles, as well as the year-to-year variability affected by weather, streamflow, and the biological interactions of food availability, predation, and competition with juveniles from other Chinook runs.

During dry years with low reservoir storage and warm spring seasons, fry from some of the earliest spawning winter run may begin to emerge as early as late June; most have emerged from the redds by the end of August. During wet years with cooler temperatures, a significant portion of the winter-run larvae and some eggs may remain in the redds until the end of August, but even in these years most have emerged by the end of August (Figure 3).

During September, fry rearing in shallow, near-shore habitat are at peak abundance by the end of the month. During October and November, the larger winter-run juveniles move into deeper water. Dispersal of fry and juveniles out of the upper reaches is moderate through October, with the exception of storms and related increases in streamflow. Large numbers of juveniles can emigrate from the upper river during November and December during large storms. Emigration continues during the winter months, particularly with high flow periods, until all juveniles have migrated from the upper river by the end of March (Table 1) (Vogel and Marine, 1991). Movement through the Sacramento-San Joaquin Delta is covered in a subsequent section.

Table 1
ESTIMATED CUMULATIVE PERCENT OF WINTER-RUN CHINOOK
YEAR'S BROOD EMIGRATING FROM THE UPPER SACRAMENTO RIVER PAST
RED BLUFF DIVERSION DAM BY MID-MONTH
(From Vogel and Marine, 1991)

| Month | Wet Year (1983) | Dry Year (1985) |
|---|---|---|
| August | 5 - 10 | <5 |
| September | 10 - 50 | 5 - 10 |
| October | 20 - 75 | 10 - 20 |
| November | 50 - 75 | 30 - 40 |
| December | 60 - 90 | 50 - 75 |
| January | 75 - 95 | 60 - 90 |
| February | 80 - 100 | 75 - 95 |
| March | 100 | 100 |

## Estimated Annual Spawning Population of Winter-Run Chinook Salmon

The best estimates of winter-run Chinook escapement have been obtained by counts of salmon passing through the fish ladders at Red Bluff Diversion Dam. Estimated numbers of winter-run adults have been recorded from 1967 to the present. The maximum number of winter-run adults passing the diversion dam was 117,808 in 1969 and the minimum was 191 fish in 1991 (Table 2). The average annual number of winter-run Chinook passing the diversion dam was 24,062 for 1967 through 1990.

Table 2
WINTER-RUN CHINOOK SALMON COUNTS AT RED BLUFF DIVERSION DAM

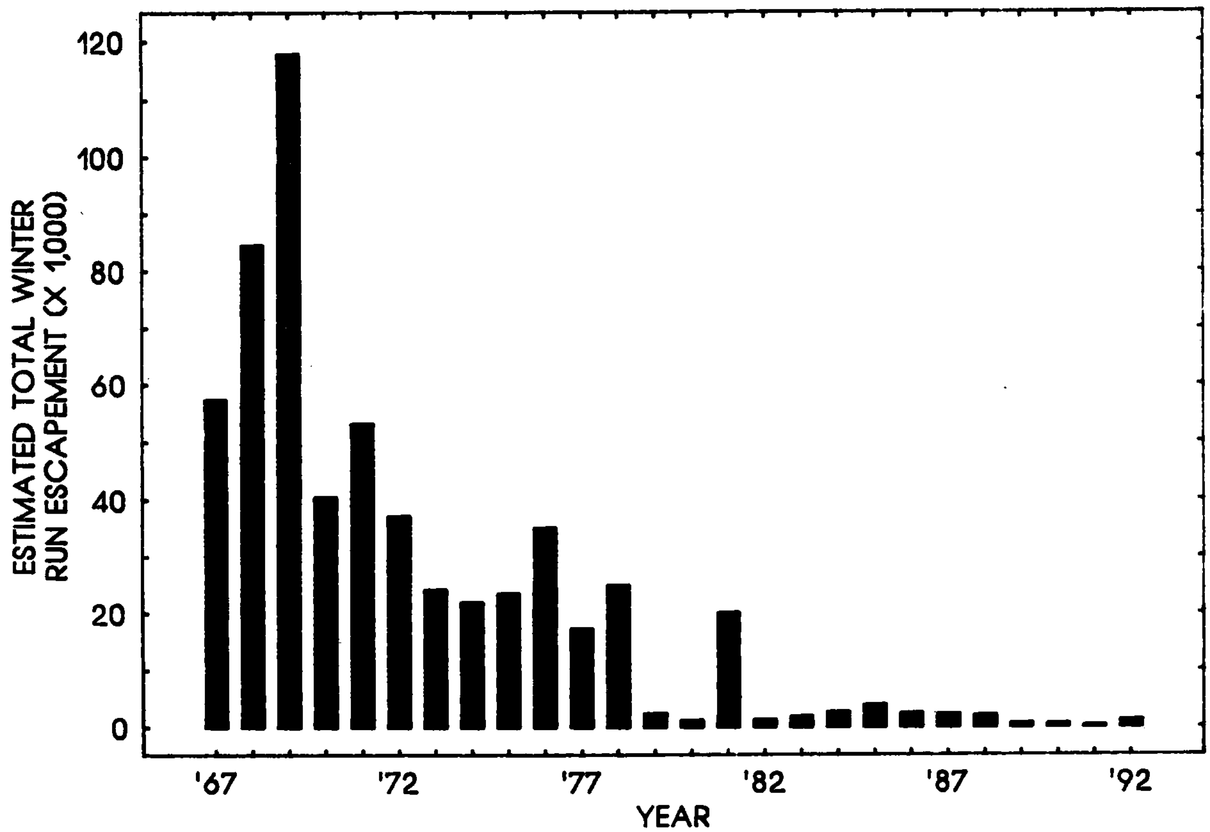
| Year | Number of Fish | Year | Number of Fish | Year | Number of Fish |
|---|---|---|---|---|---|
| 1967 | 57,306 | 1976 | 35,096 | 1985 | 3,962 |
| 1968 | 84,414 | 1977 | 17,214 | 1986 | 2,422 |
| 1969 | 117,808 | 1978 | 24,862 | 1987 | 1,997 |
| 1970 | 40,409 | 1979 | 2,364 | 1988 | 2,094 |
| 1971 | 53,089 | 1980 | 1,156 | 1989 | 533 |
| 1972 | 37,133 | 1981 | 20,041 | 1990 | 441 |
| 1973 | 24,079 | 1982 | 1,242 | 1991 | 190 |
| 1974 | 21,897 | 1983 | 1,831 | | |
| 1975 | 23,430 | 1984 | 2,663 | | |

The marked decline in numbers passing the dam in 1979 and 1980 was probably the result of drought in 1976 and 1977 (Figure 4). Because most winter-run salmon return as 3-year-old fish, the impact of such losses is evident for many years into the future, making it difficult for the runs to rebound to previous population levels. The last strong year class, which was in 1981, failed to return in large numbers during 1984. The reason for this low return is unknown, but is assumed to be the result of the 1982 and 1983 El Niño event, which created poor rearing conditions for salmon in the ocean.

The winter-run spawning populations have remained at low levels (<4,000) since 1982 and have decreased to well below 1,000 in 1989, 1990, and 1991. The 1992 estimate of 1,180 spawners is an encouraging sign and hopefully is the start of a recovery trend.

The winter-run estimates are for adults passing Red Bluff Diversion Dam. For the past five years, the Red Bluff Diversion Dam gates have been raised during the non irrigation season (about December through March) and the fish ladders were inoperable. Free-flow conditions were present at the diversion dam during this time, salmon passage was unimpeded past the dam. Without the fish ladders in operation, enumeration of salmon passing the dam was not possible, so DFG employed an alternative method of estimating each year's winter Chinook run size. This method assumes that each year's timing is the same as that exhibited for 1982 through 1986. After counts are conducted following dam gate closure at the onset of the irrigation season and the fish ladders are

Figure 4
ESTIMATED ANNUAL WINTER-RUN ESCAPEMENT, 1967-1992
(1992 is preliminary data)




operational, an estimate of the entire year's run size is calculated by using the historical run timing pattern to extrapolate actual fish counts to encompass the entire period when counts could not be conducted. For example, if the diversion dam begins operating on April 1, when historically about two-thirds of the winter run is estimated to have passed the dam, and 1,000 winter-run salmon pass the dam after April 1, the run size would be estimated to be about 3,000 fish.

### Hatchery Production of Other Chinook Salmon Races

Several Chinook salmon hatcheries have been constructed and operated in the Sacramento-San Joaquin drainage to mitigate for water project impacts. Foremost among these hatcheries are the Coleman National Fish Hatchery (USFWS), Feather River Hatchery (DWR/DFG), American River Hatchery (USBR/DFG), and the Merced River Fish Facility (DFG).

Although among them these hatcheries produce all four races of Chinook salmon, they focus on the fall run with present annual production of several million fall-run fish. Coleman National Fish Hatchery rears late-fall and winter run with all their production being released in the upper river during most years. The Feather River Hatchery produces fall-run and spring-run with the planting size and location being quite variable (Table 3). American River fall-run are generally planted in the spring as smolts in the estuary near the Carquinez Strait. Finally, fall-run salmon produced at the Merced River Fish Facility are planted as fry, smolts, and yearlings at various locations in the San Joaquin River drainage (Table 4).

This information is included because, as is shown later, the presence of hatchery-reared fish at the State and federal salvage facilities as well as in various sampling programs can confuse the process of sorting winter run from other races.

Table 3
CHINOOK SALMON PLANTING SUMMARY, FEATHER RIVER HATCHERY, 1987-1988

| Race | Month of Release | Average Size (G) | Number Released | Mark | Release Site |
|---|---|---|---|---|---|
| Spring Run 1986 BY | July | 16.5 | 367,540 | | Benicia/Mare Island |
| | August | 20.0 | 158,550 | | Benicia/Mare Island |
| | | Total | 526,090 | | |
| Spring Run 1987 BY | February | 1.7 | 60,400 | | Chico Creek |
| | March | 8.4 | 243,200 | | Benicia |
| | April | 16.5 | 263,000 | | Berkeley |
| | May | 14.0 | 297,375 | | Benicia/Berkeley |
| | | Total | 863,975 | | |
| Fall Run 1986 BY | July | 14.4 | 2,477,075 | | Benicia/Mare Island |
| | August | 24.8 | 1,860,400 | | Benicia/Mare Island |
| | September | 37.0 | 435,850 | | Benicia |
| | October | 44.8 | 552,975 | | Feather Rive (Gridley) |
| | | Total | 5,326,300 | | |
| Fall Run 1987 BY | February | 3.6 | 2,408,000 | | Mokelumne Hatchery |
| | March | 6.5 | 129,200 | | Benicia |
| | April | 7.1 | 827,600 | | Benicia |
| | May | 6.7 | 112,200 | B6-14-02 and -03 | Courtland |
| | | 8.2 | 54,324 | 06-31-01 | Ryde |
| | | 6.5 | 105,865 | B6-14-06 and -07 | Miller Park |
| | | 6.5 | 108,586 | B6-14-04 and -05 | Courtland |
| | | 8.4 | 55,550 | B6-14-08 | Port Chicago |
| | | 8.6 | 53,669 | 06-31-02 | Ryde |
| | | 12.5 | 704,850 | | Benicia |
| | June | 7.7 | 110,808 | 06-62-59 and -60 | Courtland |
| | | 8.7 | 54,310 | 06-62-63 | Ryde |
| | | 9.1 | 105,562 | 06-62-61 and -62 | Miller Park |
| | | 8.7 | 105,660 | 06-62-50 | Courtland |
| | | 9.9 | 105,527 | 06-31-05 and -06 | Steamboat Slough |
| | | 10.9 | 53,940 | 06-31-03 | Ryde |
| | | 11.0 | 54,583 | 06-31-04 | Port Chicago |
| | | 12.7 | 50,050 | | Tiburon |
| | | 12.7 | 1,525,450 | | Benicia/Mare Island |
| | | Total | 6,725,734 | | |

Table 4
1988 BY MERCED RIVER STRAIN CHINOOK SALMON SMOLTS
PLANTED FROM MERCED RIVER FISH FACILITY, 1989

| Date Released | CWT Code | Tagged | Untagged | Size/ Pound | Total Released | Release Location |
|---|---|---|---|---|---|---|
| 4/19/89 | B6-01-01<br>B6-14-11 | 79,809 | | 71.9 | 79,804 | American Trails<br>Stanislaus River |
| 4/20/89 | B6-14-09<br>B6-14-10 | 107,160 | | 76.0 | 107,150 | Knights Ferry<br>Stanislaus River |
| 4/21/89 | 06-01-11-01-01<br>06-01-11-01-02<br>06-01-11-01-03 | 79,980 | 70,425 | 111.0 | 150,402 | Hills Ferry Sports Club<br>Merced River |
| 5/2/89 | 06-01-11-01-07<br>06-01-11-01-08<br>06-01-11-01-13 | 79,950 | | 75.0 | 79,940 | Dos Reis Park<br>San Joaquin River |
| 5/3/89 | 06-01-11-01-04<br>06-01-11-01-05<br>06-01-11-01-06 | 81,106 | | 75.8 | 81,096 | Downstream from<br>San Joaquin River at Old River |
| 5/3/89 | B6-14-12 | 51,507 | 21,930 | 74.8 | 73,437 | American Trails, Stanislaus River |
| 6/16/89 | | | 2,890 | | 2,890 | UC Davis Pathology Lab |
| Subtotal | | 479,512 | 95,245 | | 574,719 | |
| | | **Net Efficiency and Vulnerability Test** | | | | |
| 4/20/89 | Blue Dye Dorsal | 9,996 | | 119.0 | 9,996 | Dos Reis Ranch, Tuolumne River |
| 5/2/89 | Red Dye Caudal | 1,300 | | 113.0 | 1,300 | Mossdale County Park Ramp |
| 5/4/89 | Blue Dye Anal | 2,550 | | 113.0 | 2,550 | Mossdale County Park Ramp |
| Subtotal | | 13,846 | | | 13,846 | |
| TOTAL | | 493,358 | 95,245 | | 588,565 | |

**Yearling Merced River Strain Chinook Salmon (1987 BY) Planted from Merced River Fish Facility, 1988-1989**

| Date Released | Size/ Pound | Total Released | Release Location |
|---|---|---|---|
| 10/17/88 | 9.1 | 12,740 | Fisherman Bend, Merced River |
| | 9.3 | 8,360 | |
| | 9.3 | 10,224 | |
| | 9.1 | 8,186 | |
| 10/18/88 | 9.3 | 20,915 | Fisherman Bend, Merced River |
| | 9.3 | 13,005 | |
| | 9.1 | 8,185 | |
| 10/19/88 | 9.1 | 22,270 | Fisherman Bend, Merced River |
| | 9.1 | 18,180 | |
| 10/20/88 | 9.1 | 20,445 | Fisherman Bend, Merced River |
| 10/24/88 | 9.1 | 1,000 | MRFF Ponds to Merced River |
| TOTAL | | 143,510 | |

# FACTORS INFLUENCING WINTER-RUN CHINOOK SALMON POPULATION SIZE

As with all organisms a variety of factors interact to control the distribution and abundance of winter-run Chinook salmon. This race of salmon is particularly vulnerable to culturally induced perturbations because access to its original habitat in the McCloud and perhaps Pit Rivers was blocked by closure of Shasta Dam in 1945. In contrast to other races and species Pacific salmon which spawn in fall/early winter period the winter run had evolved to spawn during the period when water temperatures were increasing. This reproduction strategy was only possible in rivers like the McCloud where cool spring water maintained summer river temperatures at tolerable levels. Immigration and emigration during the winter months of normally high streamflows evolved as part of this strategy.

Although records of winter-run population size in the years immediately before the USBR constructed Shasta Dam are not available, it is likely that the run was relatively small at that time with logging, pollution, agriculture, fishing, etc. contributing to its decline.

In the late 1940s through the mid-1960s Shasta Dam and Reservoir resulted in conditions between Keswick and Red Bluff that were apparently ideal for winter run. High reservoir storage levels, an abundance of wet winters, cold water released from the hypolimnion, relatively low demand for CVP water, and spawning gravel that had not deteriorated due to lack of recruitment from upriver resulted in large population increases with an estimated peak of about 118,000 spawners in 1969.

All of that changed in the late 1960s and the population declined to the point where the winter run was listed in 1989 by both the State and federal governments. During this period the Red Bluff Diversion Dam was closed with its fish passage and predation problems, the increased demands for water, toxicity problems from Iron Mountain Mine increased as dilution flows, and it became more difficult to provide the cold water during the hot summer nursery period in the river between Keswick and Red Bluff.

In 1988 a 10-point program was developed to improve conditions in the upper river. A summary of the recovery efforts can be found in Appendix 1.

# SACRAMENTO-SAN JOAQUIN DELTA

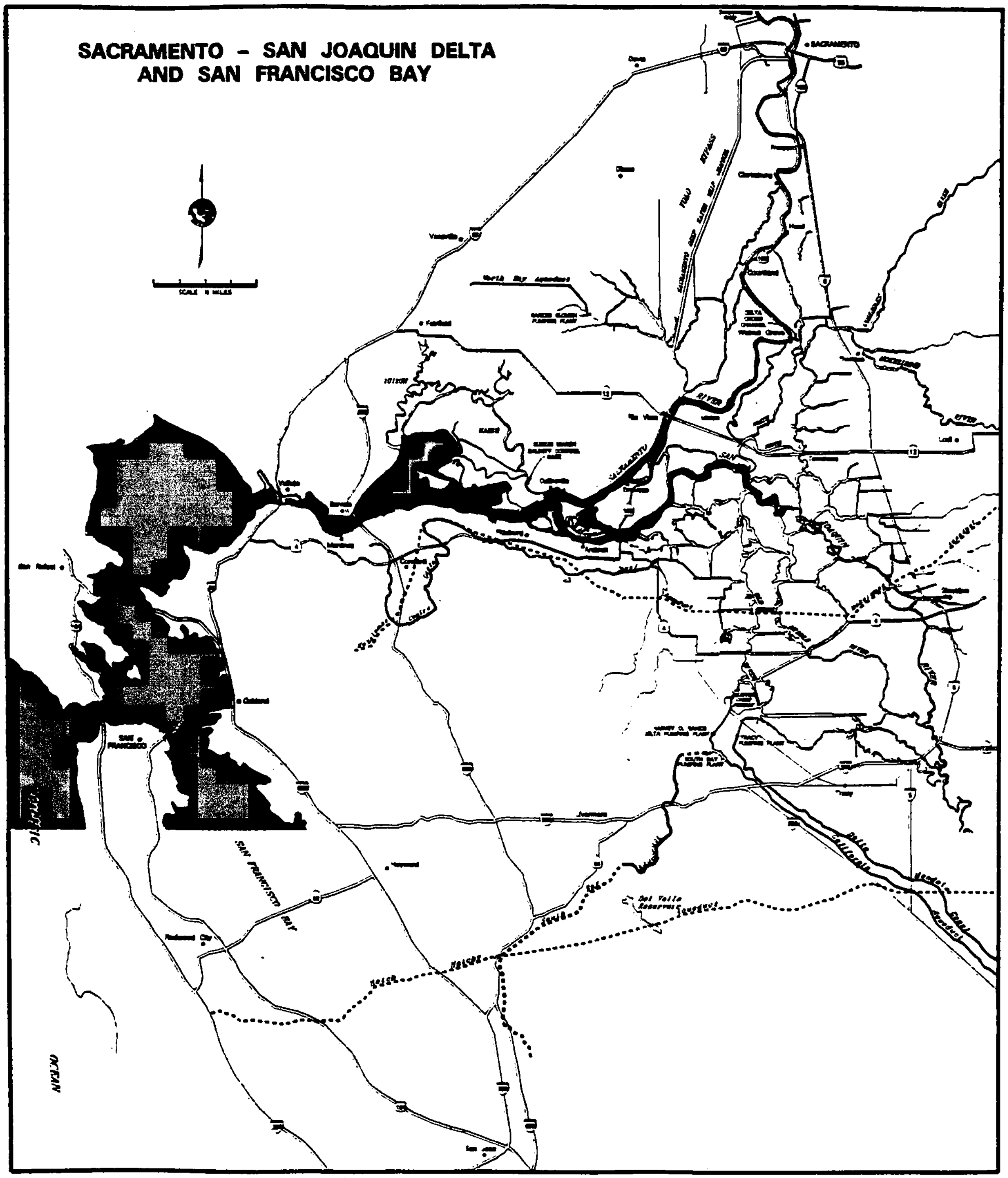
Winter-run adults and juveniles must pass through the Delta on their way to and from the spawning grounds. The Delta as a source of mortality is the subject of this evaluation.

Numerous reports provide descriptions of the Delta formed at the confluence of the Sacramento and San Joaquin Rivers. (See, for example, DWR 1987 and Herbold and Moyle 1989.) Figure 5 shows many of the Delta features and points included in this report. Following are brief descriptions of these features.

- Freeport — Site of cooperative DWR/USGS point for measuring inflow, temperature, and sediment load from the Sacramento River to the Delta and estuary.
- Hood — Location of the proposed intake for the Peripheral Canal and the New Hope Cross Channel and a sampling site for salmon trawl surveys.
- Vernalis — Site of cooperative DWR/USGS point for measuring inflow, temperature, and sediment load from the San Joaquin River to the Delta and estuary.
- Mossdale — Location of lower San Joaquin River DFG push net sampling site for downstream migrants.
- Delta Cross Channel — The Cross Channel, located near the town of Walnut Grove, is a component of the CVP constructed by the USBR to allow better exchange of water between the Sacramento River and the southern Delta. Two radial gates were installed in 1951 and one or both can be closed for flood control purposes.
- Courtland — Location of many Interagency Ecological Studies Program releases of marked Chinook salmon to test the effects of the Cross Channel on through-Delta survival. Also a fish sampling point.
- Ryde — Location of many Interagency Program releases of Chinook salmon below the Cross Channel to test through-Delta survival.
- Georgiana Slough — Ungated slough that conveys water between the Sacramento and San Joaquin Rivers. Georgiana Slough is not a SWP or CVP facility.
- Threemile Slough — Ungated slough that conveys water between the Sacramento and San Joaquin Rivers. Threemile Slough is not a SWP or CVP facility.
- Sherman Island — Westernmost Delta island.
- Horseshoe Bend — Release site for fish salvaged at SWP and CVP intakes.
- Chipps Island — Site of intensive trawl surveys conducted to recapture marked salmon and provide rough estimates of numbers of annual fall run.

- Curtis Landing — Alternative release site for fish salvaged at the SWP intakes.
- Rock Slough — Intake location for Contra Costa Canal.
- Barker Slough — Intake location for North Bay Aqueduct.
- Jersey Point — Site for calculated DAYFLOW estimates of flow in the lower San Joaquin River.
- Clifton Court Forebay — Site of intake to California Aqueduct and John E. Skinner Delta Fish Protective Facility. The Harvey O. Banks Delta Pumping Plant is located about 1 mile down the intake channel. The forebay became operational in 1968. The intake complex is often called the State's Byron facilities, named after a nearby village.
- CVP Intake — Fish facilities are located at the head of the Delta-Mendota Canal. Pumps are located about 1 mile down the canal. Often called the USBR's Tracy facilities.

Figure 5
SACRAMENTO-SAN JOAQUIN DELTA AND SAN FRANCISCO BAY



# STATE WATER PROJECT AND CENTRAL VALLEY PROJECT DELTA OPERATION

Several aspects of SWP and CVP operations, including reservoir releases and pumping, at times directly affect Delta conditions and may affect survival of winter-run salmon. Releases from Oroville, Shasta, and Folsom Reservoirs contribute to Delta inflow and outflow and, along with SWP and CVP pumping, tides, and winds, affect Delta circulation patterns. Project operations are not easily described, but there are some limitations that set the boundaries for flows and pumping. This chapter describes some of these limitations (or controlling features) and then describes some resulting Delta conditions (pumping, outflow, reverse flows) that result from a specific operational framework. Principal project features such as Montezuma Slough gates, fish facilities, and the Delta Cross Channel are included.

The USBR has prepared a document, "Central Valley Project Operations Criteria and Plan (CVP-OCAP)", that describes operations in more detail. The results of the CVP-OCAP relative to Delta operations are summarized later in this section. These results are specifically used in subsequent analyses of project impacts.

## Reservoir Releases

Release schedules from project reservoirs (Shasta, Folsom, Oroville, the Trinity complex, and New Melones) are a complex function of such factors as reservoir storage levels, hydroelectric power production, instream flow needs (including temperature), riparian and contractual irrigation demands along the streams, Delta water quality and flow requirements, Delta pumping demands, hydrologic and meteorological conditions, and Coordinated Operation Agreement account balances.

It is beyond the scope of this report to describe exactly how the operators decide on release schedules. CVP-OCAP provides many details for projected operations under a variety of water-year types, storage levels, and environmental criteria (USBR, October 1991). These descriptions may also not be particularly relevant in only a given year because actual operation is dependent on too several variables, any one of which may be controlling at a given time.

The controlling variables, plus a large number of nonproject-related events, determine inflows to the estuary at Vernalis on the San Joaquin River and Freeport on the Sacramento River. Figures 6 and 7 provide resulting inflows during the past several years. Although the data have not been developed to show project impacts on Delta inflow, the projects generally reduce inflows in the winter and spring (especially in below-normal water years) and increase them in the summer and fall.

Figure 6
MONTHLY AVERAGE SAN JOAQUIN RIVER FLOW NEAR VERNALIS, SEPTEMBER THROUGH DECEMBER, 1956-1990

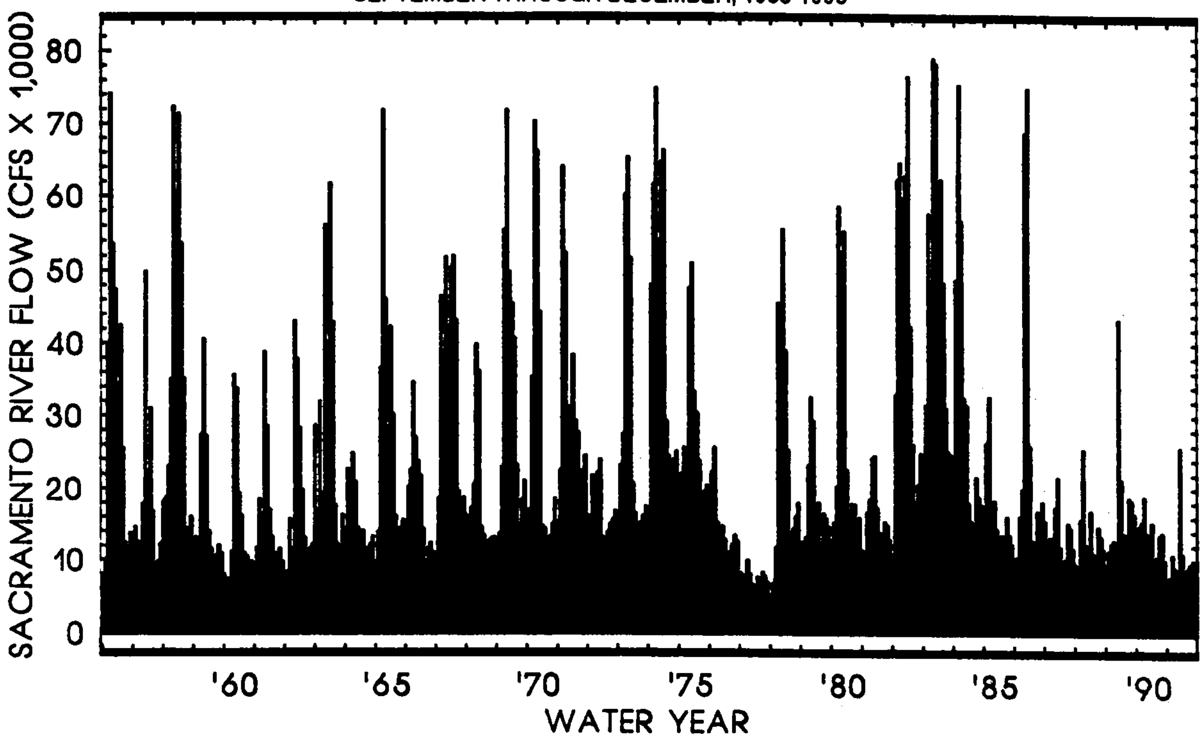
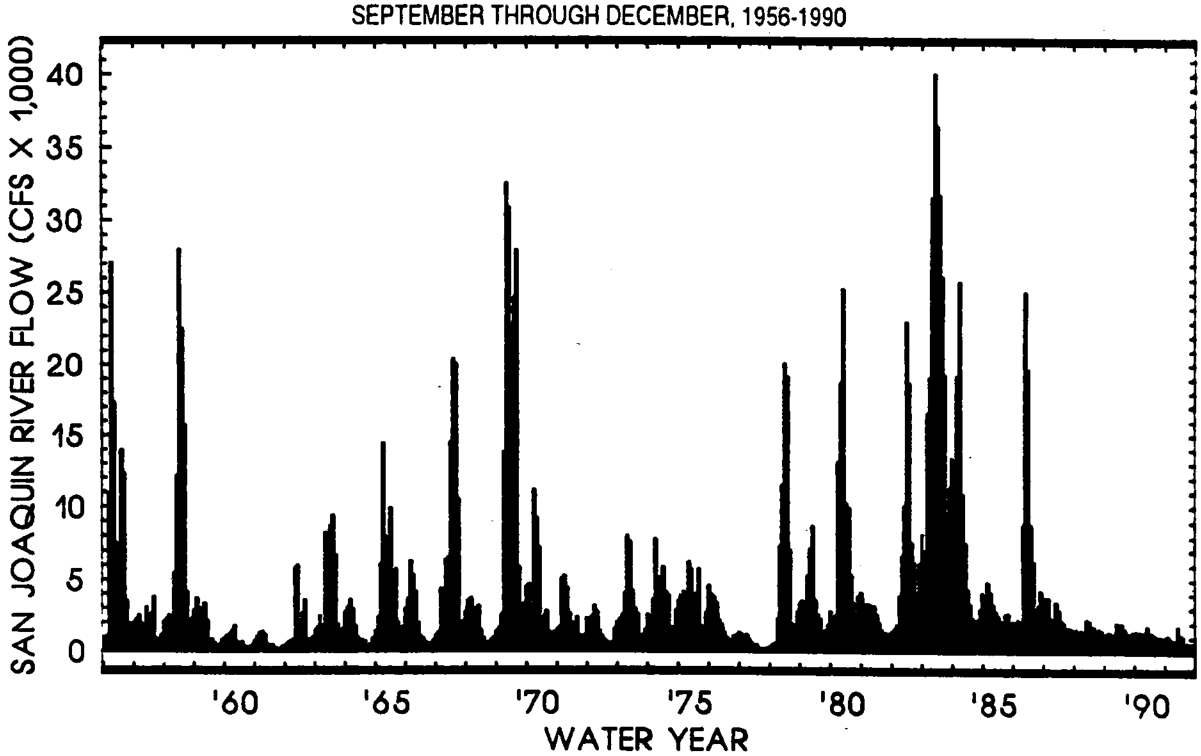



Figure 7
MONTHLY AVERAGE SACRAMENTO RIVER FLOW NEAR SACRAMENTO, SEPTEMBER THROUGH DECEMBER, 1956-1990



## Regulatory Requirements for Delta Water Quality and Flow

State Water Resources Control Board Decision 1485, issued in 1978, provides several water quality and flow requirements designed to provide without-project protection to Delta agriculture, fisheries, municipal and industrial users, and Suisun Marsh resources (Table 5 and Appendix 2). The CVP and SWP have been operated to meet those standards and with few exceptions have met them. On any day, only one of the standards may be controlling (*eg,* chloride at the Contra Costa Canal's Rock Slough intake) and reservoir releases and pumping are adjusted to meet the standard. Daily adjustments may be also necessary to account for the effects of wind, tides, in-Delta demands, and local inflows on circulation and water quality.

In addition to D-1485, operating requirements come from agreements between project operators and other parties. Examples of these agreements are:

- DFG/DWR 4-Pumps Fish Mitigation Agreement - Outside of but resulting from the agreement, DWR agreed to reduce May and June Delta diversions from 3,000 to 2,000 cfs during low flow years.
- Suisun Marsh Plan of Protection - DFG, DWR, USBR, and the Suisun Resource Conservation District agreed to changes in D-1485 Suisun Marsh standards and provided for facilities and monitoring. Provisions of this agreement have not been fully adopted by the SWRCB.
- North Delta Water Agency - DWR may provide overland supplies in lieu of meeting a Delta water quality standard).

The current round of Bay/Delta hearings to develop interim Delta standards has not yet resulted in changes to D-1485. For purposes of this report, no changes in D-1485 are considered.

## Pumping Capacity and Demand

The CVP and SWP pumping plants presently have maximum capacities of 4,600 and 10,300 cfs, respectively. The additional SWP capacity created by the installation of four new pumps cannot be used without a new permit from the U.S. Army Corps of Engineers, and an agreement with DFG on measures to offset the indirect effects of SWP pumping on the Bay/Delta. For purposes of these analyses we assume that pumping restrictions included in the present USCE permit remain in effect.

The existing USCE permit conditions are tied to a monthly maximum average inflow into Clifton Court Forebay of 6,680 cubic feet per second. During wet years with above normal precipitation the permit does allow about 50,000 acre-feet of water to be diverted that could not have been without the additional capacity. There are presently no plans to increase pumping at the CVP's Tracy intake.

## Table 5
## SUMMARY OF DELTA CONDITIONS AND CONTROLLING STANDARDS FOR 1992

| Year | Excess/ Balanced Condition | Extreme Critical Controlling Standards | Cross Channel Gates | Excess/ Balanced Condition | Critical Controlling Standards | Cross Channel Gates | Excess/ Balanced Condition | Dry Controlling Standards | Cross Channel Gates | Excess/ Balanced Condition | Above Normal Controlling Standards | Cross Channel Gates | Excess/ Balanced Condition | Wet Controlling Standards | Cross Channel Gates |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dec 91 | B | 250 CCC | O | B | 250 CCC | O | B | 250 CCC | O | X | -- | O | X | -- | O/C |
| Jan 92 | B | 250 CCC/ Chipps/EC | O | B | 250 CCC/ Chips EC | O | X | -- | O/C | X | -- | O/C | X | -- | C |
| Feb | B | 250 CCC | O | B | 250 CCC | O | X | -- | O | X | -- | C | X | -- | C |
| Mar | B | 250 CCC | O | B | 250 CCC | O | X | --- | O | X | -- | C | X | -- | C |
| Apr | B | Delta Outflow/ 150 CCC | O | B | Delta Outflow/ 150 CCC | O | B | Delta Outflow/ Jersey/ Emmaton | O | B | Antioch/ Jersey/Delta Outflow | O | X | -- | C |
| May | B | 150 CCC | O | B | 150 CCC | O | B | Jersey/ Emmaton | O/C | B | Delta Outflow | O/C | X | -- | C |
| Jun | B | 150 CCC | O | B | 150 CCC | O | B | Jersey/ Emmaton | O/C | B | Delta Outflow | O | X | -- | O |
| Jul | B | 150 CCC | O | B | 150 CCC | O | B | Jersey/ Emmaton | O/C | B | Delta Outflow | O | B | Delta Outflow | O |
| Aug | B | 150 CCC | O | B | 150 CCC | O | B | Jersey/ Emmaton/ 250 CCC | O/C | B | Jersey/ 250 CCC | O | B | Jersey/ Emmaton/ 150 CCC | O |
| Sept | B | 150/250 CCC | O | B | 150/250 CCC | O | B | 250 CCC | O | B | 250 CCC | O | X | -- | O |
| Oct | B | 250 CCC | O | B | 250 CCC | O | B | 250 CCC | O | B | 250 CCC | O | X | -- | O |
| Nov | B | 250 CCC | O | B | 250 CCC | O | B | 250 CCC | O | B | 250 CCC | O | X | -- | O |

B = balanced conditions
X = excess conditions
CCC = Contra Costa chlorides
O = cross channel gates open
C = cross channel gates closed

Note: January closure of cross channel gates contingent on timing of Coleman Hatchery winter run.

Source: USBR CVP-OCAP, 1992.

In response to population increases, projected demand for SWP water from Delta water is rising (Figure 8). DWR has proposed additional water storage and development facilities including North Delta, South Delta, Kern Fan, and Los Banos Grandes to meet this demand. This analysis does not include an evaluation of changes in flows and diversions that would be caused by these new projects. The impacts of these proposed actions will be covered in subsequent biological assessments.

Figure 8
PAST AND PROJECTED CALIFORNIA
URBAN WATER DELIVERIES
(From DWR Bulletin 160-87)

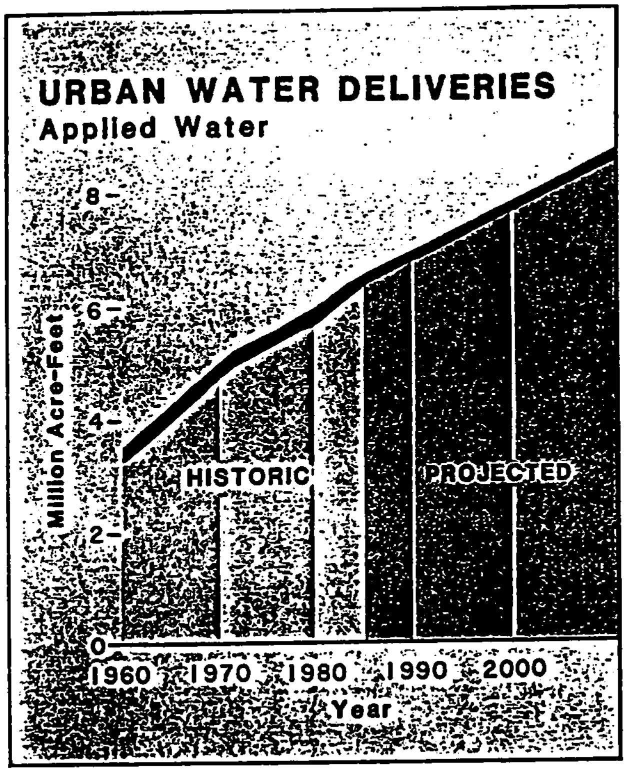



Figure 9 shows total Delta pumping by the SWP and CVP, as well as pumping for each project for the 1955 through 1992 water years. Total Delta diversions in the late 1980s and 1990 stabilized at about 5.5 to 6 million acre-feet after gradual increases during the period of record.

CVP and SWP Delta pumping are further broken down by month in Figures 10 and 11. The average monthly CVP pumping rate has been reasonably steady at between 3,000 and 4,000 cfs. The SWP, on the other hand, has much greater variation in diversion rates. From August 1989 through April 1990, SWP pumping was near maximum capacity in anticipation of a planned major outage in 1990 to repair the California Aqueduct. This is not the normal practice, because around-the-clock pumping requires use of the much more expensive on-peak power.

As discussed earlier, schedules for reservoir releases and pumping are developed by taking many variables into account, many of which change on a daily basis. DWR and the USBR do make periodic forecasts of future operation based on such factors as reservoir storage, snowpack, time of the year and demand. The projections are designed to provide water users and fish and wildlife agencies with an idea of what to expect in the upcoming months. As is expected, the forecasts become more accurate the further we proceed into the water year. Typically, the May 1 forecast is reliable for expected monthly average deliveries, reservoir and Delta operations, but does not represent flow and pumping on a daily or even weekly basis.

Figure 9
TOTAL ANNUAL CVP AND SWP PUMPING FROM DELTA, 1956-1991
(In Millions of Acre-Feet)

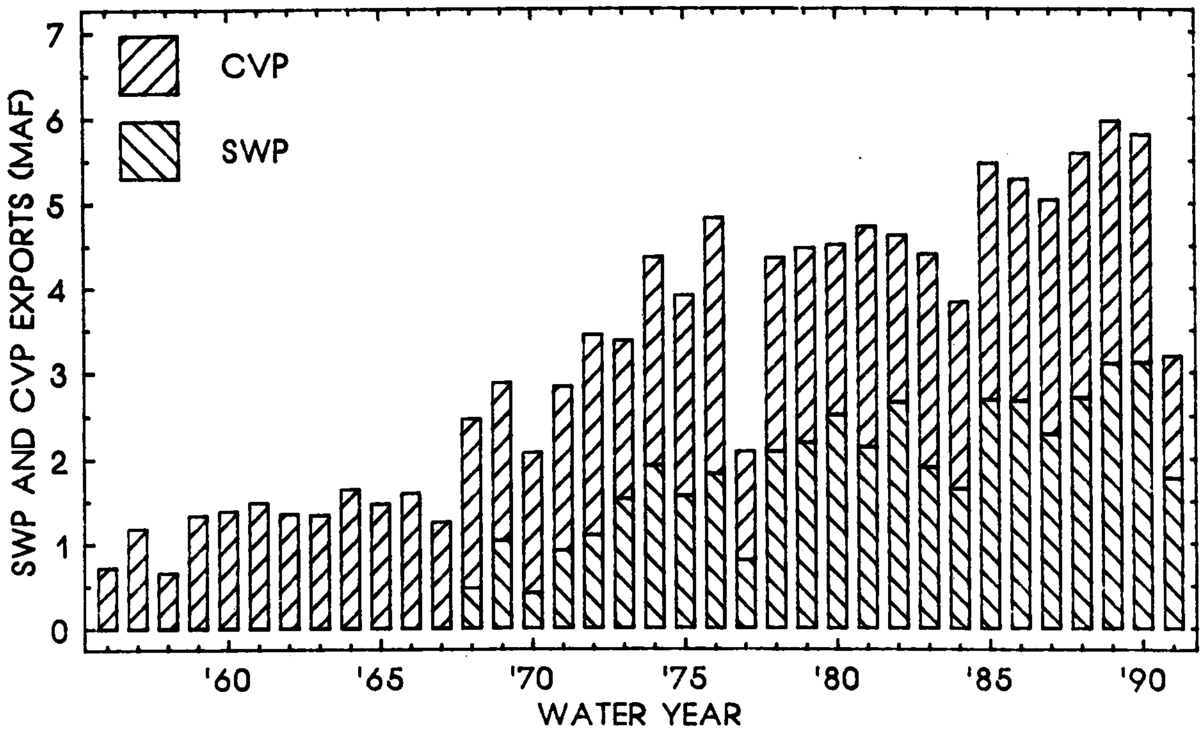



Figure 10
AVERAGE MONTHLY CVP PUMPING, WATER YEARS 1978-1991,
FROM THE DAYFLOW DATABASE

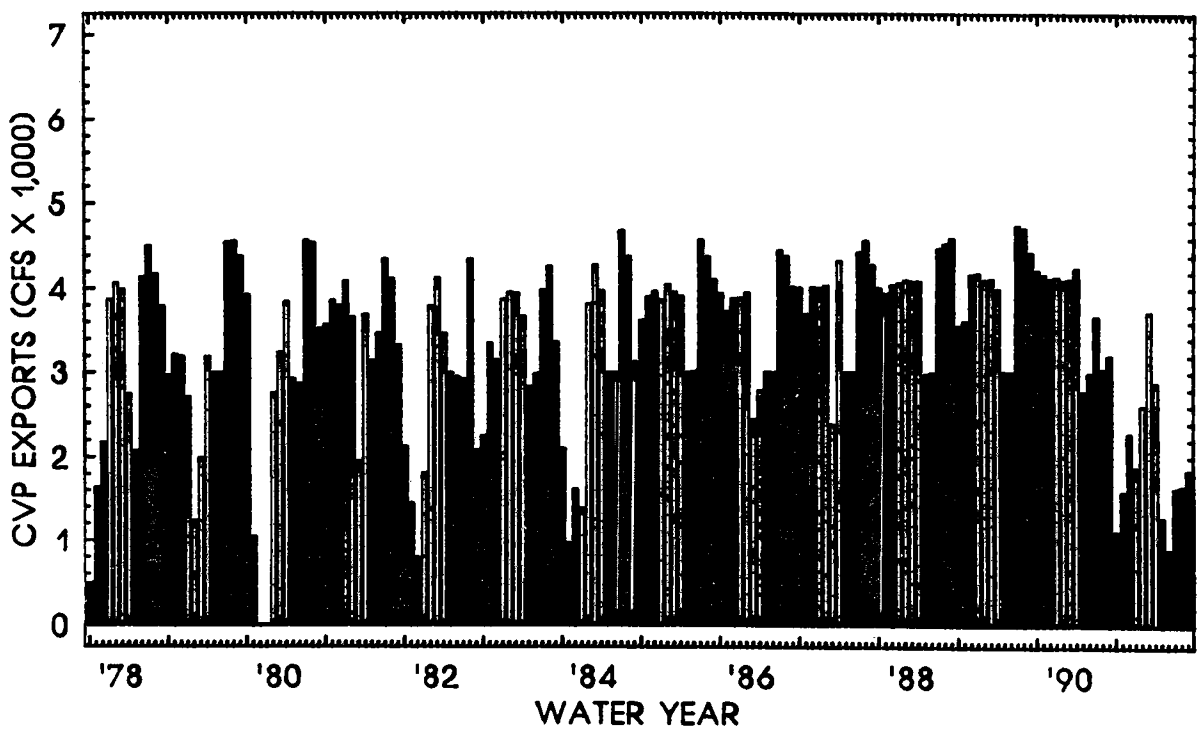
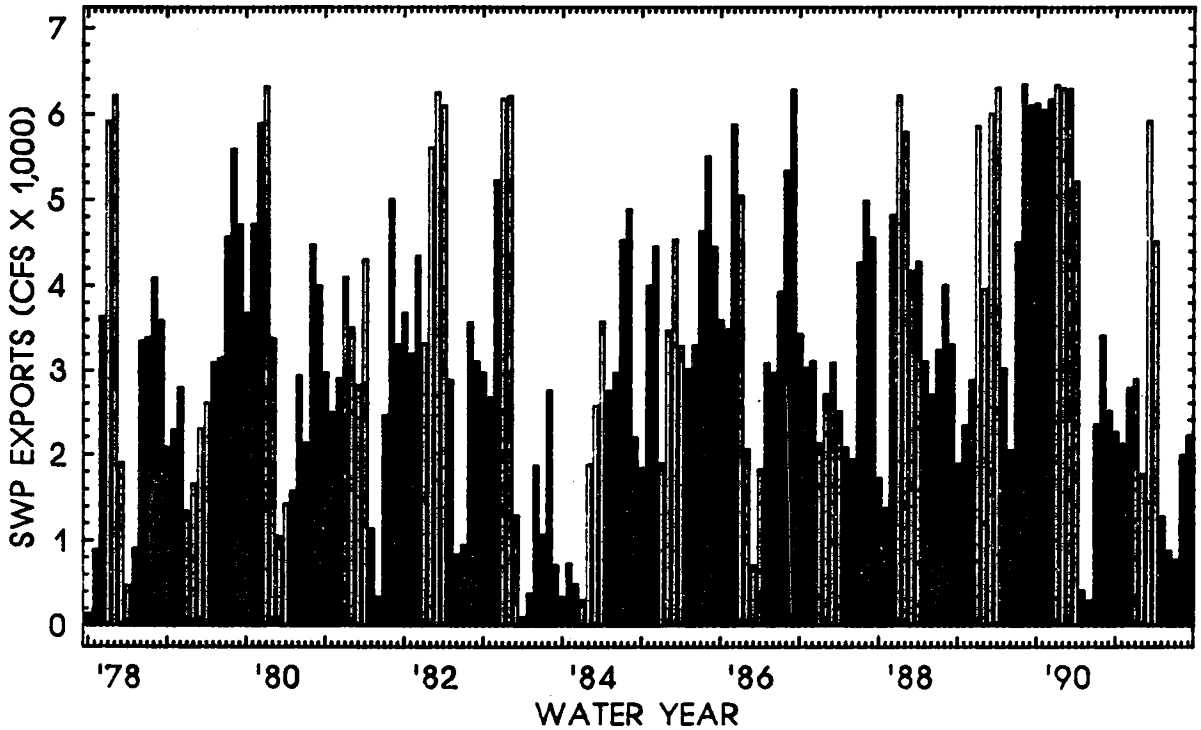


Figure 11
AVERAGE MONTHLY SWP PUMPING, WATER YEARS 1978-1991,
FROM THE DAYFLOW DATABASE



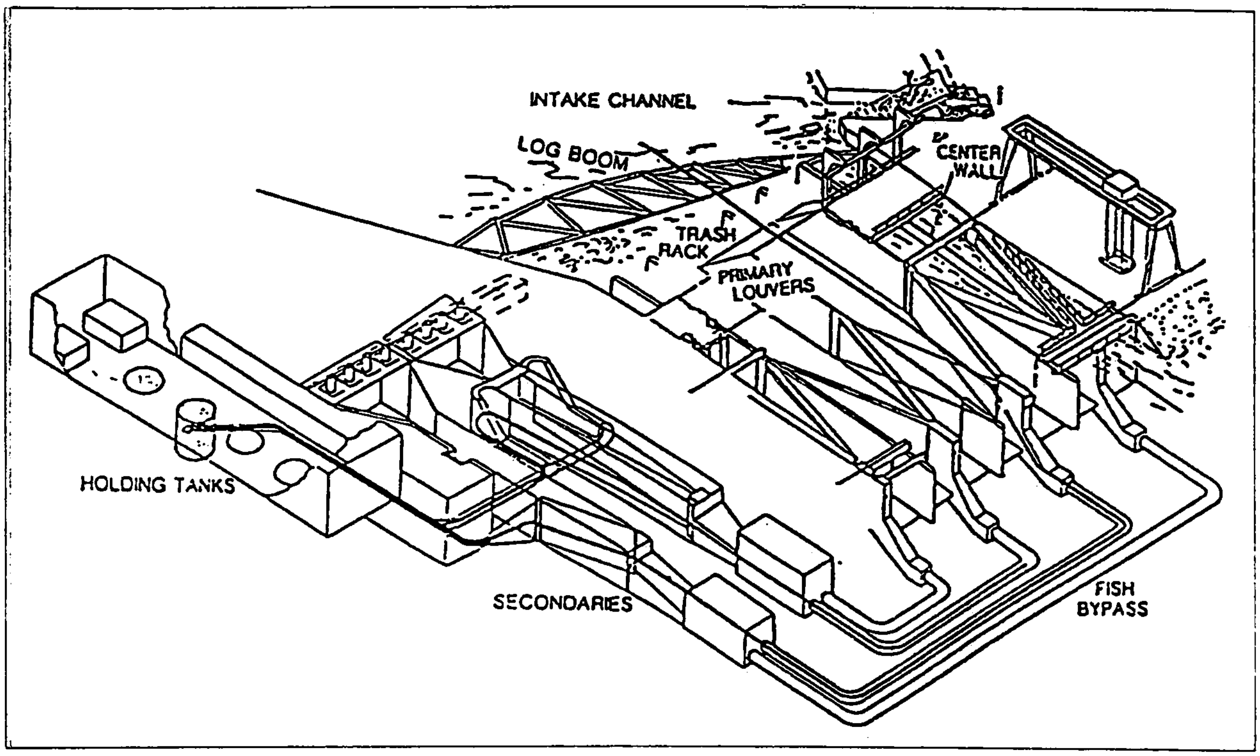

## Skinner Fish Protective Facility

The John E. Skinner Fish Protective Facility began operating in 1968, using the same basic screen design as those constructed earlier at the USBR screens near Tracy. The louver system resembles venetian blinds and acts as a behavioral barrier. Although the slots are wide enough for fish to enter, at the correct water velocities fish encountering the screens sense the turbulence and move along the screen face to the bypass.

In general, the system consists of a series of primary V-shaped bays with louver fish screens that guide the fish to a bypass at the apex of the V (Figure 12). Bypassed fish move by buried pipeline to another screening system, called the secondary screen, where they are concentrated further. Exiting the secondary by another bypass, the screened fish move to holding tanks, where they are kept until being trucked a few miles to one of two Delta release sites (Figure 5). The release sites, Horseshoe Bend and Curtis Landing, were selected to be far enough away from the pumps to reduce chances of salvaged fish being returned to the screens. Releases are alternated between sites to reduce potential predation problems. Two emergency release sites are also available. Salvaged fish are subsampled periodically at the Skinner facility to obtain information on species composition, numbers, and lengths.

On July 1, 1992, DFG staff began counting and hauling the fish salvaged at the Skinner Fish Facility. Monthly salvage estimates are published by DFG.

Figure 12
SCHEMATIC DIAGRAM OF THE JOHN E. SKINNER FISH PROTECTIVE FACILITY




In the early 1970s, DFG and DWR conducted an extensive evaluation of the Skinner Fish Facility (DWR and DFG, 1973). Subsequently, staff has evaluated specific features of the system such as trucking and handling losses, losses to predators in Clifton Court Forebay, and losses in the holding tanks. These studies have generally been confined to a relatively few species of fish, including fall-run Chinook salmon, striped bass, and American shad. No specific studies have been conducted with winter-run salmon.

In response to suggestions by DFG, DWR extensively modified the Skinner facility in the early 1980s by installing center walls in the primary bays (for improved striped bass screening efficiency); opening new bays; building a second, perforated-plate secondary; and rescreening the holding tanks to help minimize fish losses. The new secondary is a positive barrier in that the small diameter perforations are too small to allow juvenile salmon to move through the screen. In 1989, salt was added to water in the hauling trucks to reduce stress and mortality and a new 2,000 gallon handling truck was purchased for the same reason.

In 1992, DWR completed three more holding tanks to the Skinner facility, which will improve salvage efficiency for all species by allowing more efficient use of both secondary systems. The number and design of the new holding tanks were arrived at from discussions between DWR and DFG staff. The four new pumps mentioned earlier in combination with the new holding tanks will also allow better velocity control and increased salvage efficiency. This increased efficiency results from being able to optimize water velocities for salmon at any given pumping rate and from using both secondaries to ensure that flows through the holding tanks do not exceed fish protection criteria.

The above general description provides an idea of how the facility works to salvage fish and return them to the Delta. Following is a point-by-point description of each major feature of the system, with special reference to winter-run salmon.

## Clifton Court Forebay

The forebay is a 31,000-acre-foot regulating reservoir at the intake to the California Aqueduct. The reservoir is operated to minimize water level fluctuation in the intake by taking water in through gates at high tides and closing the gates at low tides. When the gates are opened at high tides, inflow can exceed 20,000 cfs for a short time and decreases as the water levels inside and outside the forebay reach equilibrium. Velocities vary with the difference in elevation and can be several feet per second when tides are high and reservoir elevation is low.

In a series of studies by DFG, there were significant losses of released marked fall-run hatchery salmon crossing the forebay. A juvenile salmon loss rate of 75 percent is presently being used by DFG to calculate losses of Chinook salmon at the State Water Project intake. The loss rate estimates have been developed by DFG by releasing known numbers of marked hatchery-reared fall-run Chinook salmon in the forebay and near the trash racks. Differential recoveries from the various release sites were used to calculate the forebay loss rate, with the losses assumed to be mostly due to striped bass predation. Three estimates of loss rates were determined, namely 88 percent (1978), 63 percent (1984), and 75 percent (1985). Although an average value of 75 percent has been used in calculations for DWR mitigation obligation, DWR and DFG have agreed that the numbers will be recalculated as new information becomes available.

There were two other predation tests, one conducted in 1976, the second in 1992, which provided a loss rate of 97 and 98 percent, respectively. These values have not been included in the average because they do not provide useful data regarding predation at typical pumping rates. In the 1976 test there was only one release group (near the intake) and the release was made when there was essentially no pumping. There was also a fungal problem noted when the fish were collected at Coleman National Fish Hatchery and large numbers of dead fish when the truck arrived at the Delta. The 1992 test also occurred when there was little pumping (average of about 500 cfs for 5 days after release) and the water temperatures were quite warm.

Aside from problems extrapolating loss rate data from hatchery to wild fish, there are several reasons why the use of a 75 percent rate does not appear appropriate for winter-run salmon during the February through March period when downstream migrating winter run are most abundant.

DFG studies have also indicated that the primary predators in the Forebay are sublegal striped bass. DFG and DWR have initiated a program to evaluate methods to safely remove striped bass from the forebay and also to evaluate the effects of predator removal on loss rates. Studies in the fall of 1991 have indicated that striped bass can be effectively captured by use of seines or hook and line. In March 1992 about 2,000 sublegal striped bass were removed from the forebay. A more intensive predator removal effort is scheduled to begin about November 1, 1992. In addition, a winter predation rate test is being scheduled for December 1992 to help determine predation during conditions when winter-run Chinook are typically in the Delta.

Predator removal studies will be accompanied by additional studies on loss of salmon in the forebay. The drought and resulting atypical pumping patterns have delayed implementation of the loss rate studies.

### Efficiency of the Primary and Secondary Louvers

The original evaluation of the Skinner Fish Facility resulted in the following equations for the combined efficiency of primary and secondary louver screens for fall run Chinook salmon:

| Length (mm) | Efficiency |
|---|---|
| A) 1-100 | Eff=0.630+0.0494 X Approach velocity |
| B) >100 | Eff=0.568+0.0579 X Approach velocity |

As indicated, screen efficiency is a function of length and channel approach velocity. D-1485 specifies the following approach velocities in both the primary and secondary channels:

- 3.5 fps November 1 through May 14 for Chinook salmon.
- 1.0 fps May 15 through October 31 for striped bass.

The new secondary is a perforated plate positive barrier screen with 5/32-inch-diameter holes. Screening efficiency for salmon longer than about 20 mm is 100 percent.

For these analyses, these screen efficiencies have been assumed to apply to winter-run salmon. The period when the 3.5 fps salmon criterion is in effect covers the period when one would expect winter-run salmon to encounter the screens.

### Predation in the Primary and Secondary Channels

Striped bass and other predators have been observed in both primary and secondary channels, and they undoubtedly prey on juvenile salmonids. There are no reliable estimates of loss rates in this part of the system, and for this evaluation these losses are included as part of the overall 75 percent prescreening losses of salmon to predation.

## Holding Tank Losses

The holding tanks were rescreened in the mid-1980s, which prevents physical losses of all salmon. D-1485 specifies a 10 cfs maximum flow through the holding tanks. With the new holding tanks this criterion can be met at all times.

Removing fish from the holding tanks entails collecting them in a crane-supported transfer bucket and moving the bucket to a tanker truck for hauling to the Delta. Hauling frequency varies from one to several times per day and is based on estimated density of fish in the tanks using guidelines provided by DFG.

## Counting and Measuring Salmon

Since it is impossible to count all salvaged salmon, estimates are made by subsampling periodically during the day and extrapolating the results to the entire day. Typically, subsamples are collected every two hours by diverting flow from the secondary bypass into a "counting" holding tank. Sampling time varies with expected fish density but is normally on the order of a few minutes. Fish are collected and counted, then returned to the holding tank. Twice each day, at 0100 and 1300, the subsamples are identified and the length of several of each species is measured to the nearest millimeter. Total daily salvage, by species and average length of each species, is then calculated by comparing the period subsampled with the total pumping time.

For the past two years, this procedure has been modified in that all salmon collected in all the counts (*ie* typically 12 per day) are typically measured, which eliminates any bias associated with failure to randomly select individuals for measuring. Sampling time has also been increased during times of low salmon abundance to improve statistical reliability. Both measures were implemented in response to the need to better assess impacts on winter-run Chinook salmon.

The above sampling design results in large but uncalculated error bars about the salvage numbers, especially when not many of a particular species are being salvaged. DFG recognized these problems when the procedures were first proposed in the 1960s but for the purposes of that time the numbers were considered adequate. DFG and DWR will be reevaluating these procedures in light of new uses for the data and as DFG assumes control of the counting and salvage operation in 1992.

In these analyses, we have assumed the salvage numbers are accurate. Upon advice from DFG (Dan Odenweller, personal communication) we have concentrated these analyses on data collected from 1980.

## Hauling

This analysis uses recent findings that handling/hauling losses for fall-run Chinook salmon are not significant hold true for the winter run as well (Table 6). This assumption is also supported by observations that the infrequent problems with transporting

Table 6
MONTHLY MEAN HANDLING AND TRUCKING MORTALITIES AND FORK LENGTH FOR CHINOOK SALMON AND WATER TEMPERATURE FOR SEPTEMBER 1984 THROUGH OCTOBER 1985 AT SKINNER FISH FACILITY
(From DFG 1987)

| Year | Month | % Mortality | | Mean Fork Length (mm) | Mean Water Temperature (Degrees F) |
|---|---|---|---|---|---|
| | | Handling | Trucking | | |
| 1984 | September | — | — | — | 72.7 |
| | October* | 0.0 | 0.0 | 175.7 | 59.9 |
| | November* | 0.0 | 0.0 | 164.4 | 53.6 |
| | December* | 0.0 | 0.0 | 172.5 | 49.2 |
| 1985 | January* | — | 0.0 | 190 | 42.8 |
| | February* | — | — | — | 44.0 |
| | March* | 0.0 | 0.0 | 104.9 | 53.1 |
| | April | 0.01 | 0.01 | 85.3 | 62.2 |
| | May | 0.0 | 0.0 | 88.6 | 63.6 |
| | June | — | — | — | 74.3 |
| | July | — | — | — | 73.8 |
| | August | — | — | — | 70.3 |
| | September | — | — | — | 69.5 |
| | October* | 0.0 | 0.0 | 175.1 | 63.5 |

* denotes sample size less than 100 fish.
— denotes no salmon present.

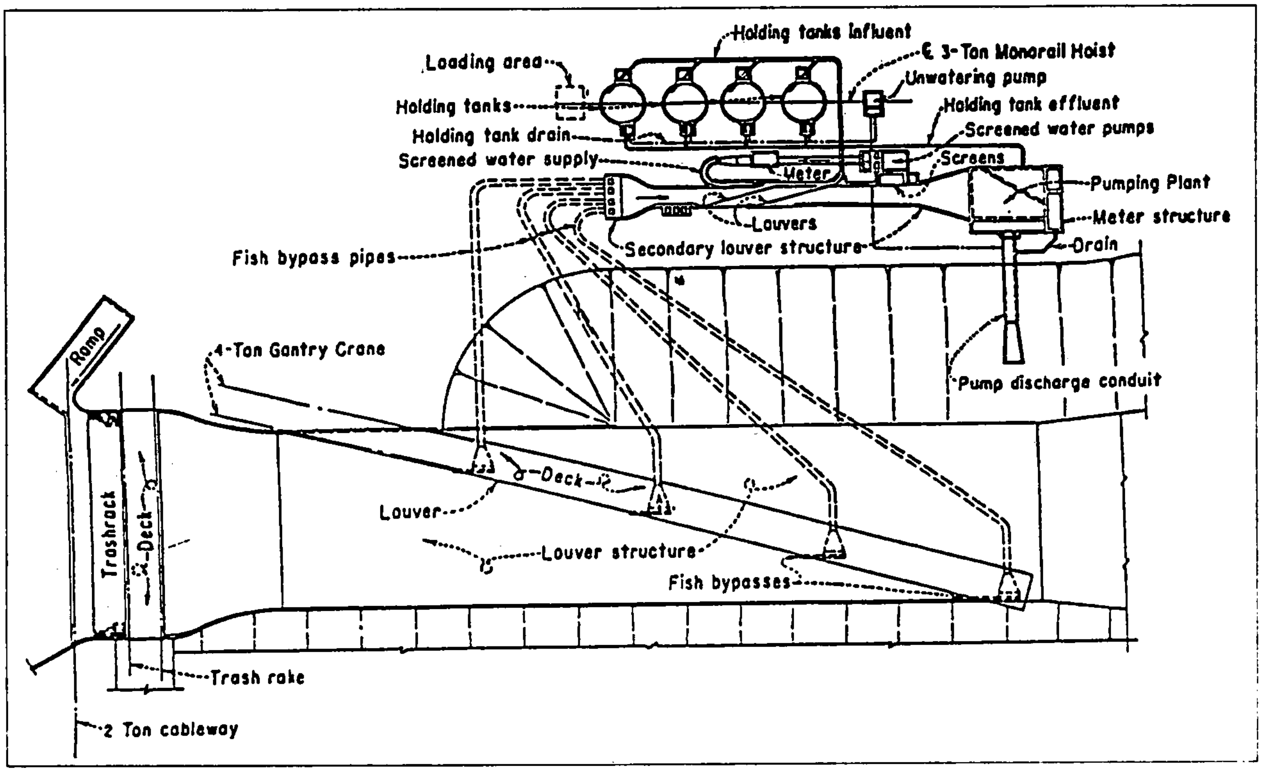
juvenile salmon occurred due to elevated temperatures — a problem that should not be present during the winter.

There are some data indicating that the salvage process reduces the survivability of fall-run smolts released to the estuary (Menchen 1980). Although it is likely that winter-run post-release mortality is lower than that for fall run because stresses induced by sudden temperature changes would be less, there are no data to support or refute this hypothesis.

## Tracy Fish Protection Facility

The USBR's Tracy Fish Protection Facility, located at the intake to the Delta-Mendota Canal, began operation in 1955. Fish protection is provided by a system of primary and secondary louvers (Figure 13). The primary screening system is a single 320-foot-long louver set at a 15-degree angle to the flow. The louver slats are 25 feet high and have a 1-inch spacing between slats. Four, 6-inch bypasses located along the louver face convey the screened fish to the secondary louvers. After passing the secondary louvers, the by-passed fish enter the holding tank building. Periodically, with frequency depending on fish abundance, the salvaged fish are transferred from the holding tanks to trucks and then hauled to the Delta for release. The USBR currently uses only one release site, which is on the Sacramento River near Horseshoe Bend, just downstream of the State's release site.

Figure 13
SCHEMATIC DIAGRAM OF THE USBR TRACY FISH PROTECTIVE FACILITIES




Unlike the State screens, the Tracy system is completely open to tidal influence. Since pumping is generally constant over a 24-hour period, channel and approach velocities vary with the tidal height. Like the State system, the screens are operated to achieve velocities specified in D-1485 for striped bass and salmon. However, having only one primary screen and constantly changing water surface elevation makes it impossible to maintain the desired velocities.

An office evaluation of the Tracy facility was completed in the late 1950s (Bates, *et al* 1960). Although there has never been a complete field evaluation of the facility, USBR staff from Sacramento and Denver are presently looking at specific hydraulic features and predation removal to decrease fish losses at the intake to the Delta-Mendota Canal.

Without specific field evaluations to define losses of Chinook salmon, the following information has been used to estimate total salmon losses at the CVP's Delta screens.

| | |
|---|---|
| Predation losses - | 15 percent (from DFG 1987) and based solely on DFG's generic estimate that structures in water attract predators and losses associated with these predators is in the order of 15 percent. |
| Screening losses - | Assume screens operate at the optimum 3.5 fps and that efficiency is a function of fish length using the equations shown for the SWP screens. Although this over estimates number salvaged there are no data to do otherwise. |

| | |
|---|---|
| Handling losses - | Assume none which underestimates losses to an unknown extent. |
| Hauling losses - | Assume none which underestimates losses to an unknown extent. |
| Salvage numbers - | Used as absolutes (*ie*, identification and counts are accurate). Although both assumptions are known to be incorrect, there is no way to correct the salvage estimates. Using only data from 1980 on helps in this assumption. |

## The Coordinated Operation Agreement

Because the CVP and the SWP use the Sacramento River and the Sacramento-San Joaquin Delta as common conveyance facilities, reservoir releases and Delta exports must be coordinated to ensure that each project retains its share of the commingled water and bears its share of joint obligations to protect beneficial uses. The Coordinated Operations Agreement (COA) between the United States of America and the State of California became effective in 1986. The agreement defines the rights and responsibilities of the two projects with respect to Sacramento Valley and Sacramento-San Joaquin Delta water needs and provides a mechanism to measure and account for those responsibilities.

### Obligations for In-Basin Uses

In-basin uses are defined in the COA as "legal uses of water in the Sacramento Basin including the water required under the provisions of Exhibit A", where Exhibit A contains the SWRCB D-1485 Delta standards (except Suisun Marsh standards). Each project is obligated to ensure that water is available for these uses but the degree of obligation is dependent on several factors and changes throughout the year.

Water conditions in the Sacramento Basin and Delta can be divided into two conditions; excess and balanced. In excess water conditions, releases from upstream reservoirs plus unregulated flow exceed Sacramento Valley in-basin uses plus exports. In balanced water conditions, releases from upstream reservoirs plus unregulated flow approximately equal Sacramento Valley in-basin uses plus exports.

As its name implies, during excess water conditions sufficient water is available to meet all beneficial needs and the projects are not required to supplement the supply with water from reservoir storage. Thus, no accounting for responsibility is required. However, during balanced water conditions the projects share in meeting in-basin uses. Balanced water conditions are further divided into two conditions when water from upstream storage is required to meet Sacramento Valley in-basin use, or when unstored water is available for export.

When water must be withdrawn from reservoir storage to meet in-basin uses, 75 percent of the responsibility is borne by the CVP while 25 percent is borne by the SWP.

(Percentages were derived from reservoir operations studies that simulated CVP operations with and without the influence of the SWP while preserving the yield of the CVP.) When unstored water is available for export (balanced water conditions when exports exceed storage withdrawals) the sum of United States stored water, State stored water, and the unstored water for export is allocated 55/45 to the CVP and SWP respectively.

## Accounting and Coordination of Operations

To achieve the provisions of the COA, the CVP and SWP operators must maintain regular communication. Daily coordination is necessary to determine target Delta outflow for water quality, reservoir release levels necessary to meet in-basin demands, and schedules for use of each other's facilities for pumping and wheeling.

During balanced water conditions, daily accounting of CVP and SWP obligations are accumulated. Thisallows for flexibility in operations and avoids the problems of attempting to make daily changes in reservoir releases that originate several days travel time from the Delta. It also means that the variables of reservoir inflow, storage withdrawals, and in-basin uses can be dealt with after-the-fact rather than by prediction.

Although the accounting language of the COA provides the mechanism for determining the responsibility of each project, real-time operations, not formulas, dictate actions. For example, conditions in the Delta can change rapidly. Weather conditions combined with tidal action can quickly affect outflow requirements. If, for this example, the SWP could only respond by increasing its Oroville release, the change would not be seen in the Delta for three days (three day travel time from Oroville to the Delta). In actual operations, the CVP would probably increase the Folsom release (one day travel time from Folsom to the Delta). Similarly, if the CVP had to increase its contribution during a period when increasing the Keswick release was desirable, the Folsom release might be increased temporarily until the Keswick water arrived (five day travel time from Keswick to the Delta).

Releases are not the only way that the projects can adjust to changing in-basin conditions. During balanced water conditions an increase in Delta outflow can be achieved immediately by reducing project exports.

Standards contained in D-1485 require that the projects limit pumping to 3,000 cfs during May and June. This condition is particularly exacting on the CVP since its annual exports are limited by the capacity of the Tracy Pumping Plant and the Delta Mendota Canal. Because this export limitation was a result of the SWP becoming operational, the SWP compensates by pumping from the Delta up to 195,000 acre-feet of CVP water each year. If this water is pumped during balanced water conditions, the CVP is responsible for supplying the water in the Delta under the terms of the COA.

When real-time operations dictate project actions, an accounting procedure tracks the water obligations of the two projects. When the balance of the projects' obligations are sufficiently great, adjustments are made in reservoir releases. These adjustments allow the project that has carried more than its obligation to recoup the water while the other project makes up for its deficient contribution in the preceding period.

During the year, water conditions can go in and out of balance. Account balances continue from one balanced water condition through the excess water condition and into the next balanced water condition. When, however, the project with a plus balance enters into flood control operations, the accounting is zeroed out.

The language of the COA incorporates a provision for the review of the agreement every five years. The first of these reviews is scheduled for 1991. The USBR is now in an internal review prior to formal review with the DWR.

A basic tenet of the COA is that it provides a mechanism by which the CVP and SWP can function more efficiently by operating together than they could if operating independently. Working together can provide both environmental and project benefits. Shasta, Oroville, and Folsom Reservoirs can be operated conjunctively to provide flows and temperature control that could not be obtained otherwise. With specific reference to winter-run salmon, Delta inflows during the summers of dry years could come from the SWP's Lake Oroville, which would help conserve cold water in the CVP's Lake Shasta. Through the USBR/COA account, Shasta flows would be used later to pay back the water owed to DWR. Use of the COA account to help winter-run salmon is discussed in chapter on project impacts.

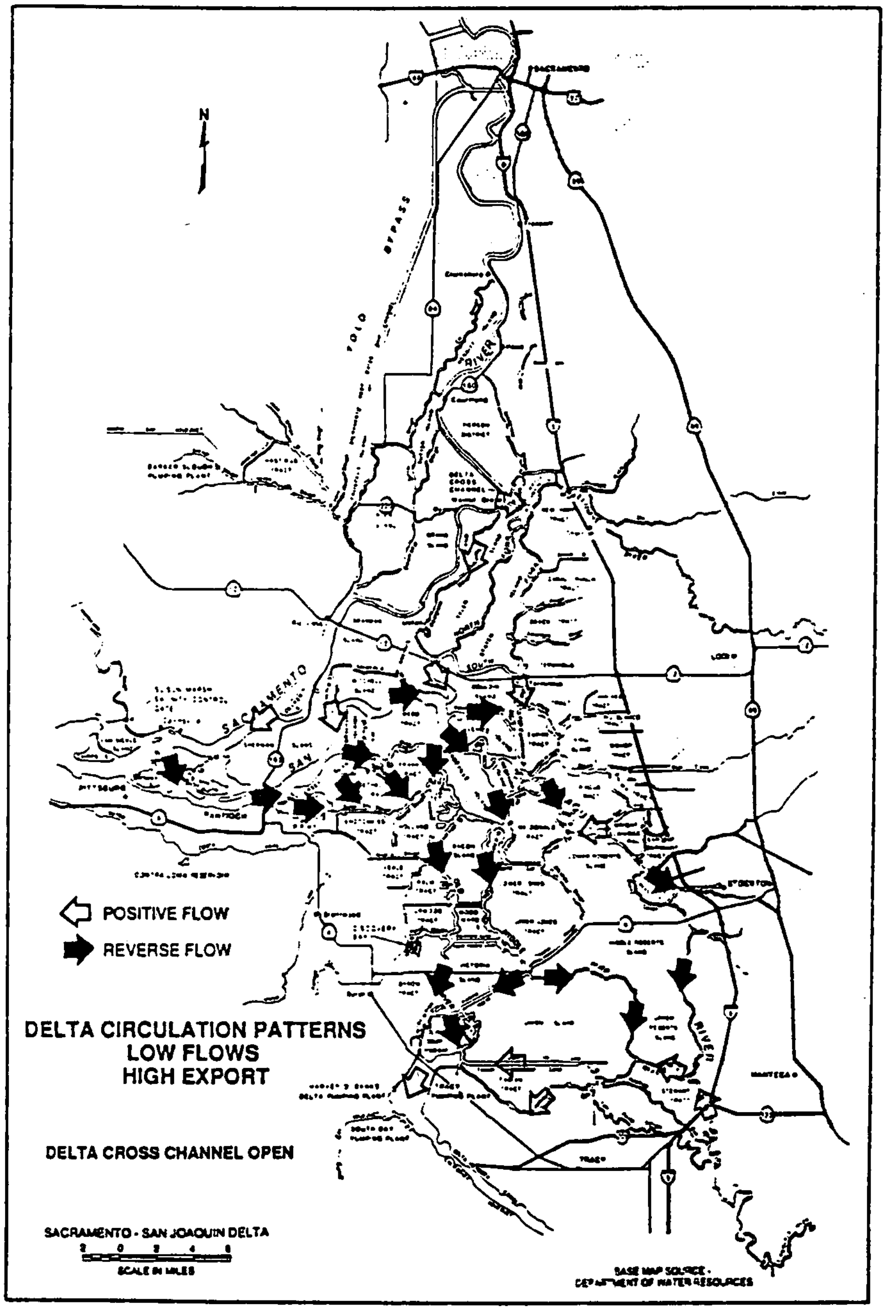
Outside the COA, the USBR hosts annual fall and spring meetings of biologists and project operators in an effort to facilitate inclusion of environmental concerns in project operation. During these meetings, information is exchanged on projected reservoir levels, releases, diversions, and fisheries concerns. Although operational changes may not be decided at these meetings, much of the information needed to identify upcoming fishery concerns is made available. Subsequent meetings are often called to work out details of operational changes for conducting environmental (river temperatures, fish flushes, for example) or fish protective measures.

## Reverse Flows

Although not an operational feature, reverse flows result from SWP and CVP operations and are an environmental concern. Flow distribution in the Delta channels is a function of Sacramento River and San Joaquin River inflows, channel capacity, Delta depletions, SWP and CVP pumping, and tides. At any given time and location in a Delta channel, the major flow component is the tide. For example, on a summer ebb tide, the total outflow in the lower Sacramento River may be several tens of thousands of cubic feet per second, only 5,000 of which may be freshwater flow. The strength of the tidal component varies monthly and seasonally as the tide changes from spring to neap.

If tidal effects are removed, a net flow will remain which is an indication of direction a water particle will move over an extended time period. In the Delta, water project pumping can result in net flows in the lower San Joaquin River being toward the pumps, *ie* up river (Figure 14). The flows, often called "reverse flows", occur when project

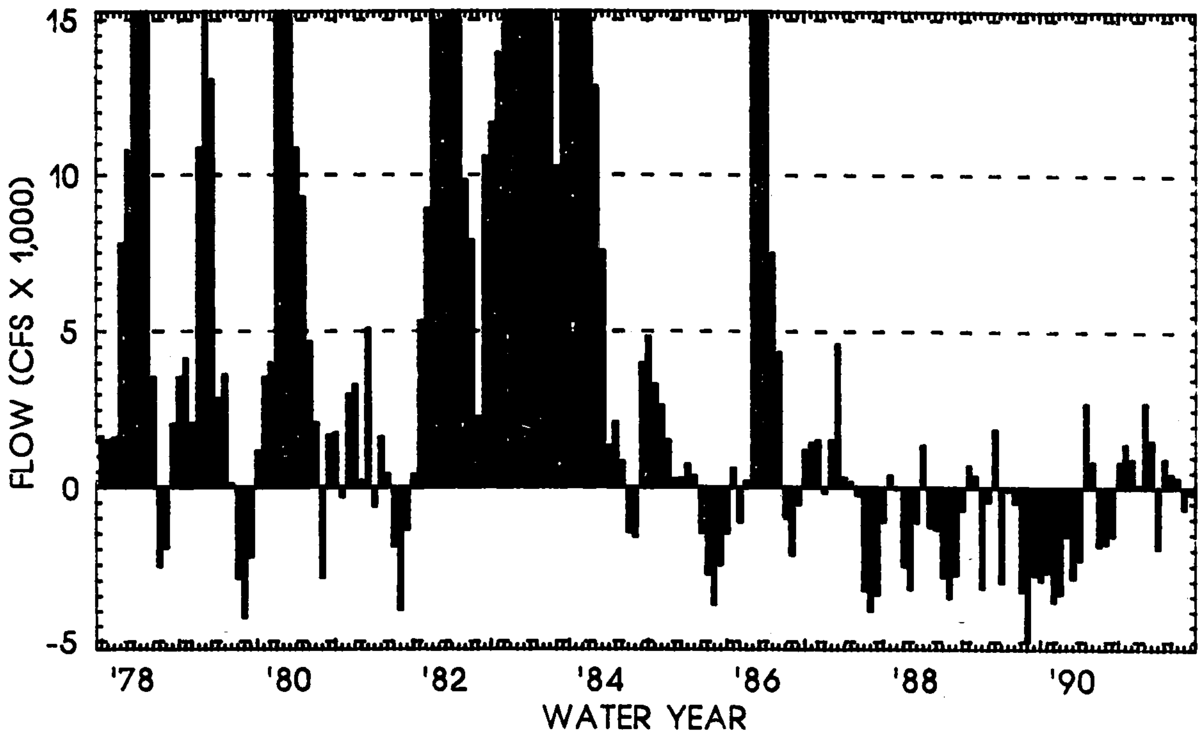
Figure 14
SCHEMATIC OF NET FLOW PATTERN DURING PERIODS OF LOW INFLOW AND
AND HIGH CVP, SWP, AND INTERNAL DELTA DIVERSIONS




pumping and a portion of the internal agricultural demand exceeds inflow from the San Joaquin River plus cross-Delta flows from the Sacramento River. Since capacities of the cross-Delta channel, Georgiana, and Threemile Slough is fixed, additional Sacramento River water needed to meet pumping demands takes the path of least resistance and flows around the westward tip of Sherman Island and up the San Joaquin River.

As might be expected, during the past seven years of mostly dry conditions, the frequency of flow reversal has increased (Figure 15). The data plotted in Figure 15 are calculated average monthly flows past Jersey Point (in the lower San Joaquin River), with negative values indicating reverse flows. It must be emphasized that these values are water balance calculations based on balancing Delta flows and depletions and are to be used as indices of flow reversals.

Figure 15
AVERAGE FLOW PAST JERSEY POINT, WATER YEARS 1978 THROUGH 1990,
FROM THE DAYFLOW DATABASE



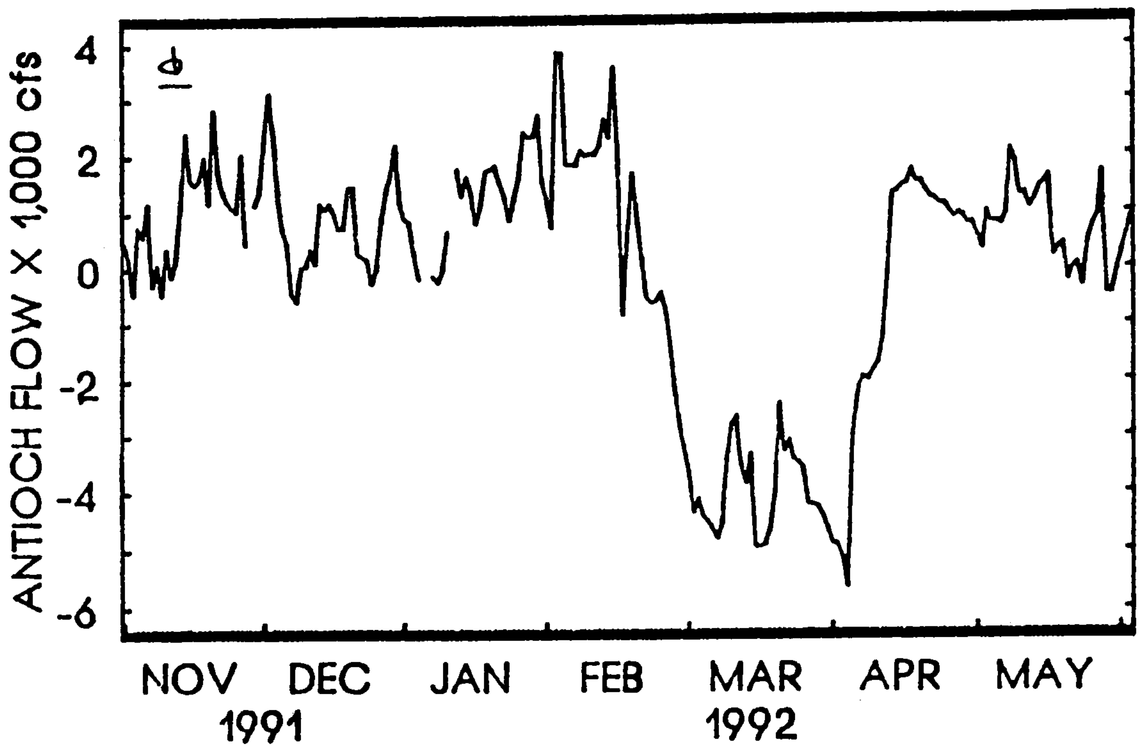

The months in which reverse flows occurred during 1978 through 1989 are shown in Table 7. As the drought continued, the numbers of months with reverse flows increased.

Table 7
MONTHS DURING WATER YEARS 1978-1989 IN WHICH THE
AVERAGE CALCULATED FLOW PAST JERSEY POINT WAS NEGATIVE

| Water Year | Months with Negative Flow | Water Year | Months with Negative Flow |
|---|---|---|---|
| 1978 | July, August | 1984 | July, August |
| 1979 | July, August, September | 1985 | June through December |
| 1980 | August, November | 1986 | July, August, September |
| 1981 | April, July, August, September | 1987 | January, June through December |
| 1982 | None | 1988 | All but April, November, December |
| 1983 | None | 1989 | All but March |

In 1992 a combination of Delta Cross Channel closure and high pumping resulted in relatively high reverse flows during the February-March period (Figure 16). The effects of flow reversal are discussed in a subsequent chapter.

Figure 16
CALCULATED FLOW AT ANTIOCH, NOVEMBER 1991 THROUGH MAY 1992
(Preliminary Data from DWR's Dispatcher Report.)




## Suisun Marsh Salinity Control Structure

Phase II of the Plan of Protection for Suisun Marsh was completed in November 1988, with the Suisun Marsh Salinity Control Structure (also referred to as Montezuma Slough salinity control gates) operating for the first time. The primary objective of Phase II is to help meet channel water salinity standards established by D-1485 at control sites at Collinsville (C-2), the SMSCS (S71), National Steel (S64), and Beldons Landing (S49) (Figure 17).

### Description of the Salinity Control Structure

A schematic of the SMSCS is presented in Figure 18. The structure is located about 2 miles northwest of the confluence of the eastern end of Montezuma Slough and the Sacramento River near Collinsville (Figure 17). The structure spans Montezuma Slough, a width of 465 feet. The schematic shows the southern, or upstream, side of the structure. From left (west) to right (east), the structure consists of the following components:

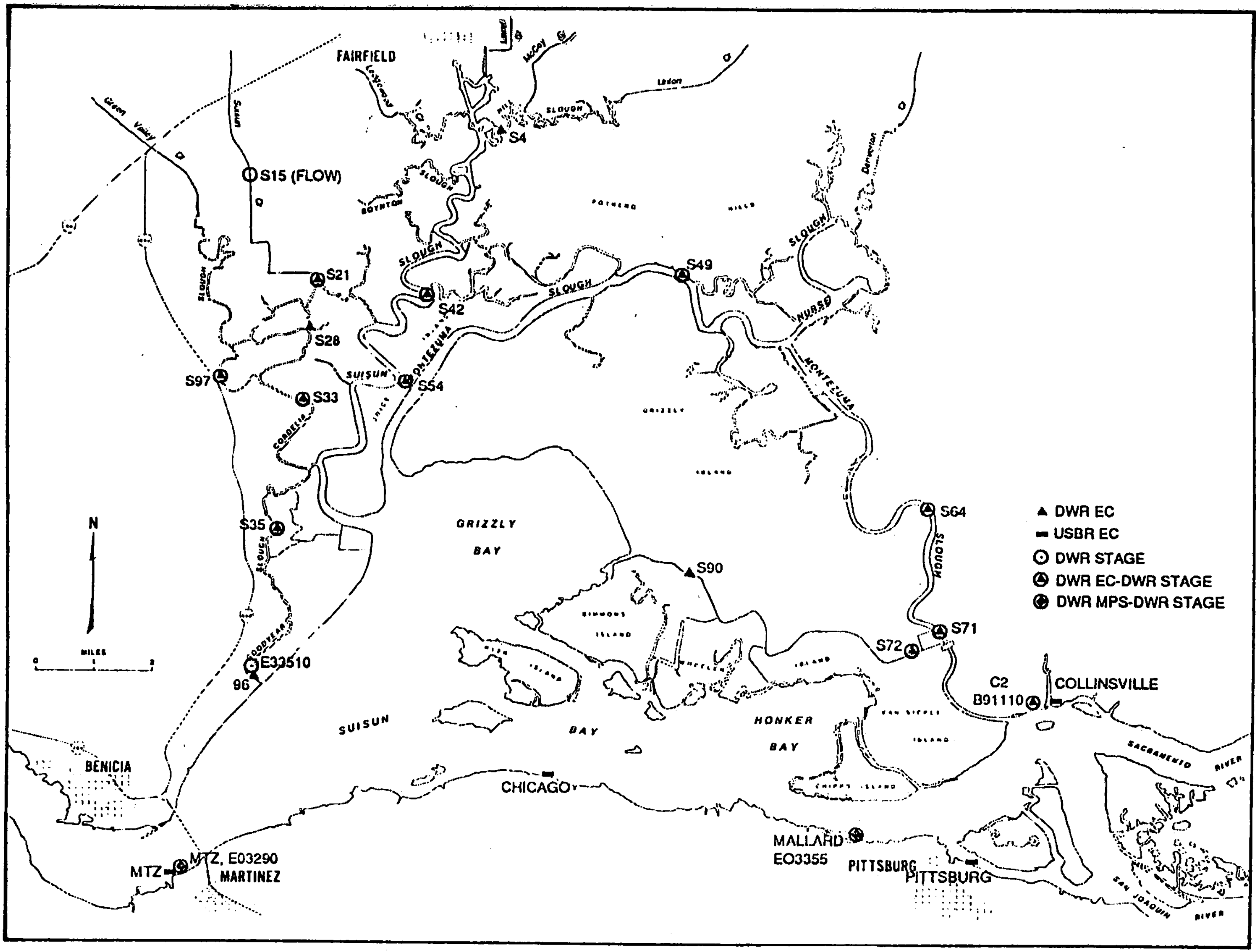
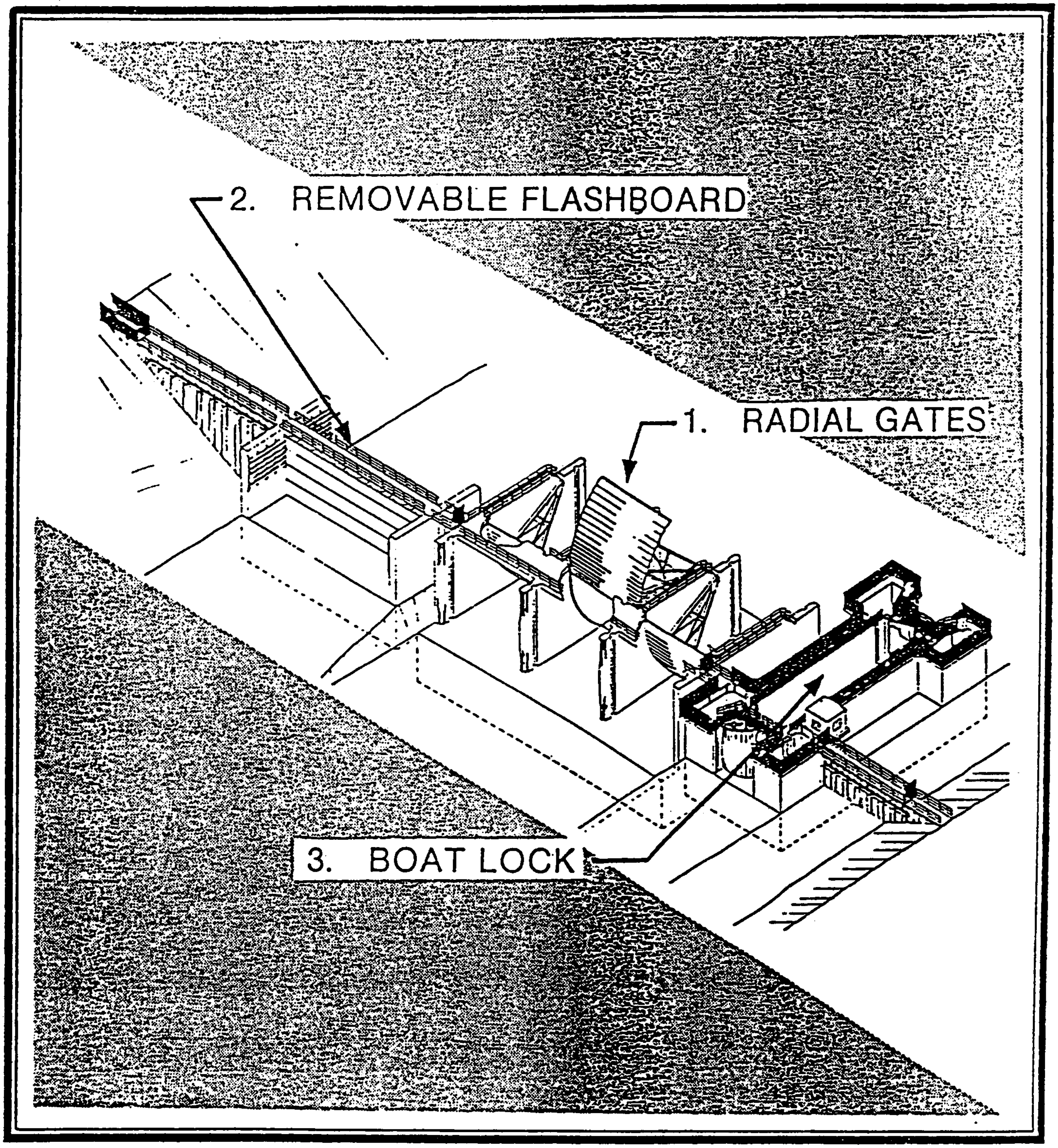



Figure 17
SUISUN BAY AND SUISUN MARSH

Figure 18
SCHEMATIC DIAGRAM OF MONTEZUMA SLOUGH SALINITY CONTROL GATES



- A permanent barrier, 89 feet across, extending from the western levee to the flash board module.
- The flash board module with a 66-foot opening that is closed to flow during the October 1 through May 31 control season. This module can be removed in case of emergency work within the Marsh requiring large barge mounted equipment.
- The radial gate module, 159 feet across, containing three radial gates, each 36 feet across.
- The boat lock module, 20 feet across, which is operated when the flash board module is closed off.
- A permanent barrier, 131 feet across, extending from the boat lock module to the eastern levee.

An acoustic velocity meter is located 300 feet upstream (south) of the gates to measure water velocity and flow in Montezuma Slough near the structure. Water level recorders are located on both sides of the structure to determine the difference in water level. The three radial gates are opened and closed automatically using the water level and velocity data.

### Operation of the Salinity Control Structure

The SMSCS is operated only when needed from October 1 through May 31, designated as the control season, to meet channel water salinity standards. From June 1 through September 30, the gates are generally not operated, although there has been some testing of the effectiveness of gate operation with the flash boards out. Operation is necessary during control seasons of below normal, dry, and critical water year types to meet D-1485 standards. The gates are operated:

- To divert less saline water from the Sacramento River near Collinsville into Montezuma Slough.
- To limit intrusion of higher salinity Grizzly Bay water into the western end of Montezuma Slough.

The gates can either be operated "full bore" to divert the maximum quantity of water from the Sacramento River at Collinsville into the eastern end of Montezuma Slough or intermittently to divert the quantity needed to meet standards. During "full bore" operation, the gates open and close twice each tidal day (approximately 25 hours long). The gates are opened during the ebbing portion of the tide, when the water level is higher on the Collinsville (upstream) side, and remain open about 7 hours each cycle. The gates are closed during the flood tide, when water in Montezuma Slough begins to flow upstream toward Collinsville.

The quantity of flow tidally pumped by the salinity control gates is primarily a function of the shape and sequence of ocean tides and hydrologic conditions in the Delta. When in operation, flows past the gates recorded on a 15-minute basis, vary from no flow when the gates are closed to several thousand cubic feet per second with the three gates open. When operating "full bore", net flow through the gates is about 1,800 cfs when averaged over one tidal day. When the gates are not operated from June through September and the flash boards are removed, the net flow in Montezuma Slough over one tidal day is low and often in the upstream direction, as estimated by hydrodynamic model simulations.

Operation During the 1988-89 Control Season (Dry Water Year). During the 1988-89 control season, the gates were operated for 157 days from October 31, 1988, through April 7, 1989. Operation was "full bore" when possible to test gate operation and help determine the maximum effectiveness of the system to lower channel water salinity in Suisun Marsh. Because of intermittent equipment problems, operations were recorded for 132 of the 157 days. During the recorded period, the gates opened 268 times totaling 1,812 hours, and nearly 480,000 acre-feet of water was tidally pumped past the structure. On a calendar-day basis, average flow through the gates during this period was 1,830 cfs.

Operation During the 1989-90 Control Season (Critical Year). During the 1989-90 control season, the gates were operated "full bore" when possible to further test and evaluate operations. The system was operated 248 days between September 26, 1989, and May 31, 1990. Because of intermittent equipment problems, operations were recorded 170 of the 248 days. During the recorded period, the gates opened 295 times totaling 2,931 hours, and nearly 490,000 acre-feet of water was tidally pumped through the system. On a calendar day basis, average flow through the gates during this period was 1,430 cfs. Using a hydrodynamic simulation model to fill the 78-day data gap, an estimated 818,000 acre-feet of water was tidally pumped past the structure, averaging 3,300 acre-feet or 1,670 cfs each calendar day.

Operation During the 1990-91 Control Season (Critical Year). During the 1990-91 control season, the salinity control structure was operated intermittently from October through mid-December and "full bore" during the remainder of the control season. The structure was not operated during November 1990 because the one cable that raises and lowers the gates broke. The number of gate openings and volume of flows are not available at this time.

## Discrete Flow Diversions from Montezuma Slough

Water is diverted from Montezuma Slough at discrete diversion points onto private ownerships along the slough and at the Roaring River Distribution System intake (one of the initial facilities of the Plan of Protection). Roaring River is by far the largest diversion point off Montezuma Slough in the Marsh.

The intake to Roaring River is currently screened to prevent entrainment of fish larger than about 1 inch. The design average approach velocity is 0.5 fps, but velocity is usually below this value. (Design flows occur only at maximum high tide with all culverts open.) The 0.5 fps approach velocity criterion was provided by DFG to protect salmon and striped bass. DWR designed and installed the screens using DFG screen criteria. USBR and DWR paid the approximately $1 million installation cost and are providing routine screen maintenance.

Over 30 private ownerships and DFG along Montezuma Slough divert water from the slough through more than 60 culvert pipes of varying diameters. The diameters and numbers of the culverts are reported in Table 8 (from a survey of waterways and control structures in Suisun Marsh, USBR and Hugo B. Fischer, Inc., 1976).

Table 8
DISCRETE DIVERSIONS FROM MONTEZUMA SLOUGH

| Culvert Diameter (inches) | Number |
|---|---|
| 12 | 3 |
| 18 | 2 |
| 24 | 15 |
| 30 | 4 |
| 36 | 28 |
| 40 | 1 |
| 42 | 1 |
| 48 | 9 |

Most of these diversions are used to supply water for ponds in adjacent waterfowl management areas. The area flooded with these diversions is roughly 12,000 surface acres, and if an average flooding depth of 1.5 feet is used, 18,000 acre-feet of water is diverted from Montezuma Slough (numbers extracted from 1976 USBR survey data cited above). Maximum diversion rates usually occur during October, when the managed wetlands are flooded for the first time. On average, initial flooding requires approximately two weeks. Therefore, this would give an average diversion rate by these 30 ownerships of 1,285 acre-feet per calendar day, or 650 cfs. Maximum diversion rates will be higher than this average rate and will be experienced during high tides, especially when the managed wetlands are dry.

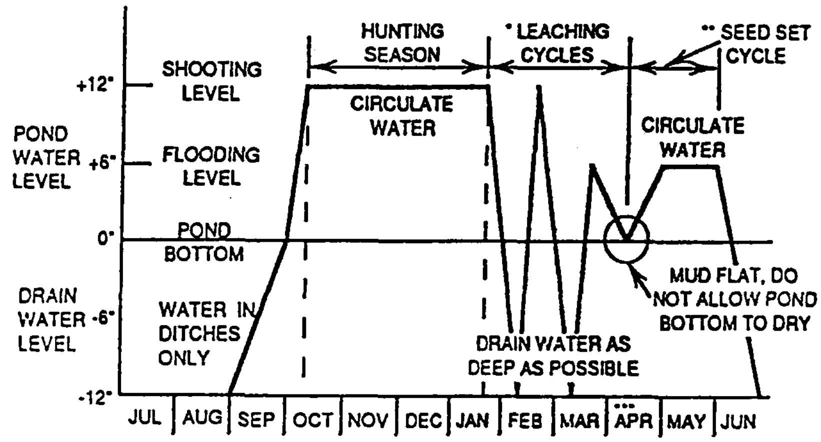
Annual water management practices vary greatly in Suisun Marsh, but the Suisun Resource Conservation District is working to establish and enforce efficient management schedules for the private ownerships. Two representative schedules are presented in Figure 19. During the control season, diversions from Montezuma Slough occur during initial flooding in October, water circulation from November through mid-January, and leach cycles from February through May.

DFG and private ownership diversions are not currently screened.

Figure 19

TWO OPERATIONAL SCENARIOS FOR MANAGED WETLANDS IN SUISUN MARSH

**LATE DRAWDOWN**
**(ALKALI BULRUSH)**
**WATER MANAGEMENT SCHEDULE**

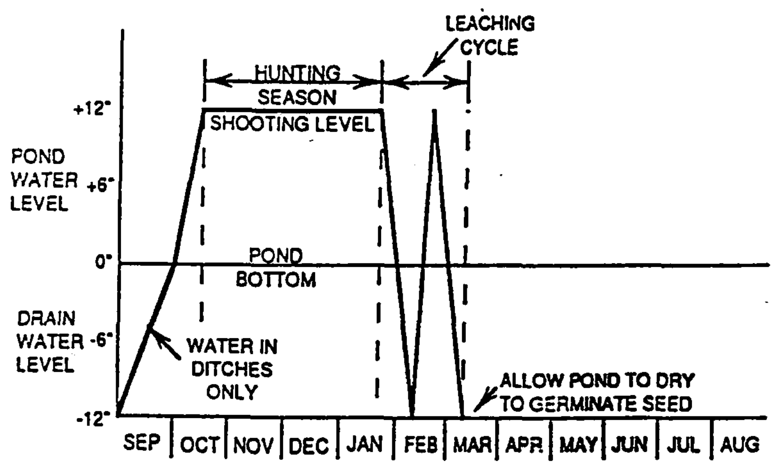



* The leaching cycles are calculated using a 10 day flood and 20 day drain period, however, many clubs can accomplish one total flood and drain cycle in less than 30 days. The flushing cycles should be completed as fast as possible, however, do not cut short the 20 day drain period unless the water level in the ditch is 1" below pond bottom.

** Ideally, stabilized water levels of the seed set cycle should be accomplished before April 1.

*** Stabilized water levels of the seed set cycle should be accomplished before April 1. Any duck club planning to fluctuate pond water levels in April must notify the Solano County Mosquito Abatment District. **Pond bottoms are not allowed to dry out during April prior to reflooding for the seed-set cycle.**

**EARLY DRAWDOWN**
**(FAT HEN)**
**WATER MANAGEMENT SCHEDULE**




[*Rollins*, 1981]

### Lower Joice Island Fill/Drain Facility (Maximum Flow Calculation)

In September 1991, a private landowner using DWR/USBR funding installed two 36-inch-diameter culverts with flap gates on Montezuma Slough on the northeastern end of lower Joice Island under the DWR/USBR Individual Ownership Program. Estimates of maximum flow and velocity were made to indicate if fish screens were necessary.

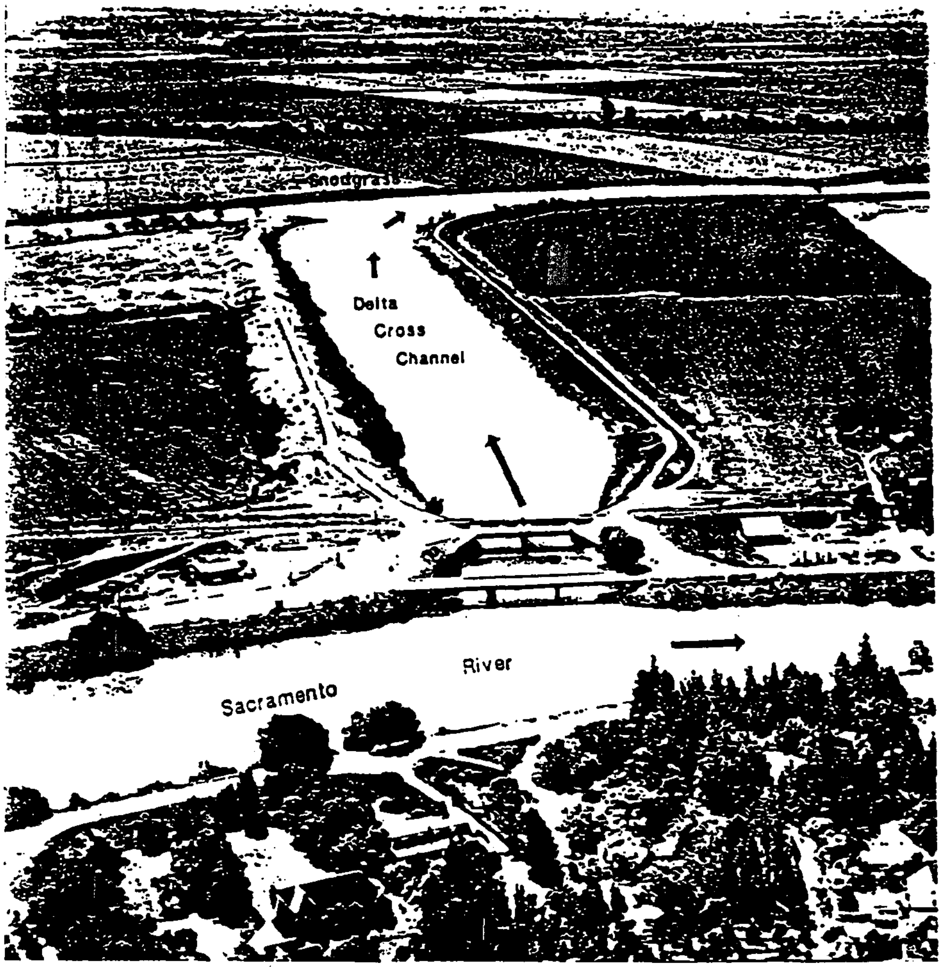
For this calculation, it is assumed that there is a 1.5-foot difference in water level between Montezuma Slough and the inside of lower Joice Island. Head loss resulting from flap gate operation was included by reducing flows by 20 percent. For a 30-foot-long culvert, the resulting maximum flow through each culvert would be about 35 cubic feet per second. This would result in a velocity at the end of each culvert of about 2.5 feet per second. However, the effective velocity experienced by fish in Montezuma Slough will be less because the two culvert pipes are set back from the slough about 25-30 feet on a side channel. Because the opening of the side channel on Montezuma Slough is roughly 15 feet wide by 5-7 feet deep (75-105 square feet cross-sectional area), the effective diversion velocity at the western bank of Montezuma Slough would be about 0.7-1.0 fps. The Suisun Marsh Technical Committee (with DFG as a participant) is addressing screening of these culverts. It may not be technically feasible due to head-loss problems. If deemed necessary and feasible a screen can be in place by the 1993-94 control season.

In the spring of 1992, the February 14, 1992 National Marine Fisheries Service Biological Opinion resulted in dramatically changed operation of the salinity control over what would normally have occurred in a critically dry year. The gates were ordered to cease operating on March 1 and remained closed until March 27. Full gate operation began on March 27 but individual owners were not allowed to take water onto their clubs through unscreened diversions. Since Roaring River is the only screened intake, most clubs were unable to take water until May 1, 1992, when permit conditions in the opinion ceased to be in effect.

### Delta Cross Channel and Georgiana Slough

The Delta Cross Channel (Figure 20) was constructed by the USBR in 1951 to improve water conveyance through the Delta. The Delta Cross Channel, about 40 miles south of Sacramento near Walnut Grove, diverts water from the Sacramento River into eastern Delta channels, including the north and south forks of the Mokelumne River. During periods of high flow in the Sacramento River (flows above about 25,000 cfs at Freeport), the gates of the Delta Cross Channel are closed to help limit flooding in the interior Delta channels. (Levee heights on interior Delta islands are generally lower than those on the Sacramento River.) During periods of normal and low flow, the gates are left open. D-1485 allows DFG to call for up to 20 days of gate closure between April 15 and May 31 when calculated Delta flows exceeds 12,000 cfs. (The 20 days are not consecutive.) Appendix 3 shows plots of flow and operation of the Cross Channel gates during the 1980-1990 period.

Figure 20
DELTA CROSS CHANNEL, WITH TWO RADIAL GATES ON THE SACRAMENTO RIVER END




The Delta Cross Channel's two 60-foot gates are operated by the USBR's staff from Tracy.

Georgiana Slough, located about 1 mile downstream of the Delta Cross Channel, is a natural, ungated channel that conveys Sacramento River water to the San Joaquin River. Winter-run salmon could also move into the Delta via this channel.

## Delta Cross Channel and Georgiana Slough Hydraulics

The net flow rates in the Delta Cross Channel and Georgiana Slough over a tidal cycle are fundamentally determined by the net flow entering the Delta from the Sacramento River, and from the Mokelumne River to a lesser extent. Flow through the Delta Cross Channel and Georgiana Slough are not continually gauged. However, empirical equations were developed in 1978, using historical data collected before SWP exports began, to relate these flows to Sacramento River inflow (Figure 4, DAYFLOW Documentation, February 1986). These equations can be used to estimate net flow: (1) in Georgiana Slough when the Delta Cross Channel is closed, (2) in Georgiana Slough and the Delta Cross Channel with one gate open, and (3) in Georgiana Slough and the Delta Cross Channel with two gates open.

It is also understood that net flows in the Delta Cross Channel and Georgiana Slough are practically unaffected by the exports and diversions from the south Delta. This is supported by:

- The observation that the above-mentioned relationships were recalculated using field flow data collected in 1970, with no appreciable change, even though combined exports from the south Delta had increased significantly with the addition of SWP pumping.
- Hydraulic simulation model studies performed by DWR (1987) of existing physical conditions with combined export rates from the south Delta ranging from zero to over 10,000 cfs.
- Hydraulic simulation model studies performed by DWR (1989-90) of proposed south Delta project configurations and export changes with combined export rates from the south Delta as high as 15,000 cfs.

The essential independence between Cross Channel-Georgiana Slough flows and south Delta exports and diversions is explained by two basic hydraulic characteristics in the Delta.

The first characteristic is that Cross Channel and Georgiana Slough flows are caused by water level differences between the portions of the Sacramento and Mokelumne Rivers that reside in the Delta. Water level differences result from tidal action, channel configuration and characteristics, and inflows to the Delta. The particular orientation of the Sacramento and Mokelumne Rivers (configuration) with respect to the source of the tides (Golden Gate), as well as, the shape, dimensions and composition of their channels (characteristics) affect the movement and progression of the tides and inflows within their banks. Tides from San Francisco Bay are less impeded moving through the broad and deep channels of the lower Sacramento and San Joaquin Rivers than through the more narrow, shallow and braided channels of the Mokelumne River. Consequently, the various phases of the tide move through the Mokelumne River later than, or lag behind, the Sacramento River, causing differences in water level between the terminal ends of the Cross Channel and Georgiana Slough.

The flood tide moves up the Sacramento River faster and is less impeded than up the Mokelumne River causing water to flow from the Sacramento River into the Cross Channel and Georgiana Slough. Conversely, the tide ebbs in the Sacramento River before and is less impeded than in the Mokelumne River, causing one of the following flow patterns depending on the tide shape and range of the tide (spring or neap) and the relative inflows to the Delta from both rivers.

- Water continues to flow from the Sacramento River into the Cross Channel and Georgiana Slough.
- Water continues to flow into Georgiana Slough and slack flow occurs in the Cross Channel.
- Water continues to flow into Georgiana Slough and, less frequently, water flows from the Mokelumne River into the Cross Channel to the Sacramento River (relative small in magnitude).

The second characteristic is that the lower San Joaquin River from Pittsburg to the central Delta acts as a "hydraulic divide" between the north-central and southeastern Delta because of its relatively large water-carrying capacity.

When water is exported and/or diverted (agriculture) from the south Delta, it is drawn from the San Joaquin River upstream into Old and Middle Rivers. The water displaced from the San Joaquin River near Jersey Island, Bradford Island, and Webb Tract is then primarily replenished from the lower San Joaquin River near Sherman Island, taking the "path of least resistance". Because little additional water is drawn from the Mokelumne River in response to south Delta exports and diversions, net flows in the Delta Cross Channel and Georgiana Slough are essentially unaffected.

As mentioned above, flows through the Delta Cross Channel and Georgiana Slough are not gauged but are estimated by empirical relationships developed by DWR in 1978. At Sacramento River flows of 10,000 to 25,000 cfs, calculated daily average flows through the Cross Channel range from about 3,000 to 6,000 cfs. With the Cross Channel gates closed, calculated flows in Georgiana Slough range from 2,000 to 4,000 cfs when Sacramento River flows vary from 10,000 to 25,000 cfs. DAYFLOW does not calculate separate Georgiana Slough and Cross Channel flows when both gates are open. DWR's annual DAYFLOW summary includes daily values for calculated Cross Channel plus Georgiana Slough flows.

The hydraulic capacities of the Delta Cross Channel and Georgiana Slough provide a physical limitation to the quantity of Sacramento River water that can be moved toward the SWP and CVP pumping plants in the south Delta. These physical constraints cause reverse flows (described previously) when pumping plus internal Delta demand exceeds the sum of cross-Delta flows and San Joaquin River inflows.

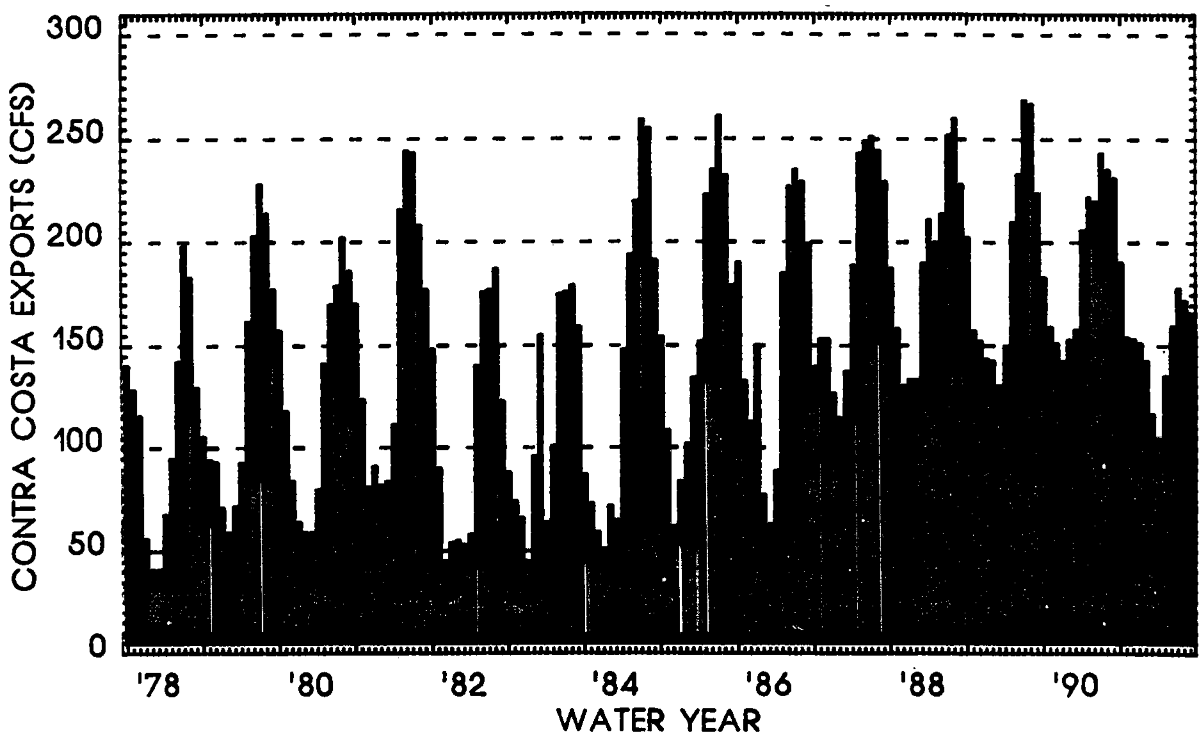
The Delta Cross Channel is not screened to prevent fish from entering the central Delta. A 1991 report for an interagency salmon management study concluded that screening the Cross Channel was not a technically feasible alternative (DFG 1991). The main problems were controlling velocity through the screens in an area where extensive tidal reversal occurs and physical limitations associated with the size and location of the Cross Channel opening (*ie* due to the need for a large screen surface area an effective screen would not fit). Biologists and engineers have long recognized these problems and have recommended that the diversion point be moved upriver where it is much more likely that effective screens can be constructed and operated.

## Contra Costa Canal

Although technically part of the CVP, the Contra Costa Canal recently has been maintained and operated by Contra Costa Water District. The unscreened intake is located at Rock Slough, which in turn draws its water from Old River (Figure 5).

Historical pumping into the Contra Costa Canal has ranged from about 50 to 250 cfs and varies seasonally (Figure 21). The trend over recent years has been toward increased diversions.

Figure 21
AVERAGE MONTHLY CONTRA COSTA CANAL PUMPING, WATER YEARS 1978-1990, FROM THE DAYFLOW DATABASE



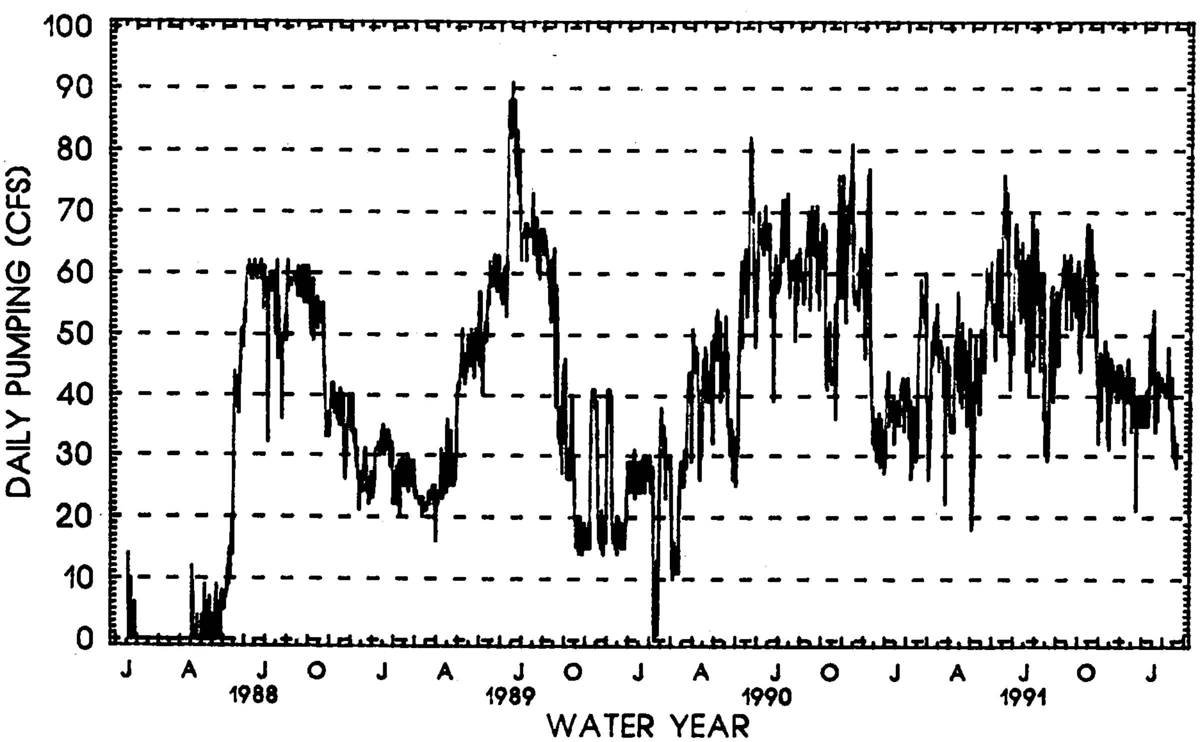
## North Bay Aqueduct

To meet project entitlements in Napa and Solano Counties, in 1987 the State Water began pumping from Barker Slough (Figure 5) through the North Bay Aqueduct. Scheduled annual deliveries were expected to be about 67,000 acre-feet. Maximum pumping capacity is about 160 cfs and has averaged much less than 100 cfs during the past two years. Figure 22 shows the total pumping for the period of record.

In response to fisheries concerns DWR constructed a state-of-the-art positive barrier fish screen at the Barker Slough intake. The screen consists of a series of flat stainless steel wedge wire panels with a slot width of 3/32-inch. The design approach velocity is 0.5 feet per second. This slot width will exclude all salmon from being diverted and the low approach velocity prevents them from being impinged onto the screens. The screens are routinely cleaned to prevent head loss across the screen face which would result in increased approach velocity. Screen design and maintenance were developed in cooperation with DFG and the final design was approved by DFG.

Pre- and post-installation monitoring studies have been conducted by DFG to evaluate impacts on fisheries resources. The results of these studies are discussed in the section on project impacts.

Figure 22
BARKER SLOUGH DAILY PUMPING RATE
(In Cubic Feet per Second)



## South Delta Facilities

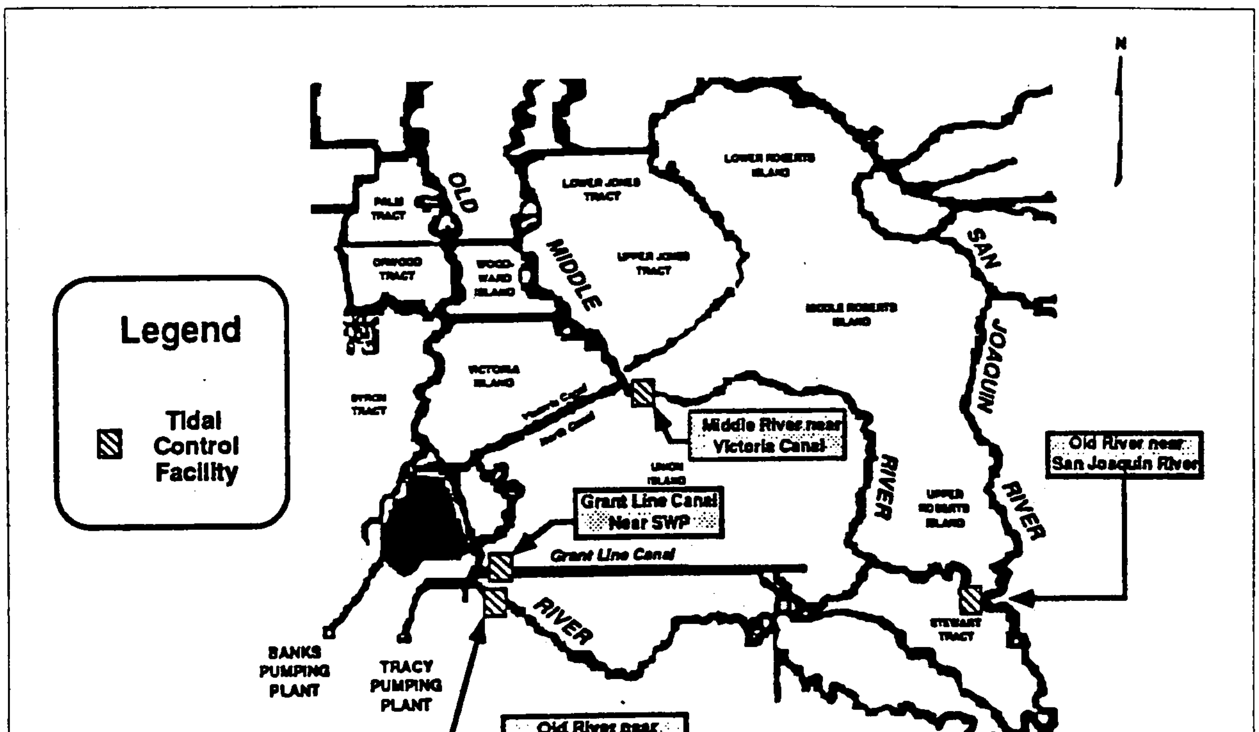
At the request of DFG and NMFS, we have included the South Delta Temporary Barriers Project in this Biological Assessment. Although technically the barriers are not part of existing CVP/SWP facilities, three of the barriers were installed in 1992 and DWR is planning to seek permits for installation during the next three summers. If the barriers prove effective in helping San Joaquin River salmon and enhancing south Delta farmers' ability to manage their water supply, and prove to have no other detrimental impacts, the eventual goal will be to routinely install them during the spring and summer of drier years. Following is a general description of the barriers.

### Head of Old River at San Joaquin River

The Temporary Barriers Project proposes a springtime barrier in the same location as the fall barrier authorized by USCE permit 9706 (Figure 23). The fall barrier has been in place each year since 1968, between September 15 and November 30, and permit 9706 authorizes installation during these months until 1997.

In 1992 the spring barrier was installed on April 23 and removed on June 8. The proposed 1993 installation date is April 1. Design of the spring barrier is similar to that of the fall barrier except that the spring barrier will not be notched and will have boat portage facilities.

Figure 23
LOCATION MAP, SOUTH DELTA FACILITIES



Both the fall barrier and the spring barrier consist of about 1,800 cubic yards of rock and sand, which would be placed across Old River about 0.5 mile west of the confluence with the San Joaquin River. The barrier would be abut 200 feet long and 50 feet at its widest point. Side slopes would be 1.5 vertical to 1 horizontal. Flow of water over the barrier would be prevented completely.

When the period of the barrier placement concluded, all rock would be removed and stockpiled for use the following period. Facilities would be designed so as not to impede floodflows, and installation of these facilities would not compromise the integrity of the channels.

### Old River near Tracy

The proposed temporary tidal control facility is in the same location as a temporary barrier installed for three months during the drought in 1977 and for about a month in 1991 under USCE permit 199100192 (Figure 23). The barrier may be placed as early as April 1 and be in place through September 30 each year during the testing program. The proposed 1993 installation date is April 1.

About 5,700 cubic yards of rock and sand would be placed across Old River near Tracy about 0.5 mile west of the Delta-Mendota Canal intake. The barrier would be about 250 feet long and 100 feet at its widest point. Nine 48-inch pipes each 56 feet long with flapgates would be placed in the barrier to permit unidirectional flow. The crest elevation is +2.0 feet and will allow water to flow over the top of the structure during flood (inward) tides. During ebb (outward) tides, the crest elevation will retain the tidal volume below the +2.0-foot elevation. The invert of the pipes would be at -6.0 feet elevation (NGVD). The structure would allow tidal flows to enter the channel upstream of the barrier and be retained as the tide ebbs so agricultural pumps can divert water with less probability of pump damage. Also, the barrier would circulate flows and dilute return agricultural drainage to improve the quality of local agricultural diversions.

Boat portage facilities would be similar to those for the Old River barrier near the San Joaquin. Six marking buoys would be placed about 70 feet apart, three upstream and three downstream, about 200 feet from the centerline of the barrier. Two signs providing notice to mariners would be placed on top of the barrier.

When the period of barrier placement has concluded, all rock would be removed and stockpiled for use the following period. Facilities would be designed so as not to impede floodflows, and installation of these facilities would not compromise the integrity of the channels.

### Middle River near Victoria Canal

A barrier at this location is authorized by USCE permit 9205 for yearly placement until September 30, 1992. The barrier would be installed April 1 through September 30 for each of the four additional years of the temporary barriers testing program.

As in the past, this rock barrier would be constructed with a removable center section. About 4,800 cubic yards of rock and sand would be placed across Middle River to construct a 270-foot-long berm. The ends of the barrier near the abutments each contain three 48-inch pipes with flapgates. The barrier end and pipes have been and would continue to remain in place throughout the year. The tide gates are tied open during the time the center section is removed. The center 140-foot section, with side slopes of 2 horizontal to 1 vertical, is installed seasonally from April through September 30. Crest elevation of the center section is 2 feet lower than the abutment, allowing some flow of water over the barrier even during times other than high tide. The existing boat portage facility at this site is a gravel ramp that can be used to carry or drag a small boat across the barrier.

## Grant Line Canal near SWP

The Grant Line barrier was not installed in 1992, but may be proposed for installation in 1993 under a new USCE permit. Installation may be as early as June 1 of the testing year, but after the Old River near San Joaquin barrier is removed. The barrier would remain in place until September 30 each year of the testing program. At this time, the Department has not decided to seek installation of the Grant Line Barrier in 1993.

## Operating Schedule

The proposed operating schedule (Figure 24), which will be coordinated with the NMFS, DFG, DWR Division of Flood Management, and DWR Division of Safety of Dams, is presented as a range of dates beginning with the earliest possible installation and ending with the latest possible removal. Actual barrier installation will be determined by water supply, agricultural operations, and fisheries conditions. Grant Line Canal barrier and Old River near San Joaquin River barrier will never be in place at the same time.

Figure 24

POSSIBLE INSTALLATION AND OPERATION SCHEDULES FOR THE SOUTH DELTA TEMPORARY BARRIERS

ALTERNATIVE 1

| ACTIVITIES | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|
| MIDDLE RIVER | XXXXX | XXXXX | XXXXX | XXXXX | XXXXX | XXXXX | | | |
| OLD RIVER AT TRACY | XXXXX | XXXXX | XXXXX | XXXXX | XXXXX | XXXXX | | | |
| OLD RIVER AT HEAD* | XXXXX | XXXXX | XXX | | | XXX | XXXXX | XXXXX | |
| GRANT LINE CANAL* | | | XXXXX | XXXXX | XXXXX | XXX | | | |

ALTERNATIVE 2

| ACTIVITIES | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|
| MIDDLE RIVER | XXXXX | XXXXX | XXXXX | XXXXX | XXXXX | XXXXX | | | |
| OLD RIVER AT TRACY | XXXXX | XXXXX | XXXXX | XXXXX | XXXXX | XXXXX | | | |
| OLD RIVER AT HEAD* | XXXXX | XXXXX | XXX | | | XXX | XXXXX | XXXXX | |
| GRANT LINE CANAL* | | | | | | | | | |

* The time line indicates the possible range of installation times of each of these barriers with the understanding that the Old River at Head barrier and the Grant Line Canal barrier will never be in place at the same time.

## CVP-OCAP

The USBR report long-term Central Valley Project-Operations Criteria and Plan dated October 1992, describes in detail how the various operational scenarios have been developed. Although only CVP is mentioned in the title, the OCAP includes DWR facilities, and DWR staff was involved in developing OCAP. For additional information on OCAP and how the information was developed, the interested reader is referred to the USBR document.

Only a small portion of the information in CVP-OCAP is needed to evaluate Delta impacts using the salmon smolt model (the model is described later in this assessment). The extracted data are tabulated in Table 9 for the 40 operational scenarios to be evaluated. Following is a brief explanation of the tabulated values.

- The operational scenario designation corresponds to CVP-OCAP. The first letter represents water-year type (Wet, Above Normal, Dry, Critical, Extreme Critical). The next two letters represent starting storage (High, High Middle, Low Middle, and Low). The number represents percent of project deliveries in 25 percent increments from 0 to 100 percent. The last three or four letters represent three levels of operations:

  PRE - Pre-1992 operations. See CVP/OCAP for assumptions.

  TEM - Five scenarios designed to decrease upriver temperature mortality.

  ALTB - Alternative B from Table 10, which NMFS presented at the SWRCB's recent hearings on interim standards for the Sacramento-San Joaquin Delta.

- Temperature is average monthly temperature at Freeport during the 1980-1990 period.
- Antioch flows are a value calculated from inflows, pumping, and internal Delta demand. Although Antioch flow does not enter into the smolt survival model, it is of concern in any analysis of Delta impacts.

Table 9

DATA RELATED TO DELTA OPERATIONS EXTRACTED FROM LONG-TERM CVP-OCAP

| Operational Scenario | Freeport Flow cfs Feb. | Freeport Flow cfs Mar. | Freeport Flow cfs Apr. | CVP/SWP Pumping cfs Feb. | CVP/SWP Pumping cfs Mar. | CVP/SWP Pumping cfs Apr. | X-Channel Gate Open, Closed Feb. | X-Channel Gate Open, Closed Mar. | X-Channel Gate Open, Closed Apr. | Average Monthly Water Temp. °F, Freeport 1/ Feb. | Average Monthly Water Temp. °F, Freeport 1/ Mar. | Average Monthly Water Temp. °F, Freeport 1/ Apr. | Antioch Flow cfs Feb. | Antioch Flow cfs Mar. | Antioch Flow cfs Apr. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| W HI 100 PRE | 76,716 | 53,652 | 36,566 | 11,289 | 9,043 | 9,713 | closed | closed | closed | 50.7 | 54.5 | 59.9 | 4,337 | 3,398 | 701 |
| W HM 100 PRE | 75,206 | 52,676 | 35,558 | 11,289 | 11,303 | 9,898 | closed | closed | closed | 50.7 | 54.5 | 59.9 | 4,180 | 1,488 | 448 |
| W LM 75 PRE | 70,699 | 52,676 | 35,306 | 9,237 | 10,734 | 10,873 | closed | closed | closed | 50.7 | 54.5 | 59.9 | 5,353 | 1,944 | -358 |
| W LO 50 PRE | 61,843 | 52,090 | 35,306 | 9,363 | 10,734 | 10,873 | closed | closed | closed | 50.7 | 54.5 | 59.9 | 4,332 | 1,883 | -358 |
| A HI 100 PRE | 40,525 | 42,365 | 23,206 | 11,289 | 10,929 | 10,873 | closed | closed | closed | 50.7 | 54.5 | 59.9 | -1,804 | 1,753 | -3,095 |
| A HM 100 PRE | 28,474 | 40,723 | 23,206 | 11,289 | 10,669 | 10,873 | closed | closed | closed | 50.7 | 54.5 | 59.9 | -3,057 | -1,716 | -3,095 |
| A LM 75 PRE | 27,079 | 32,781 | 19,211 | 9,237 | 10,360 | 10,873 | closed | closed | open | 50.7 | 54.5 | 59.9 | -1,561 | -2,290 | -31 |
| A LO 50 PRE | 27,079 | 32,740 | 18,852 | 11,289 | 10,750 | 10,672 | closed | closed | open | 50.7 | 54.5 | 59.9 | -3,202 | -2,615 | 44 |
| D HI 100 PRE | 20,893 | 19,753 | 18,163 | 11,253 | 10,799 | 10,672 | closed | open | open | 50.7 | 54.5 | 59.9 | -4,313 | -1,039 | -995 |
| W HI 100 ALTB | 76,716 | 53,652 | 36,566 | 11,289 | 10,994 | 9,512 | closed | closed | closed | 50.7 | 54.5 | 59.9 | 4,337 | 1,837 | 864 |
| W HM 100 ALTB | 75,206 | 52,676 | 35,558 | 11,289 | 10,994 | 10,453 | closed | closed | closed | 50.7 | 54.5 | 59.9 | 4,180 | 1,735 | 5 |
| W LM 75 ALTB | 70,695 | 52,676 | 35,306 | 9,237 | 10,425 | 10,419 | closed | closed | closed | 50.7 | 54.5 | 59.9 | 5,351 | 2,195 | 5 |
| W LO 50 ALTB | 60,844 | 52,090 | 35,306 | 8,768 | 10,425 | 10,420 | closed | closed | closed | 50.7 | 54.5 | 59.9 | 4,702 | 2,134 | 5 |
| A HI 100 ALTB | 41,371 | 42,999 | 23,772 | 9,129 | 8,815 | 7,058 | closed | closed | closed | 50.7 | 54.5 | 59.9 | 13 | 0 | 16 |
| A HM 100 ALTB | 28,349 | 40,834 | 24,383 | 7,418 | 8,522 | 7,126 | closed | closed | closed | 50.7 | 54.5 | 59.9 | 27 | 9 | 25 |
| A LM 75 ALTB | 26,653 | 33,415 | 18,917 | 7,202 | 7,546 | 6,420 | closed | closed | closed | 50.7 | 54.5 | 59.9 | 24 | 19 | 22 |
| A LO 50 ALTB | 26,829 | 33,330 | 19,417 | 7,256 | 7,563 | 6,486 | closed | closed | closed | 50.7 | 54.5 | 59.9 | 4 | 0 | 20 |
| D HI 100 ALTB | 20,893 | 18,102 | 11,928 | 5,834 | 4,846 | 4,436 | closed | closed | closed | 50.7 | 54.5 | 59.9 | 15 | 0 | 7 |
| D HM 100 ALTB | 20,039 | 16,876 | 11,923 | 5,726 | 4,684 | 4,437 | closed | closed | closed | 50.7 | 54.5 | 59.9 | 13 | 3 | 11 |
| D LM 75 ALTB | 19,339 | 15,924 | 11,928 | 5,618 | 4,554 | 4,436 | closed | closed | closed | 50.7 | 54.5 | 59.9 | 26 | 8 | 7 |
| D LO 50 ALTB | 19,339 | 15,924 | 11,915 | 5,654 | 4,603 | 4,470 | closed | closed | closed | 50.7 | 54.5 | 59.9 | 0 | 0 | 17 |
| C HI 100 ALTB | 10,948 | 13,794 | 8,382 | 3,818 | 4,196 | 3,983 | closed | closed | closed | 50.7 | 54.5 | 59.9 | 18 | 7 | 2 |
| C HM 100 ALTB | 10,948 | 13,794 | 8,381 | 3,818 | 4,228 | 4,034 | closed | closed | closed | 50.7 | 54.5 | 59.9 | 18 | 8 | 3 |
| C LM 75 ALTB | 10,948 | 14,037 | 8,371 | 3,818 | 4,228 | 4,016 | closed | closed | closed | 50.7 | 54.5 | 59.9 | 18 | 33 | 10 |
| D HM 100 PRE | 20,039 | 16,374 | 18,365 | 11,253 | 10,799 | 10,873 | closed | open | open | 50.7 | 54.5 | 59.9 | -4,402 | -1,850 | -1,108 |
| D LM 75 PRE | 20,039 | 16,374 | 13,222 | 11,253 | 10,717 | 5,731 | closed | open | open | 50.7 | 54.5 | 59.9 | -4,402 | -1,778 | 1,772 |
| D LO 50 PRE | 19,789 | 16,124 | 12,236 | 9,849 | 9,059 | 4,790 | closed | open | open | 50.7 | 54.5 | 59.9 | -3,305 | -491 | 2,325 |
| C HI 100 PRE | 13,006 | 13,994 | 11,155 | 11,001 | 10,620 | 6,755 | open | open | open | 50.7 | 54.5 | 59.9 | -2,882 | -2,341 | 456 |
| C HM 100 PRE | 13,006 | 13,994 | 9,962 | 11,001 | 10,783 | 5,563 | open | open | open | 50.7 | 54.5 | 59.9 | -2,882 | -2,476 | 1,124 |
| C LM 75 PRE | 12,073 | 13,544 | 7,774 | 10,065 | 10,392 | 3,429 | open | open | open | 50.7 | 54.5 | 59.9 | -2,360 | -2,243 | 2,349 |
| C LO 50 PRE | 11,659 | 13,763 | 6,800 | 9,651 | 9,173 | 2,454 | open | open | open | 50.7 | 54.5 | 59.9 | -2,128 | -1,217 | 2,895 |
| E HI 100 PRE | 8,490 | 6,102 | 7,215 | 5,600 | 2,634 | 2,353 | open | open | open | 50.7 | 54.5 | 59.9 | - 353 | 1,658 | 2,663 |
| E HM 100 PRE | 6,390 | 6,086 | 6,345 | 3,493 | 2,618 | 1,479 | open | open | open | 50.7 | 54.5 | 59.9 | 822 | 1,667 | 3,150 |
| D LO 50 TEM | 19,789 | 16,124 | 10,858 | 9,849 | 8,685 | 3,411 | closed | open | open | 50.7 | 54.5 | 59.9 | -3,305 | -190 | 3,096 |
| C HM 100 TEM | 13,685 | 13,994 | 8,438 | 11,001 | 10,783 | 4,083 | open | open | open | 50.7 | 54.5 | 59.9 | -2,719 | -2,450 | 1,978 |
| C LM 75 TEM | 12,073 | 14,130 | 6,791 | 10,065 | 10,783 | 2,437 | open | open | open | 50.7 | 54.5 | 59.9 | -2,354 | -2,417 | 2,900 |
| C LO 50 TEM | 12,073 | 13,763 | 5,262 | 9,291 | 9,270 | 907 | open | open | open | 50.7 | 54.5 | 59.9 | -1,735 | -1,295 | 3,756 |
| E HI 100 TEM | 7,996 | 5,336 | 6,539 | 5,096 | 1,870 | 1,680 | open | open | open | 50.7 | 54.5 | 59.9 | -77 | 2,087 | 3,041 |
| C LO 50 ALTB | 10,948 | 14,037 | 6,421 | 3,818 | 4,228 | 2,067 | closed | closed | closed | 50.7 | 54.5 | 59.9 | 18 | 33 | 1,367 |
| E HI 100 ALTB | 6,388 | 6,035 | 5,857 | 2,340 | 2,569 | 992 | closed | closed | closed | 50.7 | 54.5 | 59.9 | 5 | 8 | 1,760 |
| E HM 100 ALTB | 6,374 | 6,035 | 5,470 | 2,340 | 2,569 | 605 | closed | closed | closed | 50.7 | 54.5 | 59.9 | 3 | 8 | 2,029 |

1/ Water Temperature is average monthly value for the 1980-1990 period at Freeport.

Table 10
PROTECTIVE ALTERNATIVES FOR JUVENILE WINTER-RUN CHINOOK SALMON

| Alternative | Close Delta Cross Channel | Close Georgiana Slough | Maximum Total Daily CVP/SWP Exports |
|---|---|---|---|
| A | 2/1 through 4/30 | Open | 2/1 through 3/31 Vernalis Q<br>4/1 through 4/30 75% Vernalis Q plus<br>10% DOF when DOF ≥ 50,000 cfs |
| B | 2/1 through 4/30 | Open | San Joaquin River, Jersey Point, Q<br>0 to +1,000 cfs 2/1 through 4/30 |
| C | 2/1 through 4/30 | Open | 3,000 cfs 2/1 through 4/30 |
| D | 2/1 through 4/30 | 2/1 through 4/30 | 2/1 through 3/31 Vernalis Q<br>4/1 through 4/30 75% Vernalis Q plus<br>10% DOF ≥ 50,000 cfs |
| E | 2/1 through 4/30 | 2/1 through 4/30 | D-1485 Salinity |
| F | 11/1 through 4/30 | 2/1 through 4/30 | D-1485 Salinity |
| G | 1/1 through 4/30 | 3/1 through 4/30 | 3,000 cfs 2/1 through 2/29 |
| H | 2/1 through 4/30 | 2/1 through 4/30 | San Joaquin River, Jersey Point, Q<br>0 to -2,000 cfs 2/1 through 4/30 |

# ANALYSIS OF CENTRAL VALLEY AND STATE WATER PROJECT IMPACTS IN THE DELTA

The approach used in this section is to provide a qualitative view of salmon migration through the Delta, examine the means of separating winter-run Chinook salmon from other races, develop information on the timing of migration through the Delta to the ocean, and analyze to the extent possible, the impacts of specific project features described previously.

The discussion and analyses focus on juvenile outmigrants. Although there is almost no information on upstream migrating adults, when possible the impacts on this life stage are addressed.

## Juvenile Salmon Movement Through the Delta

Before analyzing the impacts of Delta CVP/SWP operation it may prove worthwhile to provide a general, qualitative description of how a juvenile Chinook coming down the Sacramento River may move through the Delta. The description also includes brief discussions of causes of mortality during this movement. It must be pointed out that much of this description is informed speculation. There is not a great deal of published literature on the subject.

Most of the following description applies to smolts, a life stage in which the juvenile salmon have undergone physical and physiological changes in preparation for their journey to the ocean. In this stage we assume that the young Chinook are actively migrating — not passively moving with the flow.

In the free-flowing river downstream migrants undoubtedly use flow as a guidance mechanism and as a means of conserving energy. In fast water areas they typically move downstream tail first, probably because they are able to better control their direction and velocity. Although accurate estimates of migration speed in the mainstem are not available, catches in the Delta of salmon released in the upper river from Coleman National Fish Hatchery indicate that they may be moving at a slightly slower rate than the average water velocity.

When Chinook reach the lower river and estuary, where tidal influence often dominates, they must begin to use a different cue than flow to guide them toward the ocean. Interagency salmon study data have shown that fall-run smolts move through the estuary in a relatively short period (a few days) and the time required is independent of flow. (They do move through the upper estuary at a slower rate than they do in the river.) This finding is not surprising in that during low-flow periods and weak tides, the net downstream rate of movement of a theoretical particle suspended in the water is quite slow. For example, calculated outflows may be on the order of a few thousand cfs while tidal flows may be on the order of 100,000 to 200,000 cfs. Of course when the salmon reach the lower bay there is essentially no freshwater flow (at least velocity) signal which can be used for guidance.

In any event the salmon smolt reaches the Delta and must find its way to the ocean. Although the information is not as solid as one would like, the general distribution pattern of these fish in the river may be:

- They are in the upper part of the water column, at least during the daylight.
- They tend to move closer to the sides than to the middle.
- Although it is generally assumed that fish go with the flow (*ie* if 50 percent of water is diverted off the river, 50 percent of the fish go as well) USFWS (1990) presented limited evidence that the proportion of salmon going into the Cross Channel and Sutter Slough is less than the proportion of water.

As in the upper river, a Chinook salmon passing through the Delta is exposed to several factors that may reduce its chances of reaching the ocean alive. The following are brief descriptions of these factors and how they may impact survival.

## Toxicity

Although there are several potential toxicants in Delta waters, including pesticides, residual chlorine from waste treatment, and trace elements, there is little indication that toxicity is a significant factor influencing survival in this area.

## Temperature

Temperature changes can affect Chinook salmon survival in several ways — both direct and indirect. These are:

- Directly Lethal — Depending on previous temperature history (acclimation), temperatures in the upper 70s ($^{0}$F) can kill salmon juveniles. This is probably not a problem for Chinook salmon entering the Delta from the Sacramento River and is almost certainly not a concern for winter-run salmon which pass through in the colder months.
- Indirectly Lethal — Indirect impacts can occur because higher temperatures cause increased metabolic rates and resultant greater need for food. Higher temperatures also make juvenile Chinook more vulnerable to disease. Both indirect impacts can decrease the salmon's scope for activity and make it more vulnerable to factors listed below. Indirect temperature impacts in the Delta are not well quantified, but are probably significant, especially when the exposure time (transit time through the Delta) is increased. Again the winter-run migration period minimizes indirect temperature impacts.

## Predation

In the Delta, Chinook juveniles are exposed to such predators as striped bass and Sacramento squawfish. Presumably, losses to predators are affected by water temperature, turbidity, exposure time, and salmon size. In general, conditions during the winter-run outmigration (*ie* cold water and Other high turbidity) should result in lower losses to predators than for fall-run smolts which emigrate later in the year.

## Losses to Local Agricultural Diversions

Brown (1983) in an unpublished examination of the possible impacts of local Delta agriculture diversions on striped bass and Chinook salmon, found that there were about 1,800 small diversions in the Delta. The average size of intakes to these pumps and siphons was 10-12 inches with average flows in the low cfs range.

At the time of this review (and it hasn't changed much since) there was only one unpublished USFWS/DFG study which provided any useful information on losses of juvenile Chinook salmon to these diversions. Based on those data it did not appear that the small diversions caused significant losses of smolt-size salmon. More information is needed for a wider variety of diversion sizes. The Interagency Program initiated a pilot study in 1992 but encountered problems in obtaining access to these private diversions.

High temperatures, which may lessen the salmon's ability to avoid the intake, and greater transit time increase exposure and perhaps losses to agricultural diversions.

## Diversion Off the Sacramento River

A smolt staying in the Sacramento River has the most direct route to the ocean and in theory, the shortest residence time. All things being equal, the shorter the residence time the less likely the smolt is to die on the way.

All downstream migrants do not remain in the mainstem. At several locations there are channels off the river which result in water, and fish, leaving the mainstem. There is also the chance that even those fish remaining in the Sacramento River can be drawn around the tip of Sherman Island and drawn up the San Joaquin River by reverse flows. The Delta Cross Channel, Steamboat and Sutter Sloughs, Georgiana Slough, Threemile Slough, Montezuma Slough, and the lower San Joaquin River are described below.

Delta Cross Channel. Fish diverted off the Sacramento River by way of the Cross Channel wind up in the North or South Fork of the Mokelumne River and thence to the San Joaquin River. Those that reach the San Joaquin River can either go toward the State and federal pumps (by way of Old River or other routes) or down the San Joaquin River toward the ocean. At times the San Joaquin may have a net flow toward the pumps (reverse flow) but there are tidal flows which are 20 to 100 times stronger than the net flows. It is not clear how Chinook juveniles react to this situation.

Experiments with marked fall-run juveniles show that some fish reaching the San Joaquin River do move toward the pumps. These fish probably encounter the State intake first and, when the radial gates are operating, can be drawn into Clifton Court Forebay. Some of those salmon entering the forebay are eaten by predators, some are lost through the screens, and the remainder are salvaged. The salvaged fish are transported back to the Sacramento for release.

A significantly smaller number of Chinook salmon in Old River may proceed on toward the federal pumps. There is no forebay before the intake to the federal pumps; however, there are losses to predators in the intake channel and in the screen bays themselves. Salvaged salmon are hauled by truck to the Sacramento River.

Upon reaching the San Joaquin River from the Mokelumne River system, an unknown, but probably significant, fraction of the Chinook salmon going through the Cross Channel move directly downstream toward Antioch and the ocean. Experimental results in this area have not been as definitive as desired, however on some occasions marked salmon planted in the lower river apparently migrated toward Chipps Island and had good survival, even with flow reversals.

Georgiana Slough. Since Georgiana Slough is not gated and at low Sacramento River flows diverts 2,000 to 3,00 cfs, some Chinook salmon are diverted as well. As shown in Figure 5, those salmon entering Georgiana can reach the ocean by way of the Mokelumne and San Joaquin Rivers. Experiments in 1992 indicated poor survival to Chipps of fall-run hatchery fish planted in Georgiana Slough. These experiments were conducted when flows in the lower San Joaquin River were positive. These salmon going down Georgiana, as those entering the Cross Channel have a longer pathway to the ocean and probably incur greater mortality than salmon remaining in the mainstem.

Sutter and Steamboat Sloughs. Limited experimental information has indicated that salmon entering Steamboat and Sutter Sloughs have a better chance of reaching Chipps Island than those remaining in the river. As shown in Figure 5, this makes some sense in that the migration path via the slough is shorter and the downstream migrants are not subject to being diverted into the Delta Cross Channel or Georgiana Slough.

Threemile Slough. Although there is significant exchange of water between the Sacramento and San Joaquin Rivers through Threemile Slough, there are no data available to determine how this exchange affects downstream migrants.

Tip of Sherman Island. A downstream migrant from the Sacramento River system that has reached the tip of Sherman Island will probably continue its way to the lower bays and ocean. The importance of flow as a guidance cue has greatly diminished and it is unlikely that the juveniles will move up the San Joaquin River, even when flows are negative. This conclusion is supported by the lack of tag recoveries at the State and federal facilities from groups of fall-run hatchery salmon released in the Sacramento River below the Delta Cross Channel near Ryde.

Montezuma Slough. Fish entering Montezuma Slough encounter the salinity control gates and supporting structures. During dry years the stop-logs are in place, and the gates act as tidal pumps and are operated to meet internal Marsh salinity standards. There are likely to be predatory fish near the structures, and some salmon are eaten. As described earlier, there are several unscreened diversions in the Marsh which can cause fish losses.

This qualitative description can be summarized by the following main points.

- Not a lot is known about the mechanisms causing salmon losses in the Delta. Studies to date have not been designed to determine cause and effect or mechanistic models but mainly to develop empirical statistical models.
- Temperature apparently plays important direct and indirect roles in salmon survival.
- Longer migration pathways should result in increased mortality. Migration pathways are lengthened when salmon are diverted into the Delta Cross Channel and Georgiana Slough.
- Causes of mortality are unknown but are probably due to predation and direct losses to diversions.
- Winter-run mortality through the Delta must be lower than that experienced by fall run in most years, if only because temperatures during their outmigration are up to 20°F cooler than those present when fall-run smolts emigrate.

## Identification of Winter-Run Salmon

There are no distinguishing physical features that allow a winter-run outmigrant to be separated from juvenile of the other three races inhabiting the Sacramento-San Joaquin Basin. Also, at this time there is no biological marker (scale pattern, otoliths, blood chemistry, etc.) that can readily provide that separation. We are left with timing of the emigration and size as candidate attributes to help resolve this problem.

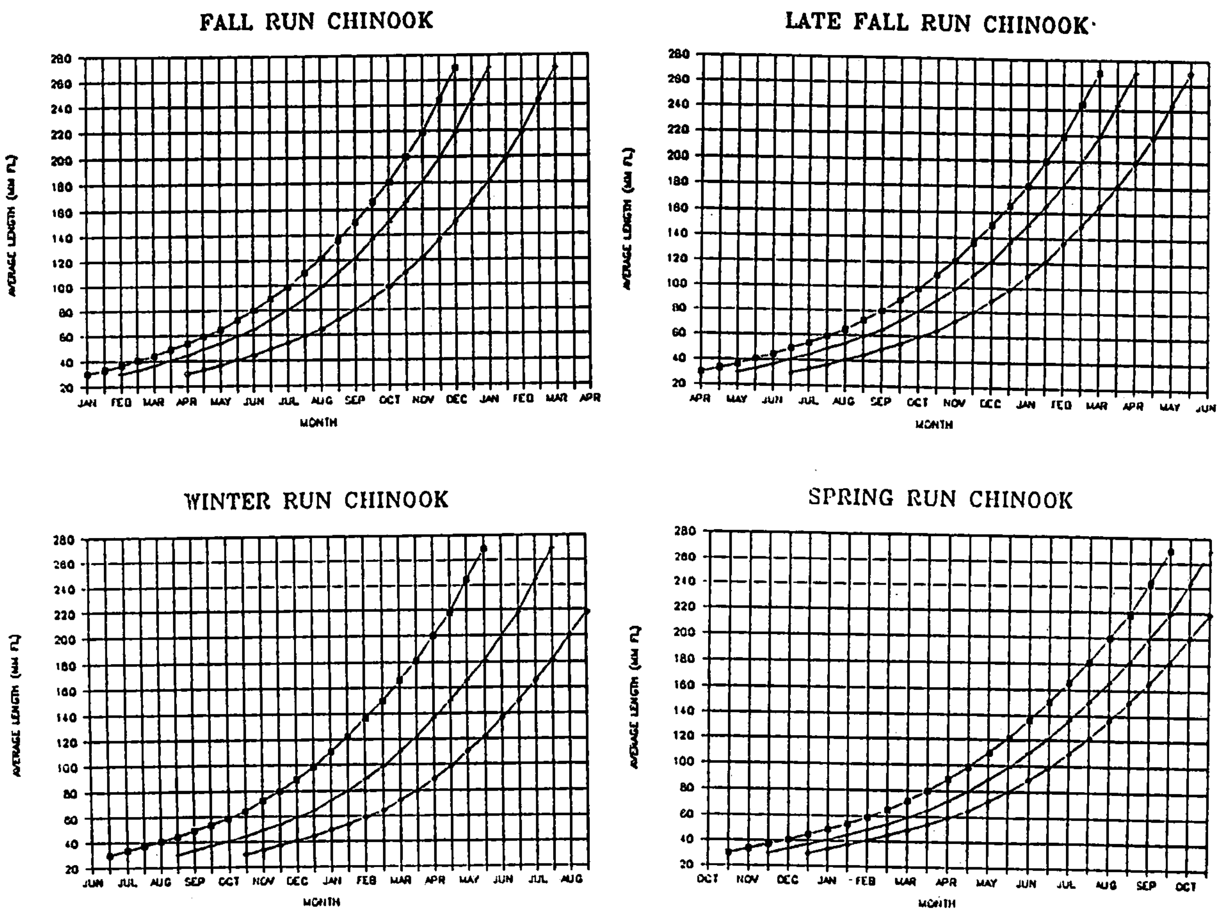
Frank Fisher (DFG, Red Bluff) has used estimated timing of winter-run spawning and emergence as well as hatchery fall-run growth rates to develop hypothetical growth curves for the four races of Chinook salmon in the upper Sacramento River (Figure 25). The original curves were limited to fish less than 130 mm.

In June 1989 Don Stevens (DFG, Stockton) used these curves to help answer the questions relating to the timing of winter-run migration through the Delta (DFG memo to Pete Chadwick dated June 19, 1989). Stevens also extrapolated the curves to expand the period of coverage. He found the curves useful in his analyses, but cautioned that the size ranges are <u>estimates</u> *(emphasis his)* only.

Frank Fisher has revised his curves several times as more data on growth of fall-run Chinook salmon became available. For purposes of these analyses of losses at the pumps, the daily growth increments were used. This modification makes use of the daily data and avoids problems with overlaps between races. (That is, each Chinook salmon fits into only one race.)

The Fisher-size classification system is used to sort salmon captured in the Delta by race. An assessment of its usefulness is made at the end of this chapter.

Figure 25
ESTIMATED GROWTH CURVES FOR THE FOUR RACES OF SACRAMENTO RIVER CHINOOK SALMON
Curves Represent Early, Middle, and Late Spawners
(Developed by Frank Fisher, DFG, Red Bluff)




## Timing of Winter-Run Chinook Salmon Migration Through the Delta

One of the key factors needed in determining the water projects' Delta impacts is an understanding of period in which juvenile winter-run salmon are in the Delta and exposed to project operations. However, there is only general knowledge of the timing of the winter-run outmigration, especially after the migrants pass Glenn-Colusa Irrigation District. This lack of understanding is mostly due to:

- Lack of emphasis by fish and wildlife agencies on developing a comprehensive data base which can be used to describe biology of the four races of Chinook salmon in the Sacramento and San Joaquin systems.
- Focus of most studies on fall-run Chinook salmon. For example, USFWS, as part of the Interagency Ecological Studies Program, has documented the problems associated with passage of Sacramento River and San Joaquin River fall-run smolts through the Delta.
- Overlap in timing and size of outmigrants from the four races.
- Confusing effects of hatchery releases including failure of hatchery managers to consistently mark large numbers of released fish and the lack of analysis on those fish that are marked and recaptured at various locations.
- The small number of winter-, fall-, and spring-run spawners in recent years which has produced relatively few outmigrants.

For this analysis, several data bases were examined to determine if they could shed light on the timing issue. Included in these data bases are:

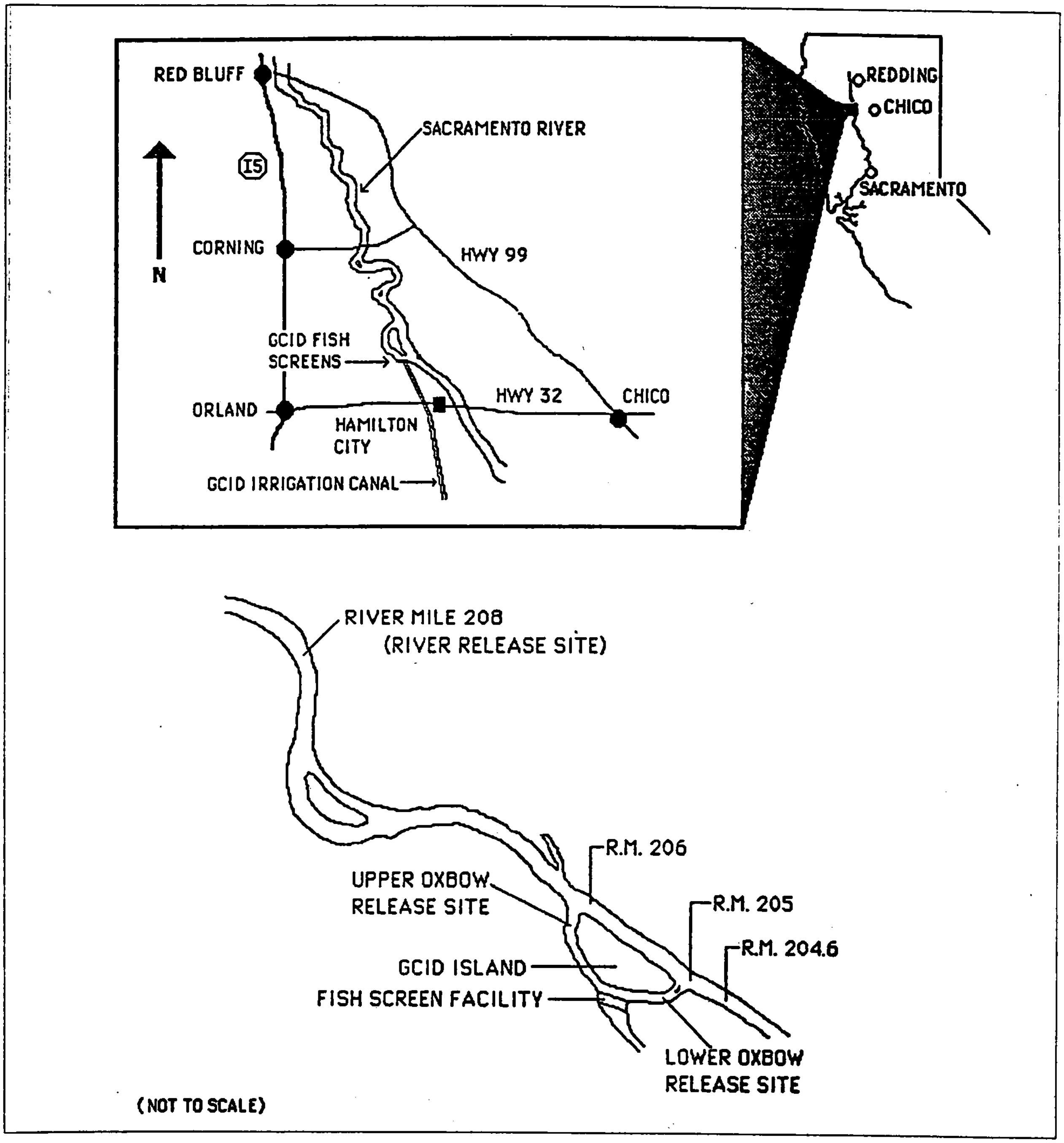
- Historical information from Messersmith (1966) and Schaffter (1980).
- Catches at Glenn-Colusa Irrigation District's fish screens.
- USFWS beach seine data.
- Interagency (USFWS) trawling data - Chipps Island.
- Interagency (DFG) trawling data - Golden Gate.
- CVP and SWP salvage data.
- Interagency evaluation of Roaring River fish screens installed by DWR and USBR as part of the Suisun Marsh Plan of Protection.
- USFWS trawling data from Montezuma Slough.
- The 1992 USFWS trawl and beach seine data set. This is a special case in that it is probably the most comprehensive for any of the period of record.

The following sections briefly describe the studies from which these data were obtained (and references for more descriptions) and the results.

## Glenn-Colusa Irrigation District

Although winter-run fry have been collected extensively at Red Bluff Diversion Dam, Glenn-Colusa was selected because it is the farthest downstream location where they are effectively sampled. A complete description of the intake, fish screens and sampling program is found in Cramer (1990). In summary, the intake is in a small bypass off the Sacramento River (Figure 26). A horizontal rotary-drum fish screen was installed by DFG in 1972 to minimize fish losses to the canal. Bay 23 of this screen contains a fish

Figure 26
LOCATION AND SITE MAP FOR GLENN-COLUSA IRRIGATION DISTRICT INTAKE




trap operated by DFG. In 1990 the district contracted with a private consultant to sample the bypass downstream of the screens using a rotary-screw trap. District staff continues to operate the screw trap and, with help from DFG, identifies, enumerates, and measures the catch.

Table 11 contains a summary of the weekly catches by the GCID trap for 1990 along with DFG's winter-run length intervals. As is apparent from the data, winter-run salmon were captured as early as July and as late as the end of December. (It is likely that migration past GCID occurs after December 31, but there are no data from these studies to verify this.) September and October had the highest catches of the months sampled.

Table 11
WEEKLY TOTAL CATCHES OF JUVENILE WINTER-RUN CHINOOK SALMON IN THE GCID OXBOW, 1988-1990

| End of Week | DFG Trap 1988 | DFG Trap 1989 | DFG Trap 1990 | GCID Trap 1990 | 1990 Pump Q |
|---|---|---|---|---|---|
| 08 JUL | 0 | 0 | 0 | 0 | 2312 |
| 15 JUL | 0 | 0 | 0 | 0 | 2358 |
| 22 JUL | 4 | 0 | 0 | 0 | 2360 |
| 29 JUL | 9 | 0 | 0 | 0 | 2367 |
| 05 AUG | 10 | 2 | 0 | 0 | 2313 |
| 12 AUG | 37 | 3 | 0 | 1 | 2352 |
| 19 AUG | 97 | 2 | 5 | 2 | 2274 |
| 26 AUG | 66 | 2 | 47 | 15 | 2106 |
| 02 SEP | 12 | 6 | 34 | 24 | 1783 |
| 09 SEP | 16 | 22 | 13 | 24 | 1414 |
| 16 SEP | 15 | 13 | 37 | 84 | 973 |
| 23 SEP | 3 | 137 | 24 | 120 | 782 |
| 30 SEP | 1 | 13 | 9 | 87 | 742 |
| 07 OCT | 2 | 19 | 0 | 17 | 700 |
| 14 OCT | 2 | 1 | 2 | 9 | 643 |
| 21 OCT | 1 | 2 | 2 | 11 | 675 |
| 28 OCT | 0 | 105 | 0 | 13 | 800 |
| 04 NOV | 0 | 21 | 1 | 7 | 778 |
| 11 NOV | 0 | 4 | 0 | 27 | 750 |
| 18 NOV | 0 | 0 | 0 | 5 | 350 |
| 25 NOV | 0 | 2 | 0 | 7 | 0 |
| 02 DEC | | 0 | 0 | 2 | 0 |
| 09 DEC | | | 0 | 0 | 0 |
| 16 DEC | | | 0 | 1 | 0 |
| 23 DEC | | | 5 | 4 | 0 |
| 31 DEC | | | 14 | 58 | 0 |
| TOTAL | 275 | 354 | 193 | 519 | |

The catch and lengths of the fish captured by the GCID trap are shown in Figure 27. From these limited data it appears that maximum size is asymptotic at about 90 mm, perhaps due to decreased growth rate as water temperature decreases or because smolting salmon generally move out at about the same general size. For comparison, the actual size range of the fish caught in the GCID trap are compared to the predicted size range using the DFG size intervals (Table 12).

Although the general trends between predicted and actual sizes are similar, there are significant differences, especially with the much narrower length intervals of the wild fish in November and December as compared to the predicted sizes. The information presented cannot be used to estimate growth in that the GCID traps are presumably capturing fish that are mixtures of active migrants and perhaps semiresident salmon that are using the shallows as nursery areas.

The information indicates that some winter run apparently began their downstream movement in the early fall and that the predicted size interval may be considerably wider than the actual interval. If the predicted vs. actual relationship remained the same in the Delta, use of the classification system could tend to overestimate the numbers of winter-run Chinook.

Figure 27

SIZE OF JUVENILE WINTER-RUN CHINOOK SALMON MIGRATING THROUGH THE GCID OXBOW DURING 1990

(Cramer, personal communication)

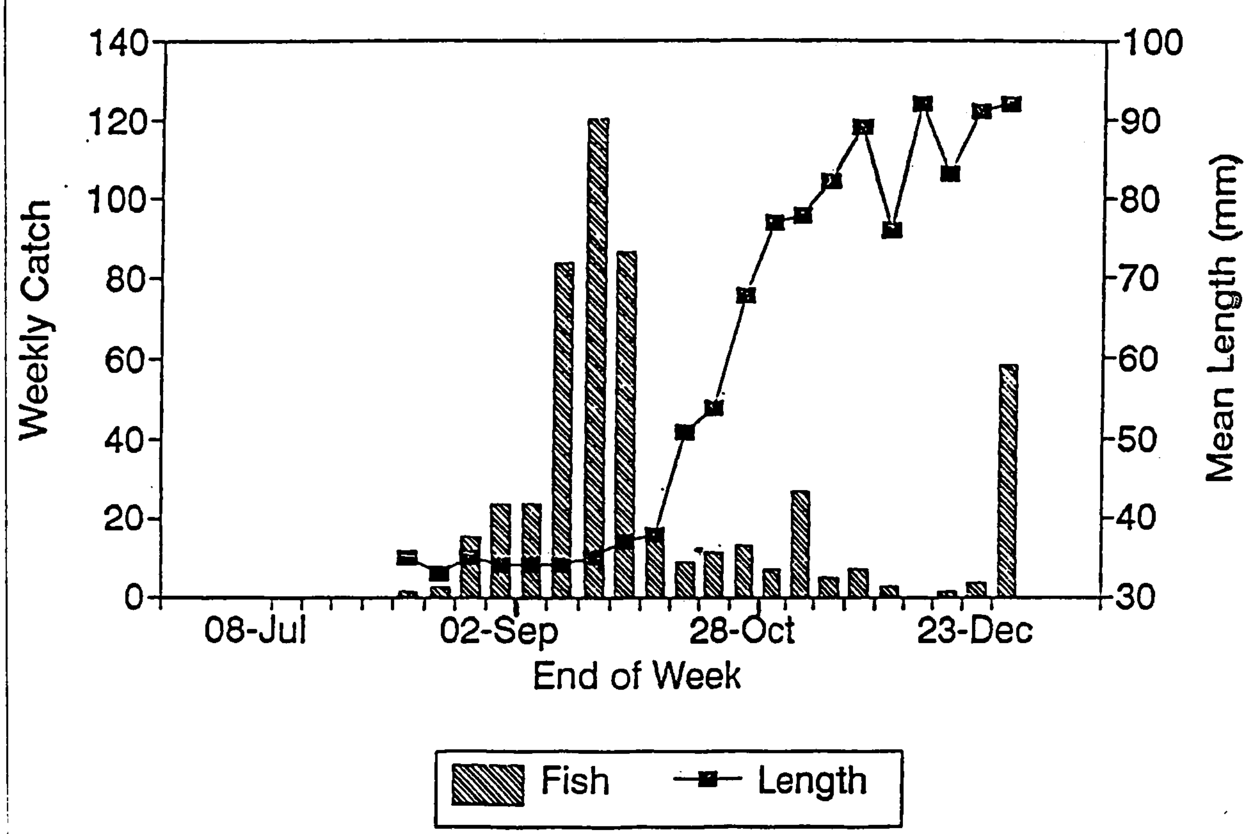



Table 12

SIZES OF 1990 WINTER-RUN CHINOOK SALMON CAPTURED AT GCID'S TRAP COMPARED TO INTERVALS PREDICTED FROM DFG'S GROWTH CURVES

| Month | Actual GCID Data (mm) | Predicted DFG Winter-Run Size Interval (mm) |
|---|---|---|
| August | 30-40 | 30-54 |
| September | 30-40 | 30-65 |
| October | 35-70 | 35-80 |
| November | 70-80 | 34-99 |
| December | 80-90 | 41-122 |

## Sacramento/Chipps Island Trawling

As part of the Interagency Ecological Studies Program, USFWS has been trawling for juvenile salmon at Chipps Island since 1978 and, in recent years, has trawled at Courtland near Sacramento as well. These efforts have been designed to provide an annual index of smolt abundance as well as provide for recapture of marked fish released as part of studies to estimate salmon survival through the Delta.

The sampling procedures have been described in annual USFWS progress reports such as Kjelson and Brandes (1987). Standard 20-minute daylight trawls were made, generally during April through June, using a 9.1 X 7.9 meter midwater trawl (3.2 mm cod-end mesh). Trawling was from two to seven days per week depending on weather, staff availability, and catch. Abundance in other months was estimated occasionally, including a special 1990 program near Hood that was specifically designed to evaluate the timing of winter-run downstream migration.

Data from these surveys were obtained from the DFG's Rancho Cordova data specialists and reformatted for use on a microcomputer. DFG criteria were used to classify captured fish as winter run salmon. Chipps Island trawl and other USFWS trawl and beach seine (described later) data were received electronically from USFWS through the DFG data unit. Files were in the form of both ASCII and SAS. The data were in various stages of editing, therefore for the purpose of the winter-run report data analysis, the data were assumed not to have been edited and the data were loaded into a personal computer database manager for editing. The data were queried for unreasonable or missing date, time, total catch, length, length frequency and media code. The sum of the length frequencies for each trawl date, time and media code were computed and compared to the total catch value. There were many occurrences of length frequencies entered as total catch. These entry errors were verified. We assumed that the electronic data were accurate representations of data from the field sheets. This assumption should be checked by USFWS.

The data are summarized in Table 13. These efforts have been designed to provide an annual index of fall-run smolt abundance as well as evaluating fall-run survival through the Delta by recapturing marked fish released at various Delta sites.

Using these data and the DFG winter-run criteria, it would appear that significant numbers of winter-run salmon pass through the Delta in April and that May and June are not important migration periods. However, these data probably overestimate the numbers of winter-run outmigrants during April, May and June. This conclusion is based on the following:

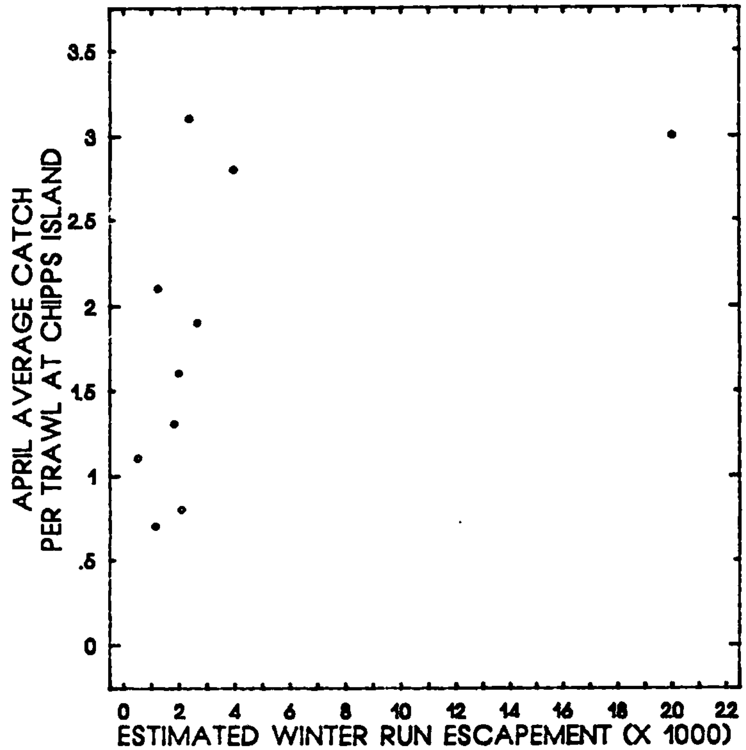
- The estimated catch of winter-run salmon in April does not appear to show any relationship with estimated spawning escapement (Figure 28). With winter-run escapement declining to low numbers in the 1980s, one would expect a similar decline in juvenile catch per unit effort. This undoubtedly means the April catches overestimate the numbers of winter-run Chinook.

Table 13
SUMMARY OF CHIPPS ISLAND SALMON TRAWL DATA, 1976-1990

| Year | Month | Number of Trawls | Total Catch | Number of Winter Run* | Winter Run Catch/Tow | % Winter Run |
|---|---|---|---|---|---|---|
| 1976** | May | 76 | 509 | 2 | 0.03 | 0.4 |
| | June | 188 | 1,101 | 1 | 0.005 | 0.1 |
| 1977** | May | 174 | 834 | 2 | 0.01 | 0.2 |
| 1978 | April | 101 | 625 | 140 | 1.14 | 22.4 |
| | June | 90 | 612 | 5 | 0.06 | 0.8 |
| 1979 | April | 77 | 490 | 77 | 1.00 | 15.7 |
| | May | 78 | 419 | 2 | 0.3 | 0.5 |
| | June | 190 | 1,080 | 1 | 0.005 | 0.1 |
| 1980 | January | 15 | 22 | 1 | 0.07 | 4.5 |
| | February | 26 | 36 | 18 | 0.69 | 5.0 |
| | March | 24 | 41 | 31 | 1.30 | 76 |
| | April | 65 | 364 | 203 | 3..1 | 76 |
| | May | 81 | 609 | 38 | 0.5 | 6.2 |
| | June | 252 | 2,699 | 1 | 0.004 | 0.04 |
| 1981 | April | 52 | 300 | 56 | 1.07 | 19 |
| | May | 61 | 341 | 1 | 0.02 | 0.3 |
| 1982 | April | 43 | 337 | 130 | 3.02 | 39 |
| | May | 120 | 1,267 | 23 | 0.19 | 1.8 |
| 1983 | April | 66 | 370 | 140 | 2.12 | 38 |
| | May | 128 | 913 | 19 | 0.15 | 2.1 |
| | June | 146 | 932 | 1 | 0.007 | 0.01 |
| 1984 | April | 73 | 238 | 92 | 1.26 | 39 |
| | May | 99 | 1,760 | 6 | 6.01 | 0.3 |
| 1985 | April | 72 | 866 | 137 | 1.9 | 16 |
| | May | 294 | 7,030 | 12 | 0.04 | 0.02 |
| 1986 | April | 95 | 2,142 | 270 | 2.8 | 13 |
| | May | 284 | 7,972 | 46 | 0.16 | 0.6 |
| 1987*** | | | | | | |
| 1988 | April | 122 | 1,199 | 200 | 1.63 | 17 |
| | May | 490 | 9,091 | 8 | 0.02 | 0.09 |
| 1989 | April | 187 | 3,764 | 154 | 0.82 | 4.1 |
| | May | 292 | 7,410 | 10 | 0.03 | 0.1 |
| 1990 | April | 175 | 2,772 | 191 | 1.09 | 6.9 |
| | May | 266 | 4,828 | 4 | 0.02 | 0.08 |

* Using DFG classification schedule.
** No April trawls.
*** Data for 1987 did not get transferred.

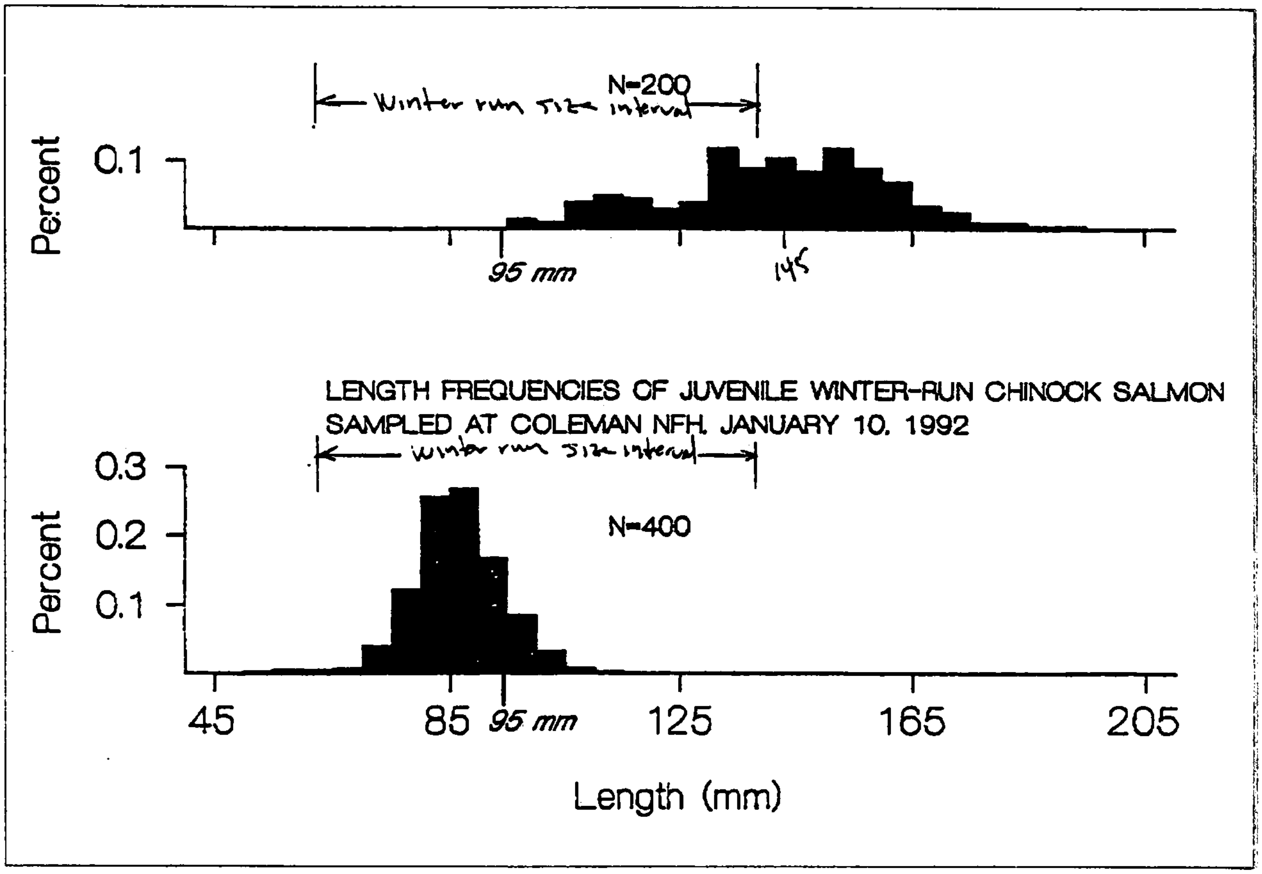
Figure 28
AVERAGE APRIL "WINTER RUN" TRAWL CATCH AT CHIPPS ISLAND VERSUS ESTIMATED "WINTER RUN" SPAWNING ESCAPEMENT THE PREVIOUS YEAR, 1980-1990 EXCEPT 1987
(USFWS unpublished trawl data)




- In April 1989, an examination of a subsample of the lengths of marked fish captured in the Chipps Island trawl indicated about 7 percent (2 of 30) would be classified as winter-run salmon. The marked fish were all fall run.
- In a special 1990 trawl survey, USFWS collected an average of 0.4 fish/tow in February and 1.67/tow in March (Hood, 1990). In both months about 50 percent of the fish captured were in the winter-run size range developed by DFG. Some of the "winter run" fish had evidence (fin erosion) of hatchery origin. During January 1990, Coleman National Fish Hatchery had released about 800,000 late fall-run fish of a size that could categorize them as winter run.

The confusing effect of hatchery releases on classifying winter run are shown in Figure 29. These data were provided by Jim Smith, USFWS, and consist of measurements of a random sample of winter-run and late-fall-run Chinook reared at the Coleman National Fish Hatchery. The late-fall fish were released in early January after the measurements, and the winter-run fish were released on January 21, 1992.

Figure 29
LENGTH FREQUENCIES OF JUVENILE LATE-FALL-RUN CHINOOK SALMON
SAMPLED AT COLEMAN NATIONAL FISH HATCHERY, DECEMBER 30 AND 31, 1991
(USFWS unpublished data)




It is apparent that a significant fraction of the late-fall fish would be classified as winter run if they were caught at Chipps Island or the fish salvage facilities. Although length data are not readily available on other hatchery releases (fish size is normally reported as number per pound), similar problems probably exist. Coleman late fall production was about 300,000 smolts which dwarfs the natural plus hatchery production of 1991 brood year winter run.

In summary, the trawl data suggest that winter-run juveniles pass Chipps Island in April. However, use of the DFG criteria greatly overemphasizes the extent of the outmigration. At present there is no means of determining if April is a significant month for winter-run outmigration. In May and June there may be occasional outmigrants, but migration during this period is probably not significant.

## Golden Gate Trawl

The DFG winter-run size interval criteria were used to classify the catch (Table 14). As with the Chipps Island data, use of the time-specific growth intervals results in apparent large overestimates of the numbers and population of winter-run salmon migrating through the Golden Gate.

Table 14
SUMMARY OF GOLDEN GATE SALMON TRAWL DATA, 1983-1986

| Year | Month | Number of Trawls | Total Catch | Number of Winter Run* | Winter Run Catch/Tow | % Winter Run |
|---|---|---|---|---|---|---|
| 1983** | April | 68 | 267 | 117 | 1.7 | 44 |
| | May | 181 | 3,191 | 222 | 1.2 | 7.0 |
| | June | 140 | 2,999 | 12 | 0.09 | 0.4 |
| | July | 29 | 193 | 0 | 0 | 0 |
| | August | 39 | 150 | 0 | 0 | 0 |
| | September | 29 | 108 | 0 | 0 | 0 |
| 1984 | April | 50 | 118 | 48 | 0.96 | 41 |
| | May | 109 | 669 | 4 | 0.04 | 0.6 |
| | June | 114 | 575 | 0 | 0 | 0 |
| | July | 150 | 598 | 0 | 0 | 0 |
| | August | 30 | 110 | 0 | 0 | 0 |
| 1985 | April | 90 | 382 | 135 | 1.50 | 35 |
| | May | 228 | 6,698 | 187 | 0.82 | 2.8 |
| | June | 74 | 952 | 5 | 0.07 | 0.5 |
| | July | 29 | 28 | 0 | 0 | 0 |
| 1986 | April | 89 | 676 | 89 | 1.0 | 13 |
| | May | 88 | 3,316 | 14 | 0.16 | 0.4 |
| | June | 153 | 2,391 | 4 | 0.03 | 0.2 |

* Using DFG length interval.
**Sampling was April through July.

## Early DFG Trawling Studies

In 1961 and 1962 (Messersmith 1966) and in 1973 and 1974 (Schaffter 1980), DFG conducted year-round trawling studies to determine the pattern of juvenile salmon outmigration from the Sacramento and San Joaquin River systems. Messersmith sampled at Carquinez Strait as part of the DWR/DFG Delta Fish and Wildlife Protection Study. Being below the confluence of the Sacramento and San Joaquin Rivers, his trawl samples included salmonids from both drainages. Schaffter, on the other hand, trawled near Hood, so his catches represented outmigration from the Sacramento River only. Schaffter's study was part of the Interagency Ecological Studies Program pre-Peripheral Canal fish distribution studies. Sampling protocols are described in the two references and are not repeated here.

The salmon catches from these two studies are summarized in Table 15. The DFG time-specific length intervals have been used to classify the Chinook salmon as either "winter-run salmon" or "other". Both surveys were conducted when winter-run spawners were probably abundant (although there are no escapement data for these years) and the confusing effects of hatchery releases were low. Flows during the two sampling periods are shown in Figure 30.

Table 15
COMPARISON OF ESTIMATED WINTER-RUN CATCH VERSUS
TOTAL SALMON CATCH AT CARQUINEZ STRAIT (1961-1962) AND AT HOOD (1973-1974)

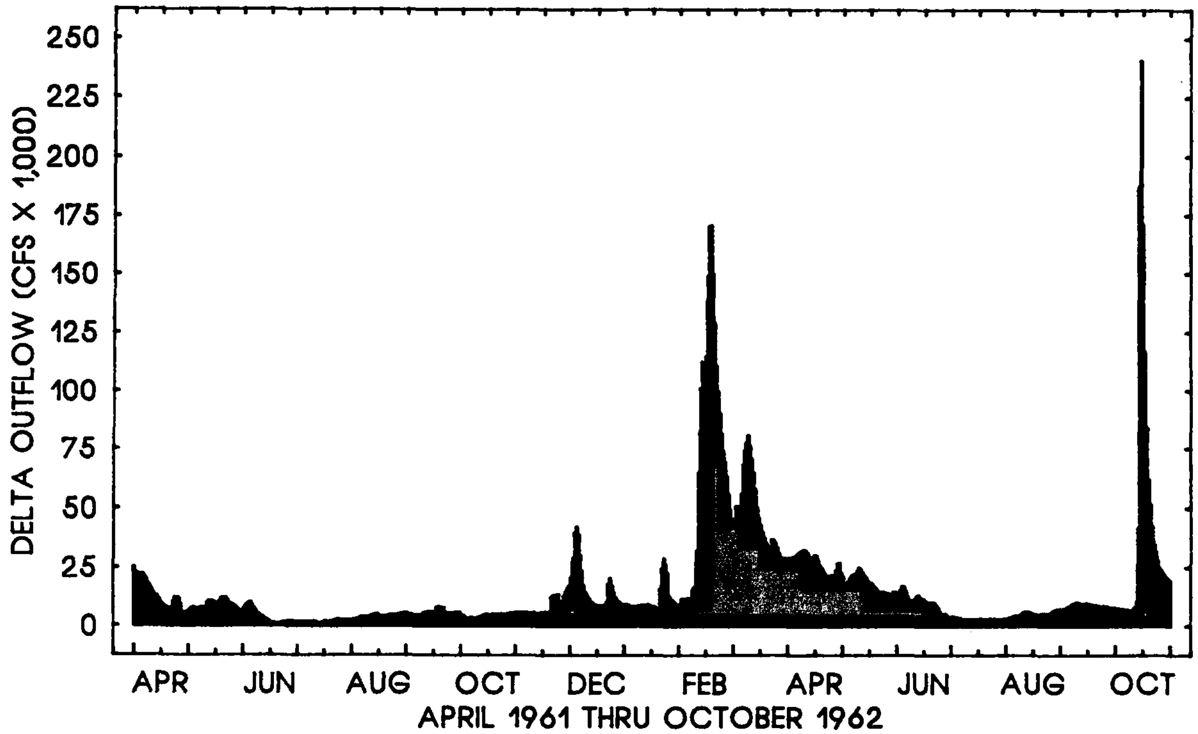
| Messersmith (1966) | | | | Schaffter (1980) | | | |
|---|---|---|---|---|---|---|---|
| Year | Month | Total Catch | Number of Winter Run* | Year | Month | Total Catch | Number of Winter Run* |
| 1961 | March | No Survey | | 1973 | March | 610 | 340 |
| | April | 726 | 294 | | April | 2,246 | 531 |
| | May | 2,076 | 18 | | May | | 0 |
| | June | | 0 | | June | | 0 |
| | July | | 0 | | July | | 0 |
| | August | | 0 | | August | | 0 |
| | September | | 0 | | September | 23 | 0 |
| | October | No Survey | | | October | | 0 |
| | November | | 0 | | November | 15 | 0 |
| | December | No Survey | | | December | No Survey | 0 |
| 1962 | January | 39 | 26 | 1974 | January | 41 | 3 |
| | February | 92 | 74 | | February | 67 | 11 |
| | March | 114 | 80 | | March | 383 | 32 |
| | April | 207 | 132 | | April | 823 | 290 |
| | May | 465 | 22 | | May | 3,847 | 21 |
| | June | 1,960 | 3 | | June | | 0 |
| | July | | 0 | | July | | 0 |
| | August | | 0 | | August | | 0 |
| | September | | 0 | | September | No Survey | |
| | October | | 0 | | October | No Survey | |

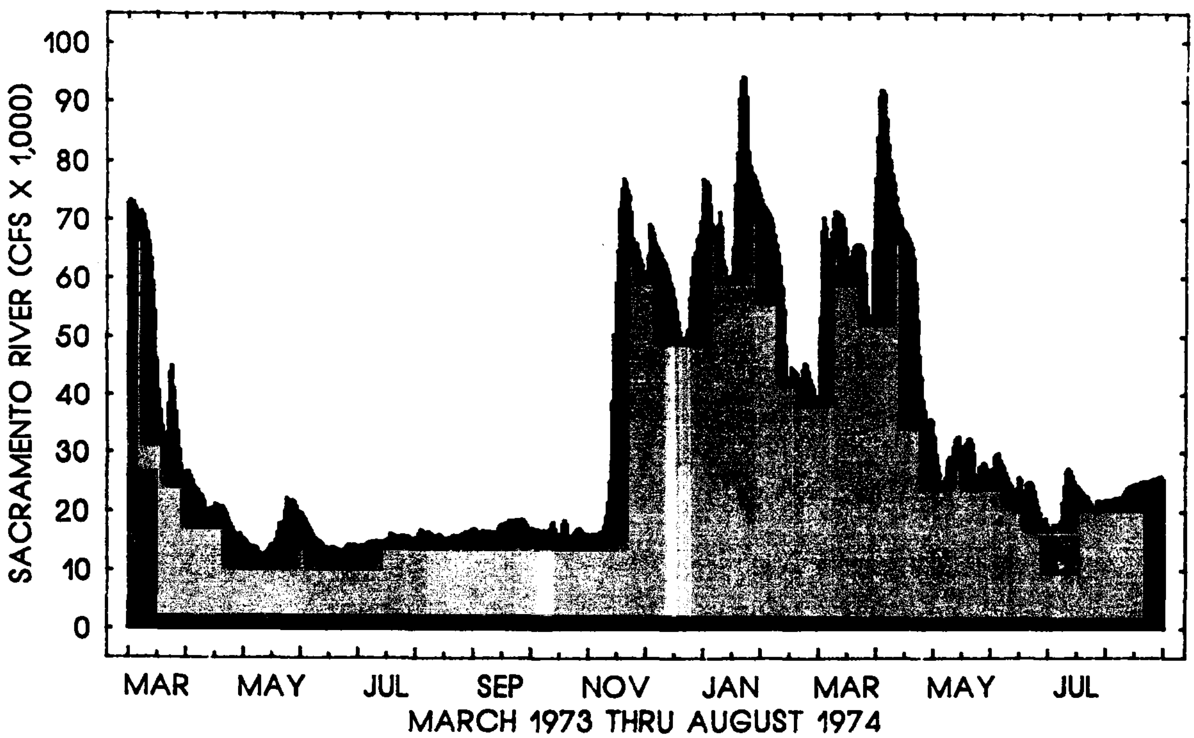
* Estimated using the DFG winter-run salmon length intervals.

In both instances, estimated peak winter-run outmigration occurred during January through April, with March and April having the highest catches. These data are not corrected for sampling effort and, thus, the total catches may not provide an accurate picture of relative abundance between months. Both samplings indicated some outmigration in May, and Messersmith also collected three salmon classified as winter run in June.

In the fall, Schaffter collected two small winter-run fish in September and three in December. All of these were of a size that clearly indicates they were winter run. As shown in Figure 30, flows during September 1973 were relatively low and uniform throughout the month, indicating that these fish were not brought down by freshets.

Figure 30
DELTA OUTFLOW AND SACRAMENTO RIVER FLOW AT FREEPORT DURING PERIODS WHEN MESSERSMITH (1966) AND SCHAFFTER (1980) WERE TRAWLING
(From DAYFLOW)



## CVP and SWP Salvage

In an effort to help resolve questions about fall and early winter winter-run outmigration, the salvage database was searched for all Chinook salmon that fit the winter-run size interval for September through December. The database includes the years 1980 through 1992. Results of this search are shown in Table 16.

Table 16
SALVAGED CHINOOK SALMON CLASSIFIED AS WINTER RUN
USING THE APRIL 1992 DFG LENGTH INTERVALS
(Because only monthly length data were available, overlaps could not be avoided.)

| Facility | Year | Month | Calculated Fork Length | Frequency Race 1 | Race 2 |
|---|---|---|---|---|---|
| State Water Project | 1980 | 12 | 109 | 1 W | LF |
| | 1983 | 12 | 93 | 1 W | LF |
| | 1983 | 12 | 96 | 1 W | LF |
| | 1983 | 12 | 99 | 1 W | LF |
| | 1984 | 10 | 69 | 1 W | LF |
| | 1984 | 10 | 70 | 1 W | LF |
| | 1986 | 12 | 103 | 1 W | LF |
| | 1986 | 12 | 107 | 1 W | LF |
| | 1986 | 12 | 109 | 1 W | LF |
| | 1987 | 12 | 100 | 1 W | LF |
| | 1987 | 12 | 102 | 1 W | LF |
| | 1987 | 12 | 104 | 1 W | LF |
| | 1987 | 12 | 109 | 1 W | LF |
| Central Valley Project | 1980 | 12 | 99 | 2 W | LF |
| | 1981 | 11 | 70 | 1 W | |
| | 1981 | 11 | 72 | 2 W | |
| | 1981 | 11 | 73 | 1 W | LF |
| | 1981 | 11 | 74 | 1 W | LF |
| | 1981 | 11 | 75 | 2 W | LF |
| | 1981 | 11 | 76 | 2 W | LF |
| | 1981 | 11 | 77 | 1 W | LF |
| | 1981 | 12 | 74 | 1 W | |
| | 1981 | 12 | 96 | 1 W | LF |
| | 1983 | 12 | 96 | 1 W | LF |
| | 1984 | 11 | 44 | 1 S | W |
| | 1984 | 12 | 103 | 1 W | LF |
| | 1984 | 12 | 104 | 1 W | LF |
| | 1984 | 12 | 105 | 1 W | LF |
| | 1984 | 12 | 107 | 2 W | LF |
| | 1984 | 12 | 109 | 1 W | LF |
| | 1984 | 12 | 109 | 1 W | LF |

Thus, out of several thousand measurements during this period, essentially none of the salmon measured during September through December would be classified as winter run. Data from high flow years such as 1982 and 1986 indicate that the fish salvage systems are capable of salvaging large numbers of small Chinook salmon and thus the absence of small fish is not due to selectivity.

Use of the salvage data to estimate timing of the winter-run outmigration during January through June is more complicated and is discussed in the chapter on project impacts.

## USFWS Beach Seine Data

Another major data base used to evaluate timing of the winter-run outmigration was the annual beach seine survey conducted during the winter and early spring by USFWS as part of the Interagency Program salmon studies. These surveys, conducted annually since 1977 are designed to provide salmon abundance indices for near-shore areas in the Sacramento and San Joaquin Rivers, the Delta, and the northern reach of the Sacramento-San Joaquin estuary. The methods are described in Kjelson and Brandes (1987). For these studies, only the data base from 1977 through 1989 was available for analysis.

Table 17 lists the stations and their locations used in these surveys. For ease of analysis, the stations were grouped into four general areas (as indicated in the table).

These beach seine surveys captured a total of 38,172 Chinook salmon during the period analyzed. The DFG winter-run criteria were used to classify the catch as "winter-run" or "other" Chinook salmon. Results of these analyses, by area, are shown in Table 18.

The data indicate that winter-run salmon were most vulnerable to seining in the Sacramento River above Sacramento (Area 1) during January through March, but some were captured in April and again in October through December. This pattern is similar to that shown at Red Bluff and GCID. Below Sacramento, most of the winter-run salmon were also caught in January through March, with relatively fewer caught in April, November, and December. No Chinook salmon classified as winter run were captured by beach seines in the northern reach of San Francisco Bay (Area 3).

The data suggest that fair numbers of winter-run Chinook salmon occurred in the San Joaquin River/Delta area, again mostly in the January through March period. Looking at the actual winter-run catch data for Area 4 reveals that 27 of the 95 "winter run" were captured at Stockton. It is highly unlikely that Sacramento River winter-run salmon migrated up the river to Stockton. This conclusion is supported by the fact that 11 of the 95 "winter-run" were marked "fall-run" Chinook.

Table 17

USFWS BEACH SEINE MONITORING SITES

| Description | Code | Station | Site | Number |
|---|---|---|---|---|
| COLUSA, STATE RECREATIONAL BOAT RAMP | A01 | RSAC315 | FWS47 | 1 |
| WARDS RESORT BOAT RAMP | A02 | RSAC304 | FWS46 | 1 |
| THE BEACH SOUTH OF MERIDIAN | A03 | RSAC291 | FWS45 | 1 |
| REELS BAR, JUST NORTH OF KNIGHTS LANDING | A04 | RSAC233 | FWS43 | 1 |
| KNIGHTS LANDING COUNTY PARK BOAT RAMP | A05 | RSAC227 | FWS42 | 1 |
| VERONA RESORT BOAT RAMP | A06 | RSAC209 | FWS41 | 1 |
| ELKHORN COUNTY PARK BOAT RAMP | A07 | RSAC194 | FWS40 | 1 |
| AMERICAN RIVER-EAST BANK RAMP-NORTH OF BRIDGE | A08 | RAM000 | FWS02 | 1 |
| SACRAMENTO RIVER AT DISCOVERY PARK BOAT RAMP | A09 | RSAC177 | FWS01 | 1 |
| MILLER PARK MWT | A10 | RSAC169 | | 1 |
| SACRAMENTO RIVER AT GARCIA BEND PARK BOAT RAMP | A11 | RSAC163 | FWS03 | 1 |
| SACRAMENTO RIVER-CLARKSBURG MIDWATER TRAWL | A12 | RSAC149 | FWS39 | 1 |
| SACRAMENTO RIVER AT CLARKSBURG PUBLIC FISHING RAMP | A13 | RSAC144 | FWS04 | 1 |
| HOOD MWT | A14 | RSAC143 | | 1 |
| SACRAMENTO RIVER BEACH AT KOKET RESORT | A15 | RSAC120 | FWS09 | 2 |
| SACRAMENTO RIVER AT ISLETON PUBLIC BOAT RAMP | A16 | RSAC109 | FWS10 | 2 |
| STEAMBOAT SLOUGH WEST OF STEAMBOAT RESORT | B01 | SLSBT17 | FWS05 | 2 |
| SACRAMENTO RIVER NORTH OF DUTRA DREDGE CO. | AB17 | RSAC103 | FWS11 | 2 |
| SACRAMENTO RIVER STUMP BEACH SOUTH OF RIO VISTA BRIDGE | AB18 | RSAC098 | FWS12 | 2 |
| SACRAMENTO RIVER AT SHERMAN ISLAND PUBLIC FISHING ACCESS | AB19 | RSAC087 | FWS14 | 2 |
| SAN JOAQUIN RIVER-ANTIOCH DUNES NATIONAL REFUGE | CDEF5 | RSAN010 | FWS18 | 4 |
| SAN JOAQUIN RIVER-SHERMAN ISLAND-EDDO'S BOAT RAMP | CDEF4 | RSAN021 | FWS17 | 4 |
| THREEMILE SLOUGH-BRANNAN ISLAND STATE PARK SWIM BEACH | F1 | SLTRM2 | FWS13 | 4 |
| MIDDLE RIVER-WOODWARD ISLAND BEACH | E2 | RMID18 | FWS20 | 4 |
| OLD RIVER-BEACH BELOW THE HIGHWAY 4 BRIDGE | E1 | ROLD36 | FWS19 | 4 |
| MOKELUMNE RIVER-B AND W RESORT BOAT RAMP | D5 | RMKL005 | FWS16 | 4 |
| LITTLE POTATO SLOUGH-TERMINOUS SWIM BEACH | D4 | SLLPT5 | FWS15 | 4 |
| GEORGIANA SLOUGH 1 MILE SOUTH OF JUNCTION WITH SACRAMENTO RIVER | D3 | SLGRG17 | FWS07 | 4 |
| MOKELUMNE RIVER SOUTH FORK AT WIMPY'S RESORT | D2 | RSMKL24 | FWS08 | 4 |
| DELTA CROSS CHANNEL-NORTH BANK, SOUTH OF KOVR ANTENNA | D1 | CHDLC0 | FWS06 | 4 |
| SAN JOAQUIN RIVER-SOUTHEAST CORNER OF VENICE ISLAND | C3 | RSAN042 | FWS23 | 4 |
| HONKER CUT-KING ISLAND MARINA BOAT RAMP | C2 | CFHKR0 | FWS22 | 4 |
| SAN JOAQUIN RIVER-STOCKTON CHANNEL-DAD'S POINT BEACH | C1 | RSAN060 | FWS21 | 4 |
| EAST OF MONTEZUMA SLOUGH ON THE SACRAMENTO RIVER | ABCDEF20 | RSAC081 | FWS24 | 3 |
| MONTEZUMA SLOUGH 1400 YARDS NORTH OF ROARING RIVER SL. INTAKE | G1 | SLMZU27 | FWS27 | 5 |
| ROARING RIVER SLOUGH INTAKE POND | G2 | SLMZU29 | FWS27 | 5 |
| SACRAMENTO RIVER AT CHIPPS ISLAND MIDWATER TRAWL | ABCDEFG2 | RSAC075 | FWS38 | 3 |
| CARQUINEZ STRAIT-BRICKYARD BEACH | ABCDEFG2 | RSAC052 | FWS28 | 3 |
| CARQUINEZ STRAIT-CROCKETT BEACH WEST OF MARINA | ABCDEFG2 | SHSSP30 | FWS29 | 3 |
| SAN PABLO BAY-POINT PINOLE UPSTREAM | ABCDEFG2 | SHSSP14 | FWS30 | 3 |
| SAN PABLO BAY-POINT PINOLE DOWNSTREAM | ABCDEFG2 | SHSSP13 | FWS31 | 3 |
| PETALUMA RIVER AT MOUTH, BLACK POINT BOAT RAMP | H1 | RPET002 | FWS36 | 6 |
| SAN PABLO BAY-CHINA CAMP STATE PARK BEACH | ABCDEFGH | SHNSP02 | FWS35 | 3 |
| SAN FRANCISCO BAY-POINT MOLATE BEACH | ABCDEFGH | SHNESF42 | FWS37 | 3 |
| SAN FRANCISCO BAY-PARADISE BEACH COUNTY PARK | ABCDEFGH | SHNWSF30 | FWS34 | 3 |
| SAN FRANCISCO BAY-BERKELEY BEACH FRONTAGE ROAD | ABCDEFGH | SHNESF18 | FWS32 | 3 |
| SAN FRANCISCO BAY-TREASURE ISLAND BEACH | ABCDEFGH | ISTRS1 | FWS33 | 3 |
| | | SLRAR0 | | |

Table 18
SUMMARY OF ESTIMATED WINTER-RUN CATCH BY MAJOR AREA,
USFWS BEACH SEINE DATA, 1977-1989

| Area | Month | Total Catch | Winter Run | Area | Month | Total Catch | Winter Run |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 3,039 | 119 | 3 | 1 | 77 | 0 |
| | 2 | 4,474 | 111 | | 2 | 60 | 0 |
| | 3 | 6,325 | 56 | | 3 | 114 | 0 |
| | 4 | 2,318 | 7 | | 4 | 34 | 0 |
| | 5 | 645 | 0 | | 5 | 2 | 0 |
| | 6 | 113 | 0 | | 6 | * | * |
| | 7 | * | * | | 7 | * | * |
| | 8 | * | * | | 8 | * | * |
| | 9 | * | * | | 9 | * | * |
| | 10 | 5 | 4 | | 10 | * | * |
| | 11 | 25 | 20 | | 11 | * | * |
| | 12 | 128 | 36 | | 12 | 1 | 0 |
| 2 | 1 | 1,819 | 49 | 4 | 1 | 1,421 | 39 |
| | 2 | 2,956 | 29 | | 2 | 3,510 | 31 |
| | 3 | 3,332 | 19 | | 3 | 3,595 | 26 |
| | 4 | 1,471 | 4 | | 4 | 1,317 | 5 |
| | 5 | 667 | 0 | | 5 | 271 | 1 |
| | 6 | 166 | 0 | | 6 | 133 | 0 |
| | 7 | 2 | 0 | | 7 | 4 | 0 |
| | 8 | * | * | | 8 | * | * |
| | 9 | * | * | | 9 | * | * |
| | 10 | 1 | 0 | | 10 | 1 | 0 |
| | 11 | 3 | 2 | | 11 | 2 | 1 |
| | 12 | 26 | 2 | | 12 | 27 | 0 |

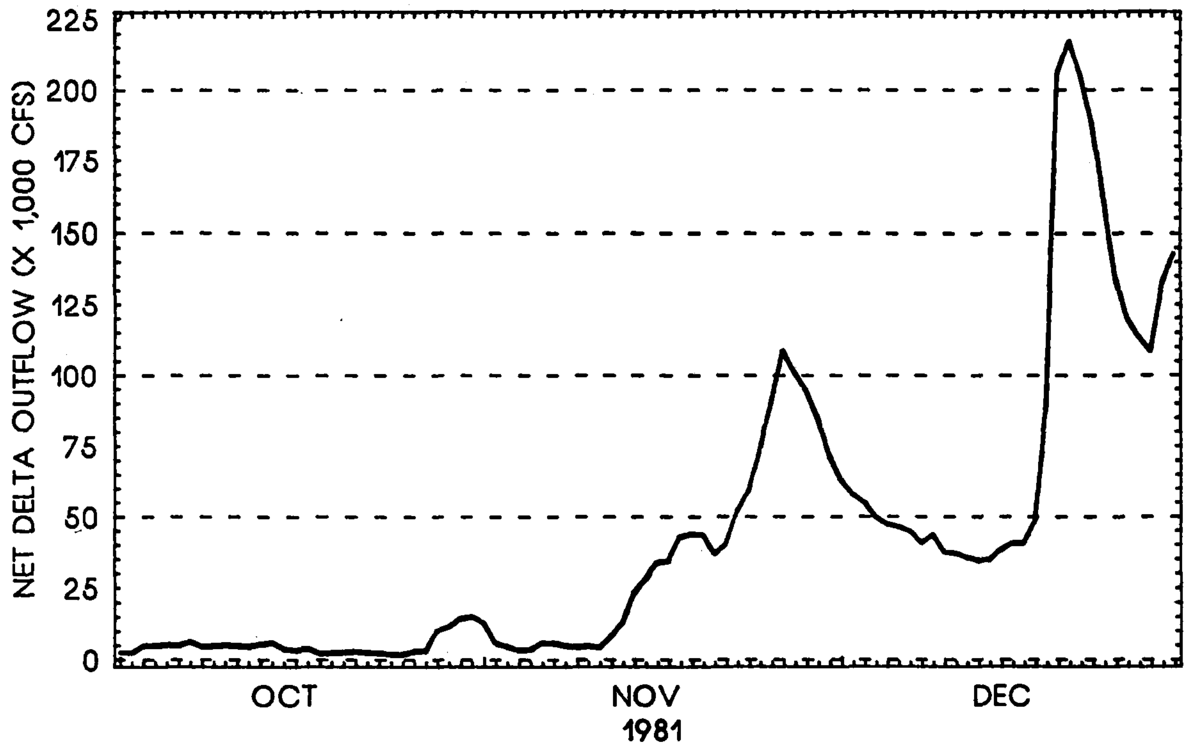
* No Sampling

## Suisun Marsh Sampling

In 1980, 1981, and 1982, DFG sampled, screened and unscreened culverts at the newly constructed Roaring River Slough intake in Suisun Marsh (Pickard *et al* 1982). The studies were to determine screen efficiency and develop estimates of the magnitude of the fish saved by having the screens in place. All culverts were subsequently screened.

On November 23 and 24, 1981, the nets caught 81 Chinook salmon, 50 of which were measured. Of those measured, 30 were in the winter-run size interval and the remainder were close enough to have been winter run as well. November 1981 was characterized by having the first major storm event of the water year with outflows exceeding 100,000 cfs (Figure 31).

Figure 31
DAYFLOW NET DELTA OUTFLOW, OCTOBER THROUGH DECEMBER 1981




Perhaps more important, from a standpoint of analyzing winter-run migration through Montezuma Slough, is the information on when winter run were not captured. In 1980, samples were collected twice in November and twice in December with no Chinook salmon being collected. In 1981, samples were collected twice monthly in January, February, March, and November, and once monthly in May, June, September, October, and December. Of the almost 900 Chinook salmon collected, only some of those captured in November 1991 fell into the winter-run size interval. Continued sampling in January, February, and March 1982 caught 192 juvenile Chinook salmon none of which would be classified as winter run. Although data are limited, it appears that winter run may be entering the slough only during extremely high flow periods.

In April and May of 1987, the USFWS trawled in Montezuma Slough as part of an Interagency Ecological Studies Program study to evaluate fish problems associated with operation of the salinity control gates. The following information was extracted from the field data sheets from this sampling effort. The data are tabulated in Appendix 4.

In April there were 36 Chinook salmon captured in 75 tows. None of these salmon were in the size range to be classified as winter-run juveniles. In May the USFWS crew made 145 individual trawls and captured 147 juvenile Chinook salmon. None of the captured fish would be classified as winter run. As mentioned earlier, the 1987 Chipps Island data did not get electronically transferred, thus we cannot compare catch/trawl in the two locations. The data do demonstrate further than juvenile Chinook salmon do use Montezuma Slough as a migratory corridor.

## 1991-1992 Winter-Run Outmigration

As part of the Interagency Studies Ecological Program, USFWS had three sampling efforts underway during the December 1991 through May 1992 period of likely peak winter-run outmigration. The first of these was their normal beach seine surveys conducted at numerous sites in the lower Sacramento River and the Sacramento/San Joaquin Delta. In addition, survey staff conducted midwater trawl sampling in the Sacramento River near Miller Park. (Miller Park is a couple of miles below the confluence of the American and Sacramento Rivers.) At Miller Park, tows were made one to three days per week during the period December 1 through March 22 and during the month of May. The Miller Park tows represent the most comprehensive winter trawling effort yet undertaken in the lower river to determine salmon outmigration. Daily tows were also made near Chipps Island during the April through May period.

The Chinook salmon collected in these tows were assigned to one of the four races by use of the DFG growth curves. We used the daily size intervals to avoid overlaps.

Figures 32, 33, and 34 illustrate the beach seines catches by area where Area 1 is generally the lower Sacramento River (Sacramento to Hood), Area 2 is the Sacramento River between Sacramento and Sherman Island, and Area 4 is the interior Delta and the San Joaquin below the mouth of the Mokelumne. (See Table 17 for a list of site names and locations.)

Figure 32
USFWS 1991-1992 BEACH SEINE CATCH, AREA 1, CLASSIFIED BY RUN

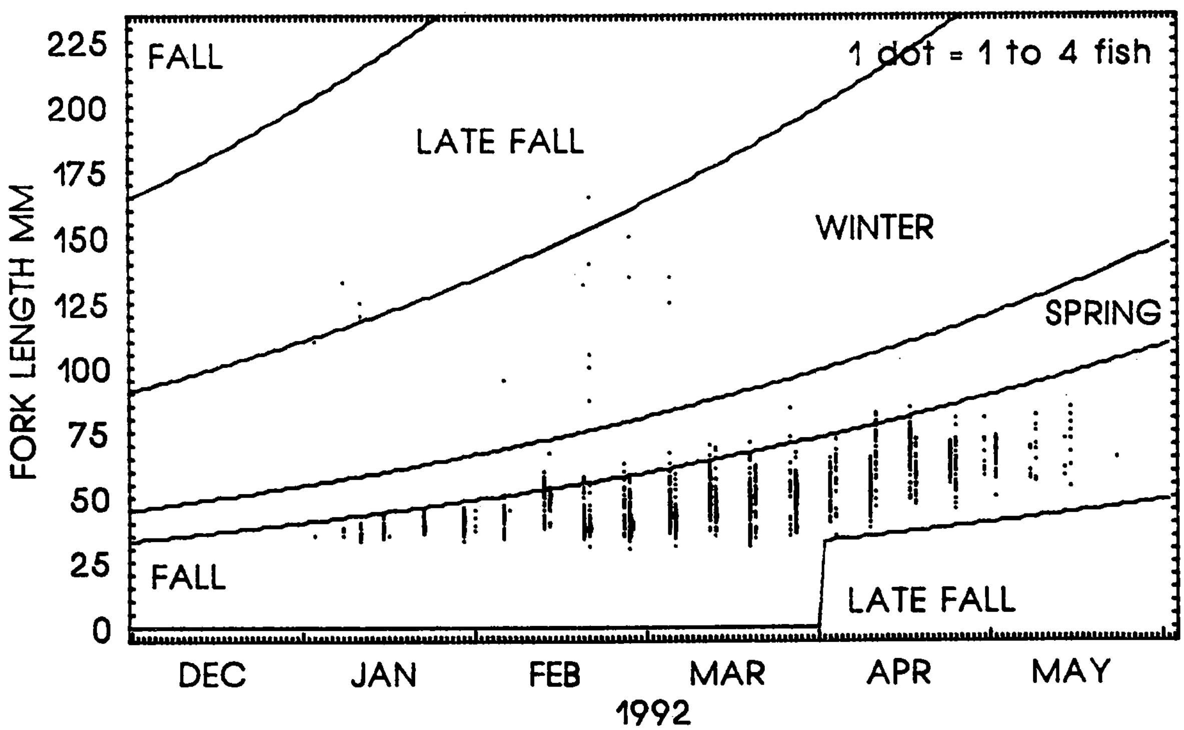


Figure 33
USFWS 1991-1992 BEACH SEINE CATCH, AREA 2, CLASSIFIED BY RUN

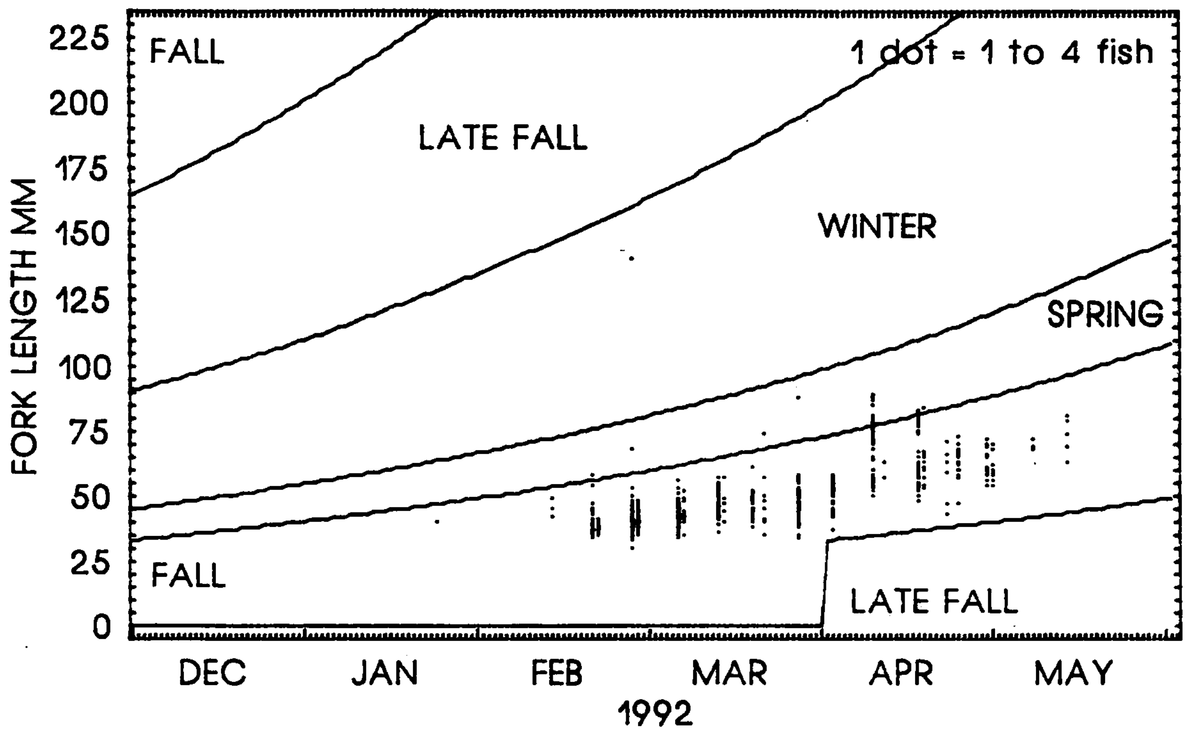
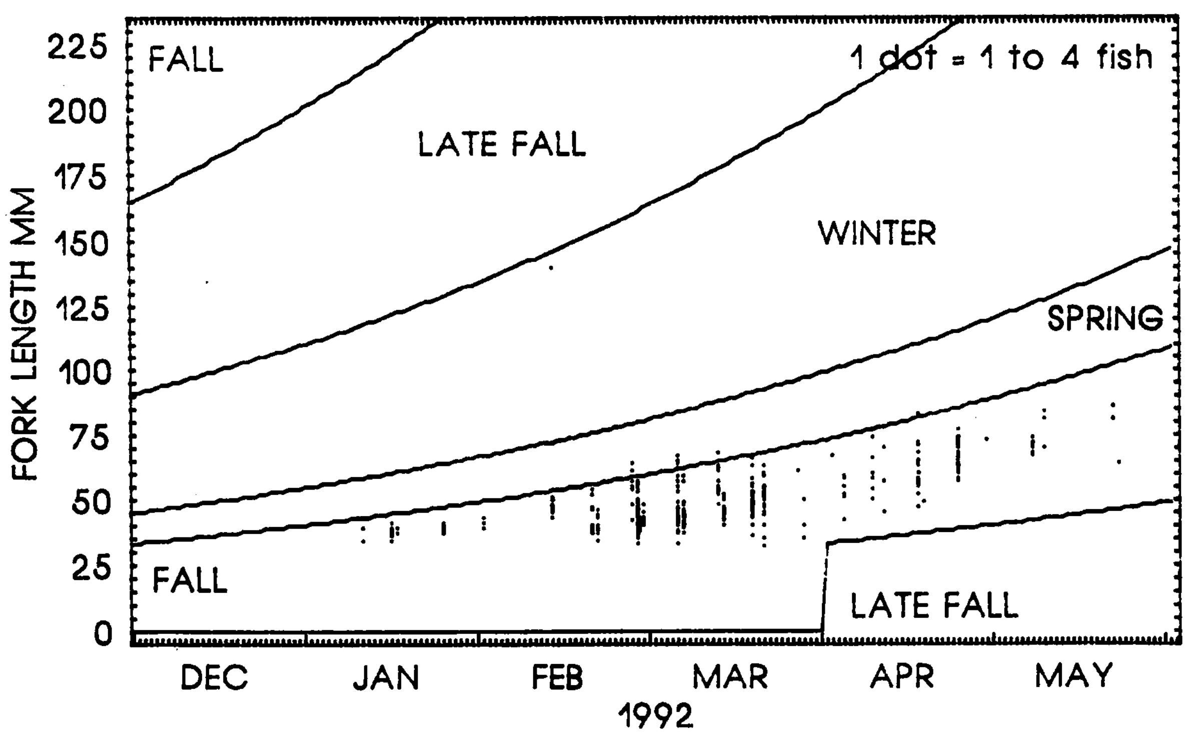



Figure 34
USFWS 1991-1992 BEACH SEINE CATCH, AREA 4, CLASSIFIED BY RUN



A few general observations can be made about the beach seine data.

- No Chinook salmon were captured at any site in December.
- Fall-run were by far the dominant race captured in the beach seine with the majority of the catch occurring after the February rains began.
- Out of a total of 3,173 Chinook salmon captured in the beach seine, 14 salmon were classified as winter-run, with two of those from the Delta (Table 19). The Delta captures occurred on February 12 and 26. None of the Chinook salmon classified as winter-run had adipose clips.
- Only four Chinook salmon classified as late-fall-run were captured and these were all from stations above Sacramento.

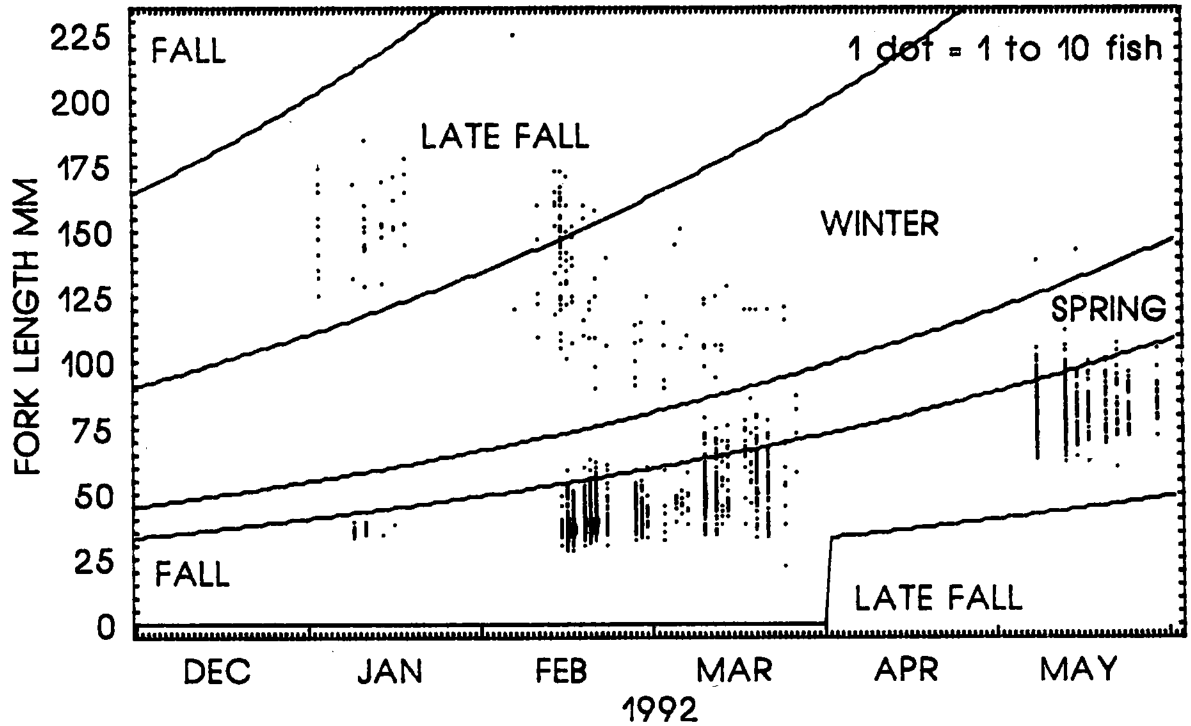
Table 19
CHINOOK SALMON CLASSIFIED AS WINTER-RUN
COLLECTED DURING THE 1991-1992 USFWS BEACH SEINE SURVEYS

| Station | Date | Time | Temperature (°F) | Fork Length (mm) | Race |
|---|---|---|---|---|---|
| FWS47 | 02/04/92 | 1332 | 52 | 91 | W |
| FWS47 | 02/04/92 | 1332 | 52 | 95 | W |
| FWS08 | 02/12/92 | 1007 | 55 | 140 | W |
| FWS40 | 02/18/92 | 0930 | 52 | 132 | W |
| FWS03 | 02/19/92 | 1020 | 53 | 87 | W |
| FWS03 | 02/19/91 | 1020 | 53 | 100 | W |
| FWS03 | 02/19/92 | 1020 | 53 | 105 | W |
| FWS03 | 02/19/92 | 1020 | 53 | 140 | W |
| FWS03 | 02/26/92 | 1047 | 58 | 150 | W |
| FWS04 | 02/26/92 | 1220 | 59 | 135 | W |
| FWS04 | 02/26/92 | 1220 | 59 | 150 | W |
| FWS10 | 02/26/92 | 1455 | 58 | 140 | W |
| FWS40 | 03/04/92 | 0918 | 59 | 125 | W |
| FWS40 | 03/04/92 | 0918 | 59 | 135 | W |

Figure 35 contains a general picture of the juvenile Chinook salmon trawl catches at Miller Park classified by run. A total of 3,536 Chinook salmon were captured during the months of December, January, February, March, and May. (No sampling occurred at Miller Park in April.) As with the beach seine data, a few general observations can be made about the Miller Park catches.

- No Chinook were captured in December and relatively few in January.
- Fall- and spring-run fry dominated the catch in February and March, probably responding to the high flows.
- Relatively large numbers of Chinook salmon classified as winter run were captured in February and March and two in May.

Figure 35
USFWS 1991-1992 TRAWL TOTAL SALMON CATCH AT MILLER PARK, CLASSIFIED BY RACE




- Fewer late-fall-run were captured than winter run which is opposite from what one would expect based on numbers of spawners and hatchery releases.
- Although it appears that peak winter-run outmigration occurred in February and March, the lack of April data weakens this conclusion.

The catches of adipose clipped fish at Miller Park by race, are shown in Figure 36. As with the other Chinook, these fish were assigned to run by size — none of the tags were read. Most of the tagged winter- and late-fall-run Chinook moved past Miller Park during the mid-February through early March period. A few late-fall apparently moved downstream soon after they were released in Battle Creek in early January. Although the sample size is small, there did not appear to be much growth in the late-fall-run between early January and mid-February.

The Miller Park catch data are summarized by race and presence of adipose clip in Table 20. About 2.3 percent of the catch were classified as winter run of which about 15 percent had clipped adipose fins. Late-fall made up about 1.9 percent of the total catch, 30 percent of which had clipped adipose fins.

We expanded the catches to obtain a rough estimate of the total numbers of Chinook salmon passing Miller Park during the 1992 outmigration period. The expansion factors were derived from a ratio of net width to channel width and fraction of time sampled. (A more refined expansion using meters in the net to obtain volume of water sampled has not been completed.) Based on the expansion, about 85,000 Chinook salmon classified as winter run passed Miller Park during February, March, and May. About 5,900 of these winter run had adipose fin clips. The estimates of wild winter-run seem somewhat high based on escapement but is in the right order of magnitude. The late-fall-run estimates of 69,000 is low considering that 300,000 hatchery-reared late-fall-run were released in Battle Creek in early January.

Figure 36
USFWS 1991-1992 TRAWL CATCH OF ADIPOSE-CLIPPED SALMON AT MILLER PARK, CLASSIFIED BY RACE

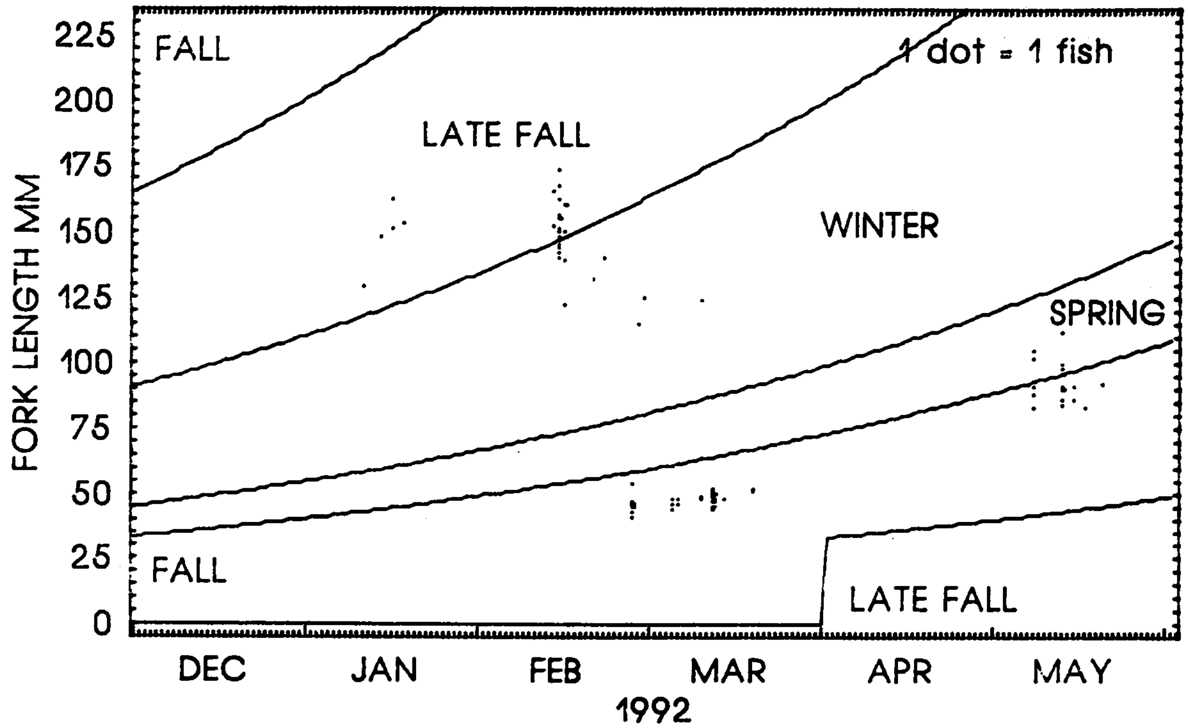



Table 20
CHINOOK SALMON TRAWL CATCH STATISTICS, USFWS SAMPLING AT MILLER PARK, DECEMBER 1991 THROUGH MAY 1992
(No April Sampling)

| | | Fall | | Spring | | Winter | | Late-Fall | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Month | No Clip | Clip | No Clip | Clip | No Clip | Clip | No Clip | Clip |
| 1991 | DEC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1992 | JAN | 16 | 0 | 0 | 0 | 0 | 0 | 30 | 5 |
| 1992 | FEB | 1,970 | 8 | 16 | 0 | 48 | 10 | 19 | 11 |
| 1992 | MAR | 447 | 18 | 55 | 0 | 24 | 1 | 0 | 0 |
| 1992 | MAY | 626 | 12 | 49 | 0 | 2 | 0 | 0 | 0 |

The USFWS began routine Chipps Island trawling in April and continued through May. The composition of total catch assigned by race, and the adipose clipped salmon by race are shown in Figures 37 and 38. These data indicate several of the salmon collected in April were classified as winter-run. As expected, the majority of the catch at Chipps Island during April and May were fall/spring Chinook. No late-fall-run or adipose fin clipped winter-run were captured at Chipps Island.

We used the USFWS' Chipps Island trawl data from to develop an estimate of April winter-run outmigration. The trawls captured 36 Chinook salmon categorized as winter-run Chinook salmon in April and 1 on May 4. Using the expansion developed by USFWS staff

$$\frac{\text{catch}}{(\text{fraction time sample})\ (0.0055)}$$

about 55,000 winter run were estimated to have passed Chipps Island in April. (There were about two weeks between the last trawls at Miller Park and the first winter run captured at Chipps Island, thus it is unlikely they were sampling the same fish.)

Combining the Miller Park and Chipps Island estimates of winter-run outmigrants, we arrived at a grand total of 141,000 outmigrants of which about 5,900 were tagged. This number is much higher than expected given the low numbers of spawners in 1991 and may reflect sampling problems and misidentification of the captured Chinook. The catch from all sampling sites and gear data do support the conclusion that downstream migrating winter-run salmon did not enter the Delta until after the rains began in February. Although most of the Chinook classified as winter-run apparently passed through in a six-week period from mid-February through the end of March, a significant number were captured at Chipps Island in April.

The picture of when winter run migrate through the Delta is not as clear as one would hope. One major problem is the failure of the present classification system to accurately assign juveniles by race. The following is a summary of our interpretation of the available data on timing.

- Although some winter run may leave the upper river in the early fall, it is likely that the main downstream migration occurs during the winter, probably tied to flow events. The strong flow/migration relation was certainly true in 1991-92 when downstream migrants apparently remained above the Delta until the February-March rains. Another piece of evidence supporting this conclusion was the high winter-run catches in Montezuma Slough during a major flow event in late November 1981.
- Although Chinook salmon classified as winter run have been reported in the Delta from late September through June, the period during which most of the juveniles migrate through the Delta is much shorter.

Figure 37

USFWS 1991-1992 TRAWL CATCH AT CHIPPS ISLAND, ALL CHINOOK, CLASSIFIED BY RUN

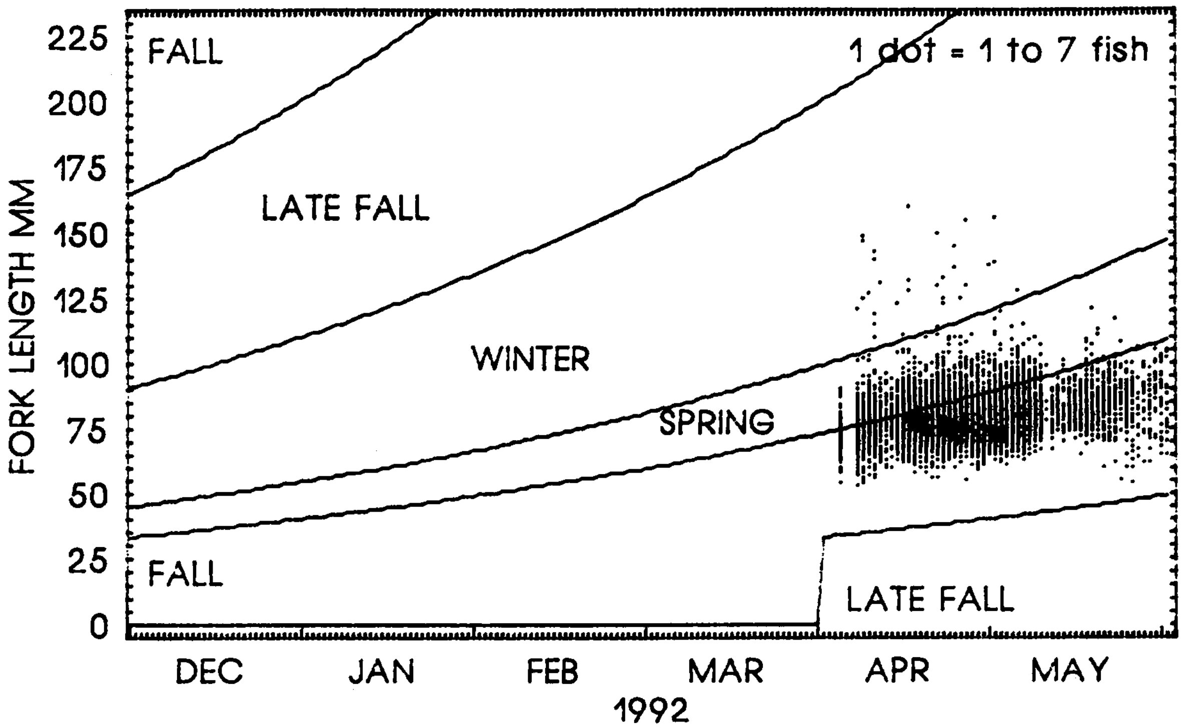
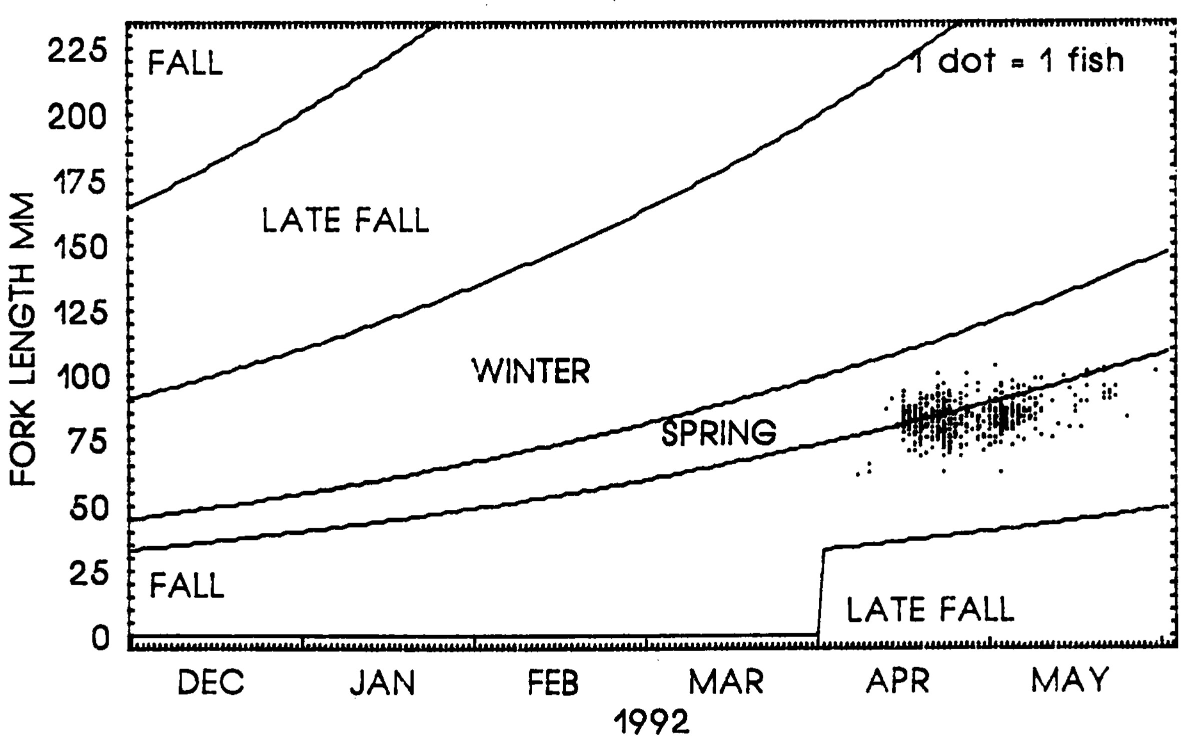



Figure 38

USFWS 1991-1992 TRAWL CATCH AT CHIPPS ISLAND, ADIPOSE-CLIPPED CHINOOK, CLASSIFIED BY RUN



- Significant flow pulses are not usually seen until December (Figure 39).

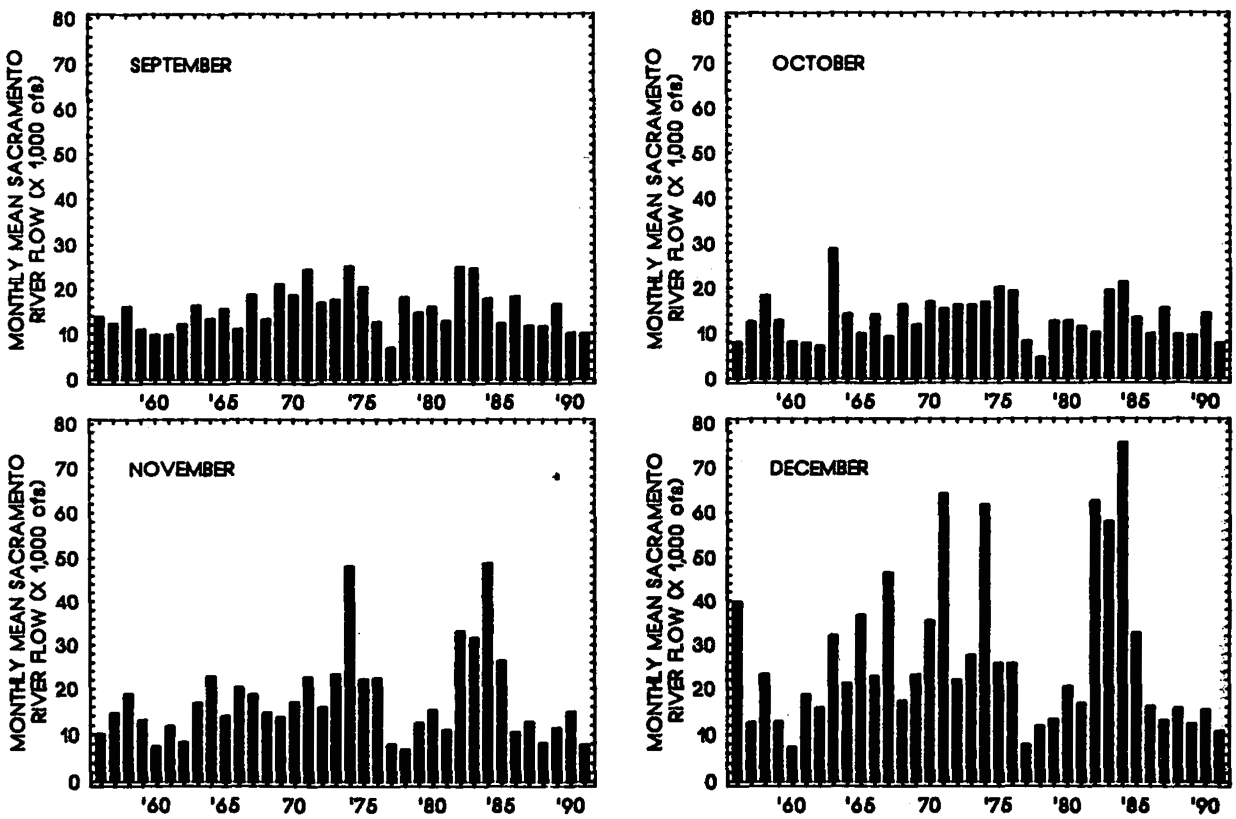
- Catches of winter-run-size fish at the federal and State fish facilities are quite low (bordering on nonexistent) until after January.

- Although there has not been extensive coverage, fall trawl catches have been low.

- It is likely that in most years most of the winter-run juveniles move through the Delta in January, February, and March, with February and March being the most important. Early high flows in December, or even late November, may change this distribution. Although April catches were often high in the trawls, and in the salvage, we need better identification of the races to verify that this is a key month.

Figure 39

MONTHLY FALL SACRAMENTO RIVER FLOWS AT FREEPORT, 1955-1991



## Delta Impacts

The approach in this section is to examine the question from three vantage points. First, we use statistical techniques to help if the Delta is a key factor in controlling the abundance of winter-run escapement. Next, an empirical Delta smolt model is used to evaluate the overall effects of such Delta conditions as flow, temperature, and pumping on survival through the Delta. Since this model integrates survival from Sacramento to Chipps Island, it, in theory, includes losses at the pumps, effects of reverse flow, etc., even though these variables may not show up in the actual model. Finally, we examine specific features and facilities such as reverse flows, losses at the pumps, Montezuma Slough salinity control gates, Delta Cross Channel, North Bay Aqueduct, and south Delta temporary barriers.

### Overall CVP and SWP Delta Impacts on Spawning Stock

In the early 1980s federal and State biologists, engineers, and water managers developed a 10-point program designed to help winter-run salmon recovery. Although the Delta was mentioned, most of the efforts focused on upstream measures such as temperature control, Red Bluff Diversion Dam improvements, gravel replenishment and toxins. This focus continued until the 1992 NMFS Biological Opinion on 1992 CVP and SWP operation included Delta measures.

Before looking at specific Delta impacts it seems reasonable to examine overall Delta conditions as factors controlling spawning stock abundance. The information from these analyses may be useful in evaluating the reasonable component when developing reasonable and prudent alternatives. This is especially important in that economic costs of Delta measures can be high, thus one needs to understand the likelihood that any given Delta measure will significantly increase the run's chances for recovery.

During the period of record, the CVP and SWP have had a combined Delta pumping capacity of about 11,000 cfs. Since the SWP came on line in 1967, total Delta exports have steadily increased (Figure 40). During this same period the estimated winter-run escapement has steadily decreased (Figure 41). We looked into a possible relationship between Delta pumping and winter-run escapement to help determine if pumping was a significant cause of the decline.

Using winter-run cohort data provided by the DFG (Frank Fisher, personal communication) and Delta combined CVP/SWP pumping during the November through May (from DAYFLOW), there is a significant relation ($r^2$ = 0.88) between exports and escapement (Figures 42 and 43). Since both escapement and pumping exhibited consistent trends (albeit in opposite directions) there was also significant autocorrelation between the two variables. In cases where autocorrelation exists, extreme values at the beginning and end of the period being examined may be driving the correlation with no correlation between variables within the period. Looking at this another way, the best equation (highest $r^2$) for explaining winter-run abundance is when time alone is the independent variable (Figure 44).

Figure 40
HISTORICAL TOTAL DELTA EXPORTS, 1966-1990

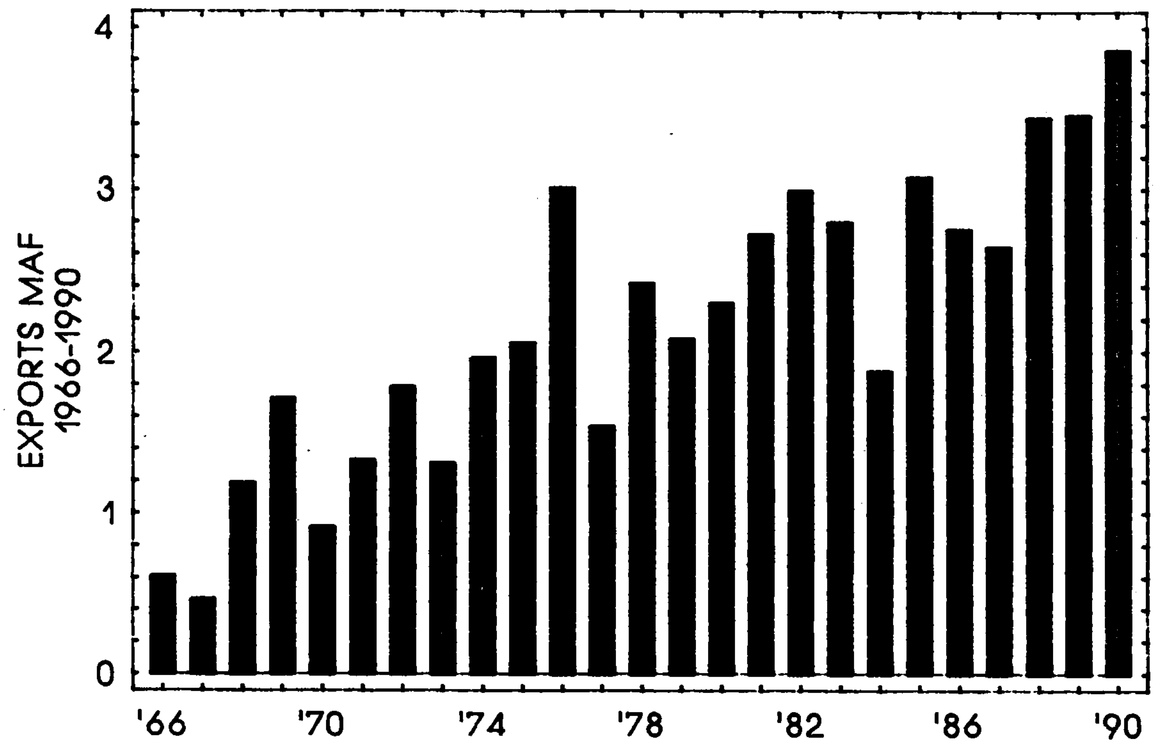



Figure 41
ESTIMATED WINTER-RUN SPAWNING STOCK, 1968-1992

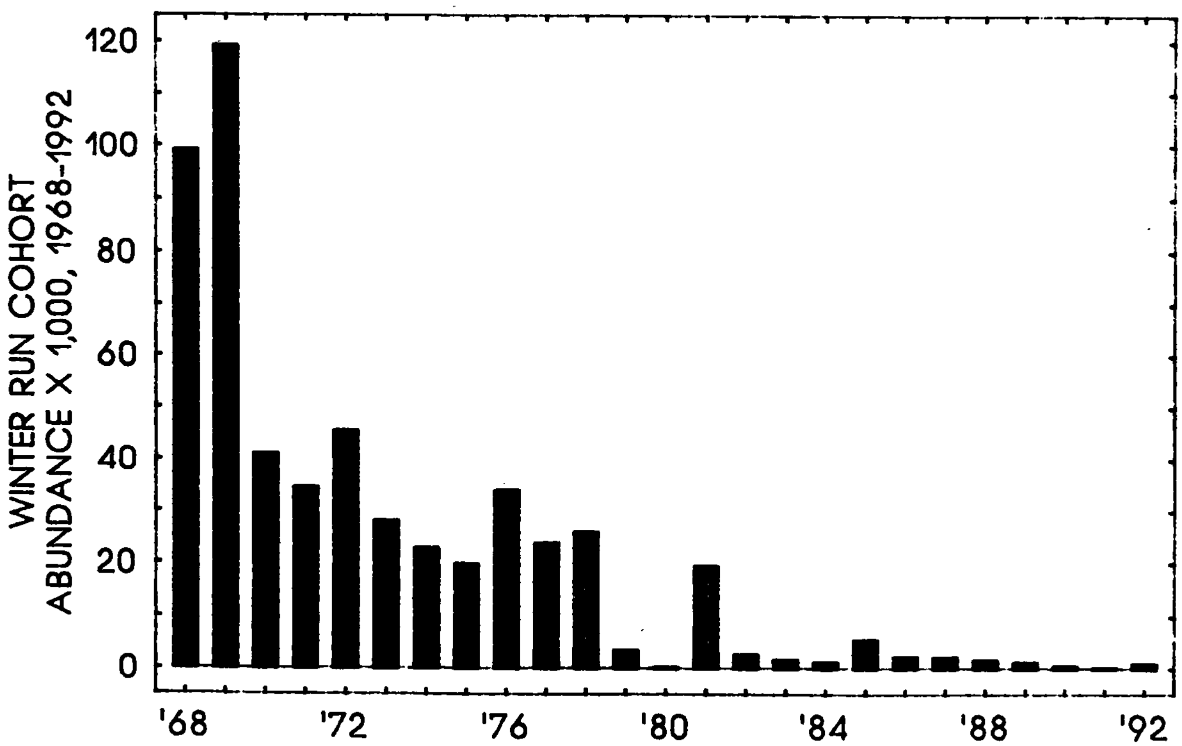


Figure 42
REGRESSION OF NOVEMBER THROUGH MAY TOTAL DELTA EXPORTS VERSUS WINTER-RUN COHORTS, 1968 THROUGH 1992

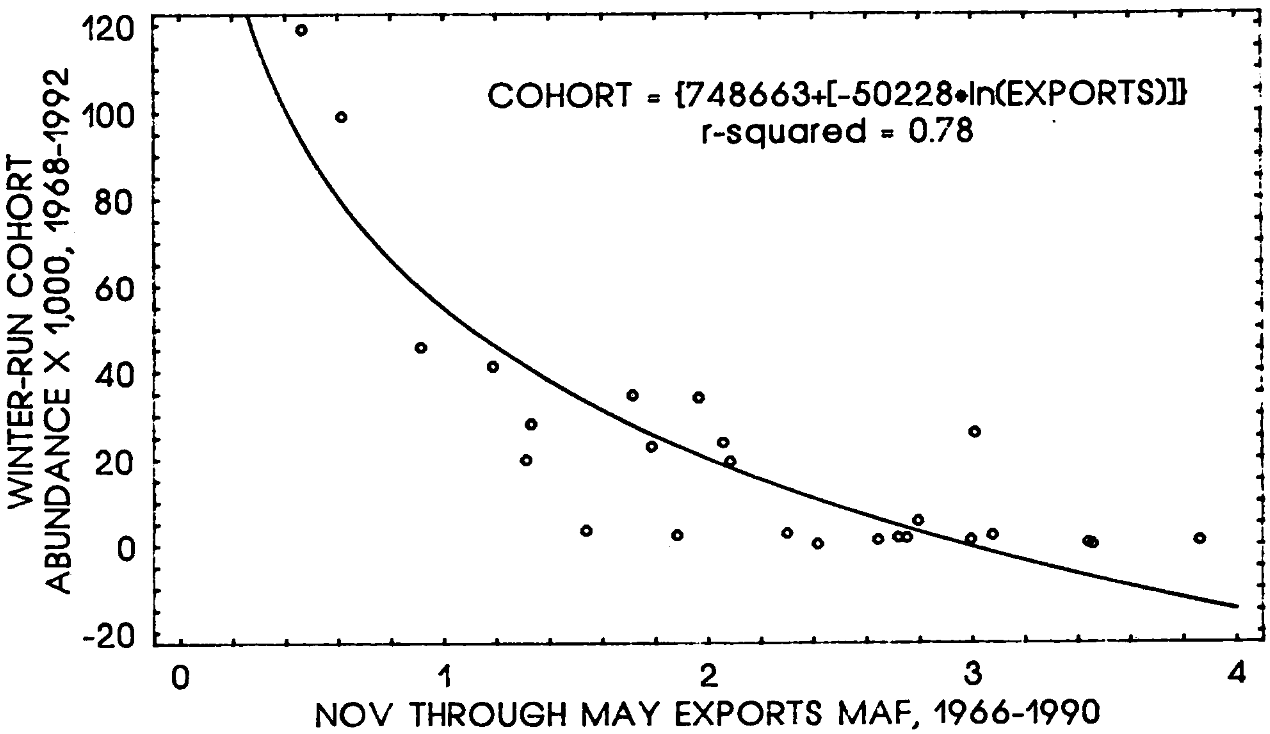



Figure 43
REGRESSION OF NATURAL LOG OF TOTAL NOVEMBER THROUGH MAY DELTA EXPORTS VERSUS WINTER-RUN COHORTS

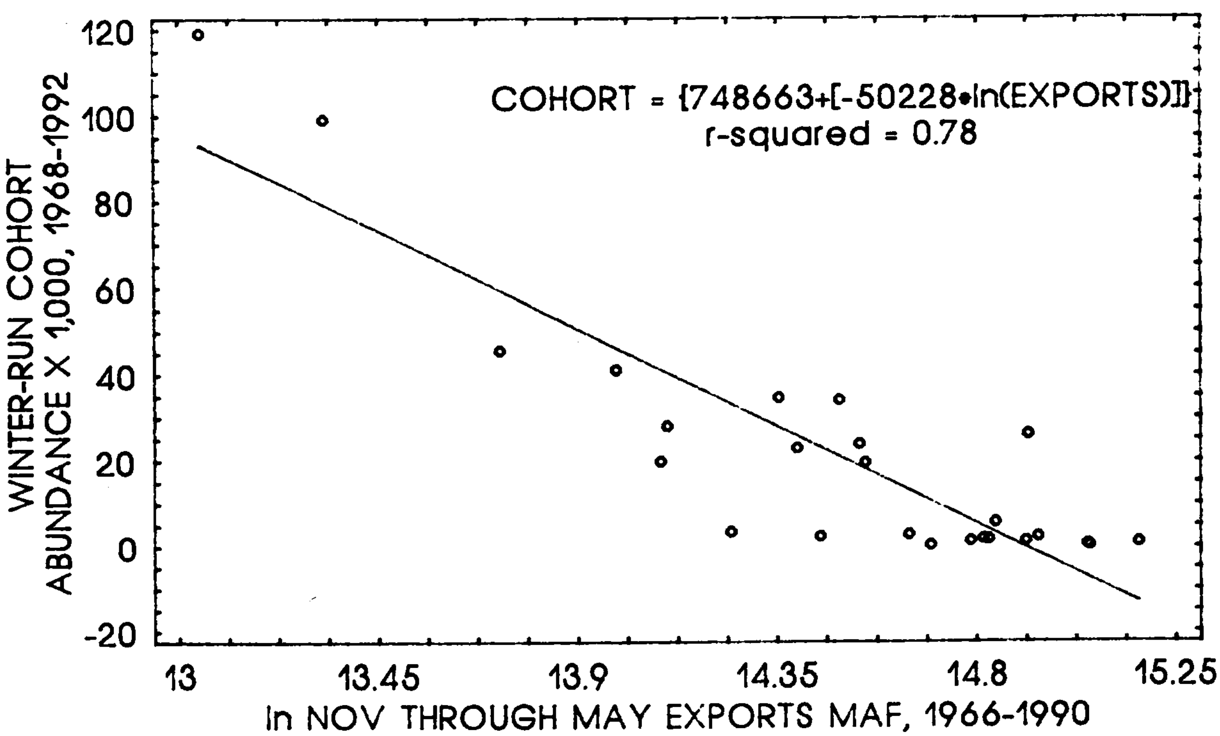
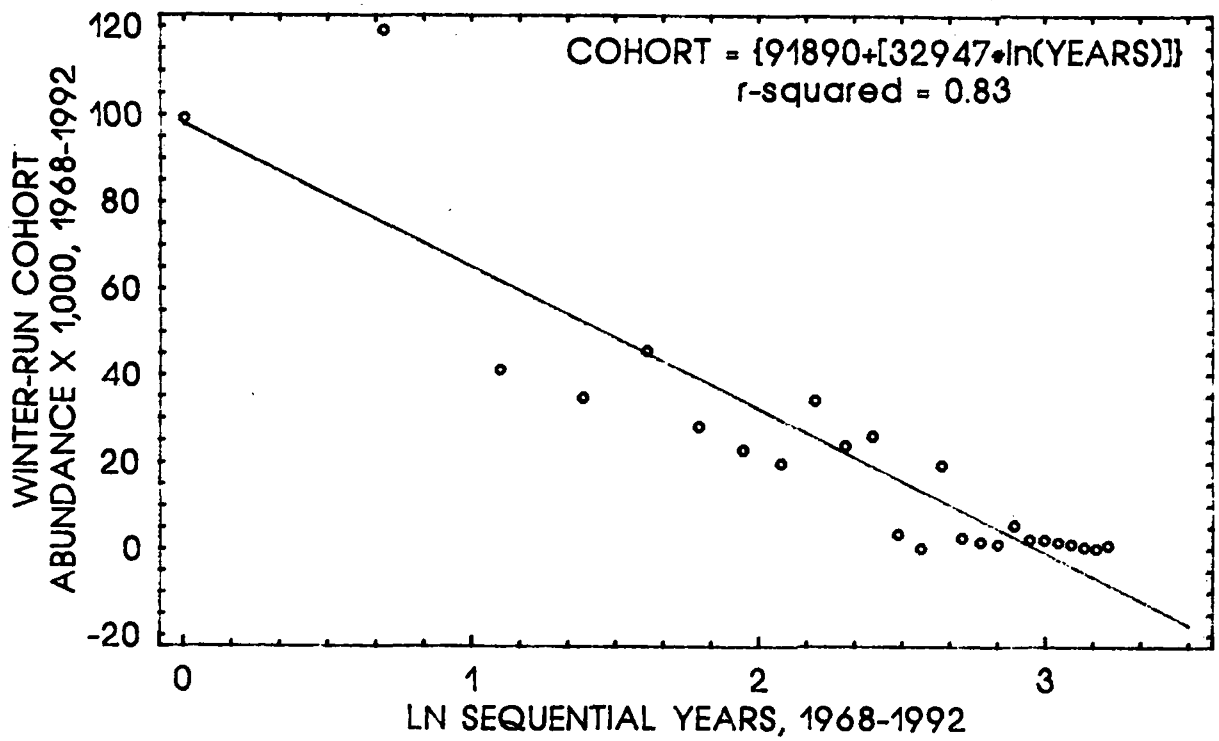


Figure 44
REGRESSION OF SEQUENTIAL YEARS VERSUS WINTER-RUN ABUNDANCE, 1968-1991




To determine if the correlation between winter-run cohort abundance and Delta export is driven by the strong temporal trends of both variables, the regression analysis was also done for detrended data. Detrending was accomplished by using the incremental difference between each time step, rather than absolute values. (Table 21 contains the original and detrended data.) There was no relation between the detrended abundance and pumping (Figure 45).

Another way to look at possible Delta impacts is to determine if there is a relationship between total exports and some measure of survival such as a recruit/spawner index. (A long-term recruit/spawner index of 1.0 would indicate that the population was reproducing itself and was stable.) Delta operations examined are total combined project exports and the ratio of total project exports to total Delta inflow (*ie* a measure of fraction inflow being diverted) during January through April. The data used in these analyses are in Table 22.

Again there was no relation between Delta conditions and operations and the subsequent number of recruits produced by a given spawning stock (Figures 46 and 47).

Although lack of statistical correlation does not necessarily imply lack of cause and effect, the above analyses do indicate that Delta pumping has not been a major factor determining the abundance of adult winter-run Chinook salmon. A look at some of individual years provides additional support for the conclusion that Delta conditions are not controlling abundance. The strong 1992 escapement came from smolts that emigrated

Table 21
ORIGINAL AND DETRENDED DATA

| ---FRANK FISHER'S CORRELATION DATA--- | | | | | ---DETRENDED DATA--- | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BROOD YEAR | COHORT ABUND | FLOW YEAR | NOV-MAY EXPORTS | LN LOG EXPORTS | BROOD YEAR | | BROOD YEAR-1 | | DETRENDED COHORT ABUND | FLOW YEAR | | FLOW YEAR-1 | | DETRENDED NOV-MAY EXPORTS |
| 1968 | 99101 | 1966 | 613228 | 13.32649 | 119153 | - | 99101 | = | 20052 | 13.04780 | - | 13.32649 | = | -0.27869 |
| 1969 | 119153 | 1967 | 464075 | 13.04780 | 41038 | - | 119153 | = | -78115 | 13.98674 | - | 13.04780 | = | 0.93894 |
| 1970 | 41038 | 1968 | 1186767 | 13.98674 | 34479 | - | 41038 | = | -6559 | 14.35450 | - | 13.98674 | = | 0.36776 |
| 1971 | 34479 | 1969 | 1714282 | 14.35450 | 45526 | - | 34479 | = | 11047 | 13.72509 | - | 14.35450 | = | -0.62941 |
| 1972 | 45526 | 1970 | 913549 | 13.72509 | 27996 | - | 45526 | = | -17530 | 14.10169 | - | 13.72509 | = | 0.3766 |
| 1973 | 27996 | 1971 | 1331327 | 14.10169 | 22732 | - | 27996 | = | -5264 | 14.39558 | - | 14.10169 | = | 0.29389 |
| 1974 | 22732 | 1972 | 1786164 | 14.39558 | 19721 | - | 22732 | = | -3011 | 14.08712 | - | 14.39558 | = | -0.30846 |
| 1975 | 19721 | 1973 | 1312068 | 14.08712 | 33960 | - | 19721 | = | 14239 | 14.49088 | - | 14.08712 | = | 0.40376 |
| 1976 | 33960 | 1974 | 1964755 | 14.49088 | 23661 | - | 33960 | = | -10299 | 14.53666 | - | 14.49088 | = | 0.04578 |
| 1977 | 23661 | 1975 | 2056806 | 14.53666 | 25855 | - | 23661 | = | 2194 | 14.91759 | - | 14.53666 | = | 0.38093 |
| 1978 | 25855 | 1976 | 3010414 | 14.91759 | 3444 | - | 25855 | = | -22411 | 14.24584 | - | 14.91759 | = | -0.67175 |
| 1979 | 3444 | 1977 | 1537766 | 14.24584 | 198 | - | 3444 | = | -3246 | 14.69723 | - | 14.24584 | = | 0.45139 |
| 1980 | 198 | 1978 | 2415057 | 14.69723 | 19369 | - | 198 | = | 19171 | 14.54969 | - | 14.69723 | = | -0.14754 |
| 1981 | 19369 | 1979 | 2083769 | 14.54969 | 2716 | - | 19369 | = | -16653 | 14.64790 | - | 14.54969 | = | 0.09821 |
| 1982 | 2716 | 1980 | 2298807 | 14.64790 | 1709 | - | 2716 | = | -1007 | 14.81565 | - | 14.64790 | = | 0.16775 |
| 1983 | 1709 | 1981 | 2718654 | 14.81565 | 1185 | - | 1709 | = | -524 | 14.91223 | - | 14.81565 | = | 0.09658 |
| 1984 | 1185 | 1982 | 2994330 | 14.91223 | 5503 | - | 1185 | = | 4318 | 14.84313 | - | 14.91223 | = | -0.0691 |
| 1985 | 5503 | 1983 | 2794398 | 14.84313 | 2308 | - | 5503 | = | -3195 | 14.44823 | - | 14.84313 | = | -0.3949 |
| 1986 | 2308 | 1984 | 1882731 | 14.44823 | 2205 | - | 2308 | = | -103 | 14.93939 | - | 14.44823 | = | 0.49116 |
| 1987 | 2205 | 1985 | 3076775 | 14.93939 | 1622 | - | 2205 | = | -583 | 14.82770 | - | 14.93939 | = | -0.11169 |
| 1988 | 1622 | 1986 | 2751607 | 14.82770 | 1187 | - | 1622 | = | -435 | 14.78737 | - | 14.82770 | = | -0.04033 |
| 1989 | 1187 | 1987 | 2642864 | 14.78737 | 478 | - | 1187 | = | -709 | 15.05125 | - | 14.78737 | = | 0.26388 |
| 1990 | 478 | 1988 | 3440929 | 15.05125 | 150 | - | 478 | = | -328 | 15.05623 | - | 15.05125 | = | 0.00498 |
| 1991 | 150 | 1989 | 3458097 | 15.05623 | 942 | - | 150 | = | 792 | 15.16675 | - | 15.05623 | = | 0.11052 |
| 1992 | 942 | 1990 | 3862205 | 15.16675 | | | | | | | | | | |

Figure 45
REGRESSION OF DETRENDED EXPORT DATA VERSUS WINTER-RUN COHORTS

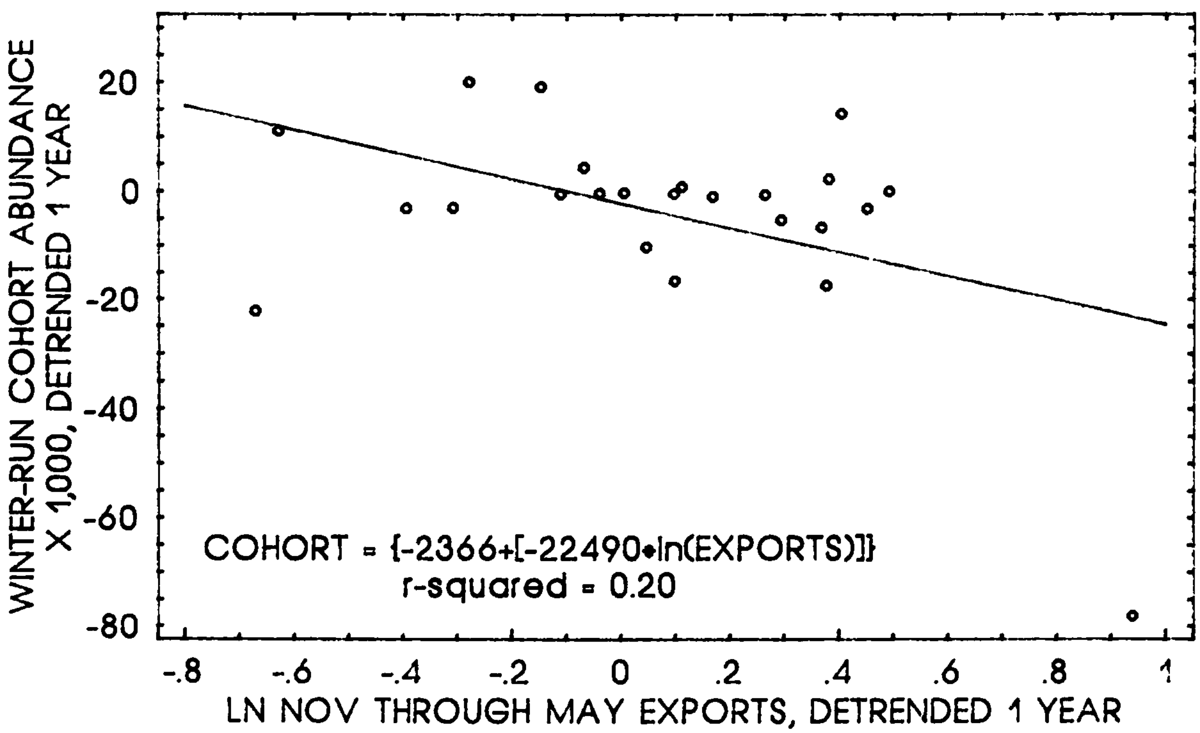


Table 22
COHORT AND DELTA DATA

| BROO | POPULAT | FRACJACK | JACKS | SPAWNERS | EMIG | EXP_J_A | SAC_J_A | INFL_J_A | REV_J_ | JACK | RECJACKS | ADUL | RECADULT | RECRUITS | REC/SPA | EXP/INFL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1964 | • | • | • | • | 1965 | 1233. | 45779. | 70496. | 0 | 1968 | • | 1967 | 32321 | • | • | 0.017 |
| 1965 | • | • | • | • | 1966 | 1592. | 26741. | 32522. | 0 | 1967 | 24985 | 1968 | 74115 | 99100 | • | 0.049 |
| 1966 | • | • | • | • | 1967 | 1137. | 44786. | 68951. | 0 | 1968 | 10299 | 1969 | 108855 | 119154 | • | 0.016 |
| 1967 | 57306 | 0.436 | 24985 | 32321 | 1968 | 3137. | 27587. | 34120. | 8 | 1969 | 8953 | 1970 | 32085 | 41038 | 1.27 | 0.092 |
| 1968 | 84414 | 0.122 | 10299 | 74115 | 1969 | 4202. | 55248. | 112947. | 0 | 1970 | 8324 | 1971 | 26155 | 34479 | 0.465 | 0.037 |
| 1969 | 117808 | 0.076 | 8953 | 108855 | 1970 | 2409. | 48640. | 94404. | 1 | 1971 | 16934 | 1972 | 28592 | 45526 | 0.418 | 0.026 |
| 1970 | 40409 | 0.206 | 8324 | 32085 | 1971 | 3477. | 38238. | 45872. | 1 | 1972 | 8541 | 1973 | 19456 | 27997 | 0.873 | 0.076 |
| 1971 | 43089 | 0.393 | 16934 | 26155 | 1972 | 4498. | 19800. | 22670. | 23 | 1973 | 4623 | 1974 | 18109 | 22732 | 0.869 | 0.198 |
| 1972 | 37133 | 0.23 | 8541 | 28592 | 1973 | 2140. | 49269. | 75900. | 0 | 1974 | 3788 | 1975 | 15932 | 19720 | 0.69 | 0.028 |
| 1973 | 24079 | 0.192 | 4623 | 19456 | 1974 | 4390. | 64834. | 100927. | 0 | 1975 | 7498 | 1976 | 26462 | 33960 | 1.745 | 0.043 |
| 1974 | 21897 | 0.173 | 3788 | 18109 | 1975 | 6047. | 37561. | 48941. | 0 | 1976 | 8634 | 1977 | 15028 | 23662 | 1.307 | 0.124 |
| 1975 | 23430 | 0.32 | 7498 | 15932 | 1976 | 7227. | 13827. | 16162. | 49 | 1977 | 2186 | 1978 | 23669 | 25855 | 1.623 | 0.447 |
| 1976 | 35096 | 0.246 | 8634 | 26462 | 1977 | 4010. | 7588. | 8285. | 36 | 1978 | 1193 | 1979 | 2251 | 3444 | 0.13 | 0.484 |
| 1977 | 17214 | 0.127 | 2186 | 15028 | 1978 | 7249. | 46259. | 72000. | 7 | 1979 | 113 | 1980 | 84 | 197 | 0.013 | 0.101 |
| 1978 | 24862 | 0.048 | 1193 | 23669 | 1979 | 4271. | 25232. | 34772. | 5 | 1980 | 1072 | 1981 | 18297 | 19369 | 0.818 | 0.123 |
| 1979 | 2364 | 0.048 | 113 | 2251 | 1980 | 5493. | 47401. | 96200. | 0 | 1981 | 1744 | 1982 | 972 | 2716 | 1.207 | 0.057 |
| 1980 | 1156 | 0.927 | 1072 | 84 | 1981 | 7008. | 21071. | 25199. | 55 | 1982 | 270 | 1983 | 1439 | 1709 | 20.345 | 0.278 |
| 1981 | 20041 | 0.087 | 1744 | 18297 | 1982 | 8584. | 65980. | 108453. | 0 | 1983 | 392 | 1984 | 794 | 1186 | 0.065 | 0.079 |
| 1982 | 1242 | 0.217 | 270 | 972 | 1983 | 7252. | 66067. | 167058. | 0 | 1984 | 1869 | 1985 | 3633 | 5502 | 5.66 | 0.043 |
| 1983 | 1831 | 0.214 | 392 | 1439 | 1984 | 5421. | 34809. | 54417. | 8 | 1985 | 329 | 1986 | 1979 | 2308 | 1.604 | 0.1 |
| 1984 | 2663 | 0.702 | 1869 | 794 | 1985 | 7232. | 15421. | 19426. | 49 | 1986 | 443 | 1987 | 1761 | 2204 | 2.776 | 0.372 |
| 1985 | 3962 | 0.083 | 329 | 3633 | 1986 | 5671. | 47060. | 110587. | 15 | 1987 | 236 | 1988 | 1386 | 1622 | 0.446 | 0.051 |
| 1986 | 2422 | 0.183 | 443 | 1979 | 1987 | 6277. | 15994. | 19422. | 45 | 1988 | 708 | 1989 | 480 | 1188 | 0.6 | 0.323 |
| 1987 | 1997 | 0.118 | 236 | 1761 | 1988 | 9197. | 16523. | 19033. | 92 | 1989 | 53 | 1990 | 425 | 478 | 0.271 | 0.483 |
| 1988 | 2094 | 0.338 | 708 | 1386 | 1989 | 9674. | 22650. | 25022. | 88 | 1990 | 16 | 1991 | 134 | 150 | 0.108 | 0.387 |
| 1989 | 533 | 0.1 | 53 | 480 | 1990 | 10190. | 15248. | 17021. | 111 | 1991 | 57 | 1992 | 885 | 942 | 1.963 | 0.599 |
| 1990 | 441 | 0.037 | 16 | 425 | 1991 | 6597. | 13592. | 15465. | 56 | 1992 | 295 | 1993 | • | • | • | 0.427 |
| 1991 | 191 | 0.3 | 57 | 134 | 1992 | • | • | • | • | 1993 | • | 1994 | • | • | • | • |
| 1992 | 1180 | 0.25 | 295 | 885 | 1993 | • | • | • | • | 1994 | • | 1995 | • | • | • | • |

Figure 46
PLOT OF TOTAL JANUARY THROUGH APRIL SWP AND CVP EXPORTS VERSUS NUMBER OF WINTER RECRUITS PER SPAWNER

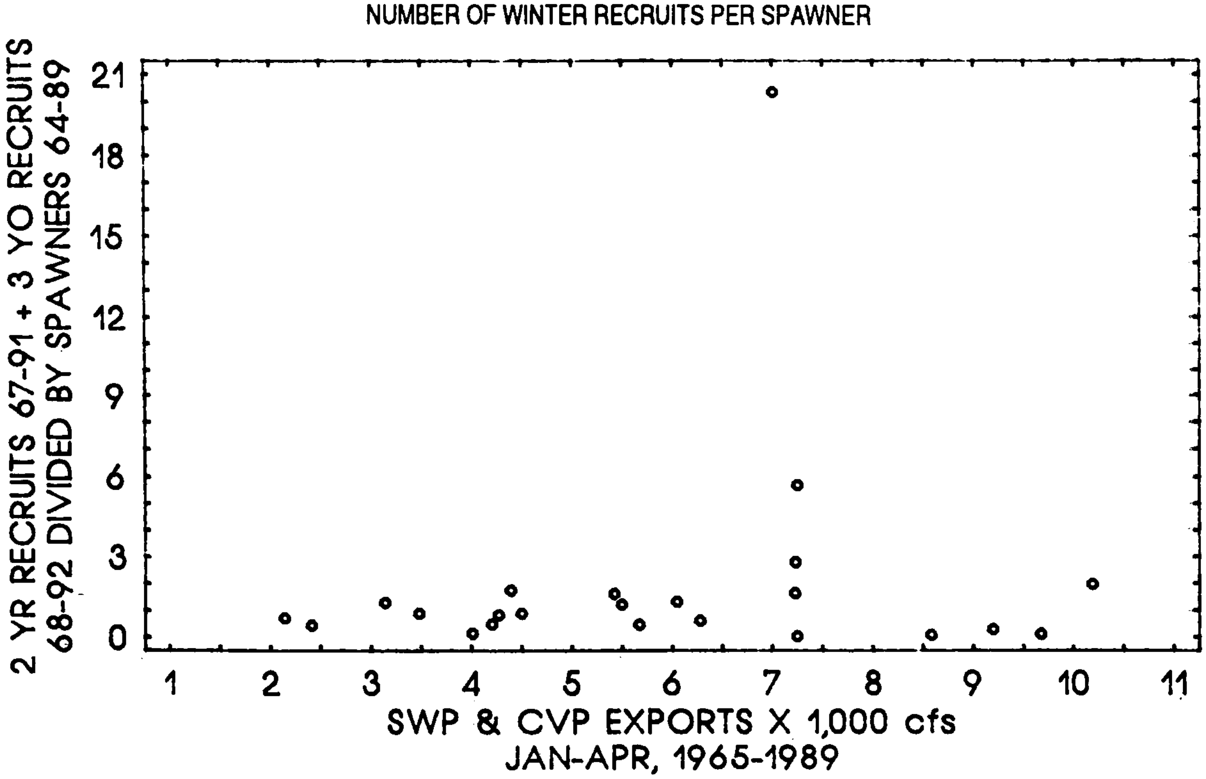
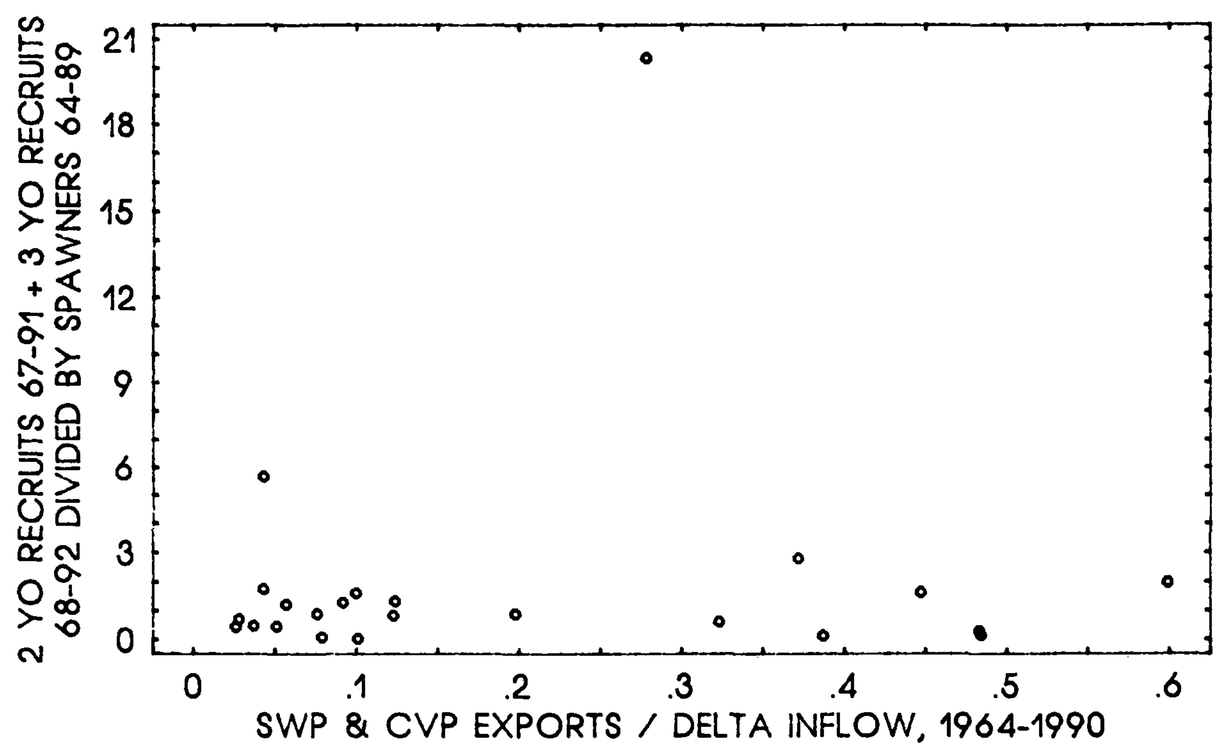


Figure 47
PLOT OF PERCENTAGE OF INFLOW DIVERTED IN JANUARY THROUGH APRIL VERSUS NUMBER OF RECRUITS PER SPAWNER




during the dry winter of 1989-90. Conditions during the January through April period, the probable period of peak outmigration were:

Thus, in 1992, Delta conditions were such that there would be concern for Delta survival.

On the other extremely wet years occurred in relatively high frequency during the winter-run decline period. From 1967 through 1992 there have been 12 wet years ('67, '69, '70, '71, '73, '74, '78, '80, '82, '83, '84, '86). During wet years, winter flows in the Sacramento and San Joaquin Rivers are typically high, the cross Channel gates are closed, and Delta pumping takes a relatively small percentage of the total inflow. (That is, Delta impacts are low.)

The occurrence of the decline in an overall wet period when probable Delta impacts are low suggests other factors other than the Delta are responsible for the decline and controlling adult population abundance. Likely factors include physical barriers, temperature, and oceanic conditions.

A corollary to the conclusion regarding lack of Delta impact is that mandated changes in Delta operations may offer little in the way of help leading to the recovery of the species. These conclusions are not completely surprising biologically in that the run has evolved in a way that takes advantage of generally favorable conditions during their migration through the Delta. Conversely, summer spawning, incubation, and rearing strategy puts this race at a particular disadvantage compared to other races in California's mediterranean climate with the long hot summers. This summer temperature problem was exacerbated when the run was forced to spawn in the Central Valley as opposed to its historic spring-fed McCloud River spawning grounds.

The above analyses and discussion are not to imply that there are no project-induced losses of winter-run Chinook salmon in the Delta. In the following sections we examine some of the sources and impacts of these losses.

## Delta Salmon Smolt Survival Model

Since 1978 the USFWS, as part of Interagency Ecological Studies Program, has released marked hatchery fall Chinook salmon at various locations in the Delta and trawled at Chipps Island to recapture some of the marked fish. Using these data, a survival index is determined for each release. Survival information from releases near Sacramento and above and below the Cross Channel have been used to evaluate the impacts of water project activities on survival of salmon smolts through the Delta.

In 1989 the results of these analyses were used to develop an empirical multilinear regression model of survival (or mortality). The principal factors included in the model were water temperature, fraction diverted into the Delta Cross Channel and Georgiana Slough, and pumping. The model developed survival indices for three reaches — from Sacramento to Walnut Grove; via the interior Delta to Chipps Island; and from just below the Cross Channel to Chipps Island.

We decided to use the survival model to evaluate the 40 alternative operational scenarios provided in CVP-OCAP. Before being used, the Smolt Survival Model was revised with 1990, 1991, and 1992 survival data. As background, there are survival indexes greater than 1 in the data set. In the 1989 version, the survival indexes were divided by 1.8 to evaluate survival transformations with values between 0 and 1, and to maintain biological "meaningfulness". The survival index should not, in theory, exceed 1, *ie* the Delta does not produce fish. The 1992 survival data included a survival index of 2.15. The survival indexes were left in their raw form in the 1992 revision for several reasons; (1) the results from the previous analysis did not indicate a statistical advantage in transforming the survival indexes, (2) dividing the indexes by the largest index value may mislead users into believing the indexes from 0 to 2.15 are equivalent to survival values of 0 to 1. The consequences of not dividing the survival indexes by the largest survival value are discussed in the section "Sacramento to the Cross Channel".

The Delta from Sacramento to Chipps Island is modeled as three sections, Sacramento to the Cross Channel, the Cross Channel to Chipps Island through the interior Delta, and the Cross Channel to Chipps Island through the mainstem Sacramento River. The survival from the Cross Channel to Chipps Island through the mainstem Sacramento River is represented by releases at Ryde; the survival from the Cross Channel to Chipps Island through the interior Delta is represented by factoring the Ryde survival from concurrent Courtland survival. The fraction of smolts continuing through the mainstem or interior Delta is assumed to be the same as the fraction of Sacramento River water continuing through the mainstem or Cross Channel and Georgiana Slough, respectively. The 1992 Georgiana survival indexes (*ie* when the Cross Channel gates were closed) were assumed to be equivalent to the factored interior Delta survival values.

Courtland Survival = (Interior Survival*Fraction Diverted into Cross Channel)+
(Ryde Survival*Fraction Remaining in the Mainstem)

Survival from Sacramento to the Cross Channel is represented by factoring the Courtland survival from the Sacramento survival. Since there were only four concurrent releases, the Courtland survivals were predicted using the survival relationships developed from the Ryde and Courtland releases from 1983 through 1992.

Sacramento Survival = Sacramento to Courtland Survival*
Courtland to Chipps Island Survival

Smolt survival in each section of the Delta was regressed to environmental factors thought to influence survival. The independent factors used were Sacramento River water temperature at Freeport, Sacramento River, San Joaquin River, western Delta, Cross Channel flows, Delta outflow, and SWP+CVP exports. Several averaging periods were used. Generally, the best predictive flows were the average of four to six days after release. The best predictive water temperatures were on the day of release or four to six days after release (Appendix 5, Tables 1-3).

Ryde to Chipps Island. The best predictive survival equation from Ryde to Chipps (Appendix 5, Figures 1 and 2) was:

Survival = 9.173846 + (-.0545419*Temp) + (-.5449393*ln Exports)
t=-3.23 t=-4.64
$r2=.71$ corrected $r2=.67$ $F=18.35$

Survival, water temperature and exports were all correlated to Julian day (Appendix 5, Figures 3-5). Equations with Julian day were not as good predictors as the equation with water temperature and ln exports. After water temperature and exports are selected, Julian day is not significant. Export was not a significant independent variable through the 1991 data. It became significant only after including the 1992 data. Each year of data were removed from the data set and regressed against exports (Appendix 5, Figure 6). The slope of the data set without 1992 was the most different from the mean slope of all subsets, and the $r^2$ value decreased from ~0.50 to 0.10 (Appendix 5, Table 4). This indicates the 1992 data are driving the equation, but there is no justification to remove the 1992 data. More data collected at low exports are needed to substantiate the relationship.

Western Delta flow has recently been shown to correlate with temperature corrected survival values, but this correlation is significant only when 1983 and 1986 data are removed from the data set (Appendix 5, Figures 7 and 8). In the process of multiple regression, using the entire data set, western Delta flow is not significant. If the 1983 and 1986 data are removed before the regression process, then water temperature is no longer significant because the 1983 and 1986 data are centrally located on the regression line. After western Delta flow is incorporated, water temperature is extremely insignificant. There does appear to be a relationship between survival and western Delta flow over a narrow range of western Delta flow, but water temperature and exports provide a better predictive equation. We did not use western Delta flow in these analyses.

Interior Delta. The best predictive equation for the interior Delta (Appendix 5, Figures 9 and 10) was:

$$\text{Survival} = 4.393222 + (-.0385240 * \text{Temp}) + (-.1879482 * \ln \text{Exports})$$

t=-4.31 t=-2.95

$r2=.74$ corrected $r2=.71$ $F=18.96$

The regression equation is similar to the previous version of the smolt survival model, but the significance is greater.

Sacramento to the Cross Channel. The equation for the Sacramento to the Cross Channel section (Appendix 5, Figure 11) was:

$$\text{Survival} = 5.819648 + (-.0752945 * \text{Temp})$$

t=-3.38

$r2=.45$ corrected $r2=.41$ $F=11.40$

This section of the Delta has always been the weakest section of the model. As mentioned earlier, the Courtland survival factored from the Sacramento survival indexes were modeled, not observed due to lack of concurrent releases. The uncertainty in the mainstem and interior regression equations confound modeling this to an unknown extent. The most significant independent parameter in this section is length of the smolt at release (Appendix 5, Figure 12). The correlation with length has caused uncertainty in the past. In the previous version, length was not used in the regression equation for two reasons; the correlation was negative indicating smaller smolts survive better (which is counter-intuitive), and smolt size was not considered a manageable factor, and other combinations of variables produced better predictive equations. In this review, length is unquestionably the best predictor. It may be that length is actually another Julian day measure in that smaller fish are planted earlier and fish planted earlier survive better than those in later plants. Further work should be performed to resolve the uncertainty due to the length correlation.

It has been pointed out that, if water temperature is used in the Sacramento to Cross Channel section of the model in addition to the Cross Channel to Chipps Island section of the model, then the relationship between water temperature and survival is multiple, resulting in a quadratic relationship of survival to water temperature. Additional work should be performed to resolve the consequences of multiplying water temperature twice in the model.

As mentioned earlier, the consequences of not dividing the survival indexes by the largest survival index occur in this section of the model. If the survival indexes in Sacramento to Cross Channel section and Cross Channel to Chipps sections were divided by ~2, then the survival from Sacramento to Chipps Island would be divided by 2 * 2 = 4. The difference between using raw survival indexes and divided survival indexes would be in the apportionment of survival to the Sacramento to Cross Channel section but factoring out the Courtland to Chipps Island survival from the Sacramento to Chipps Island survival. The greater the difference in survival indexes between these two sections, the greater the difference between using raw survival indexes and divided survival indexes. If the survival indexes are divided by the largest value, then the analyses must revised each time a new maximum survival index is obtained, and users may be misled into believing the survival indexes from 0 to 1 are equivalent to survival from 0 to 100 percent. If the survival indexes are left in their raw form, then results must be interpreted as survival indexes and used as differences between a base case and an alternative.

We need to determine whether the uncertainties and problems in using the Sacramento to Cross Channel section in series with the Cross Channel to Chipps Island section causes more uncertainty than useful information to the whole model.

Several assumptions were used in applying the 1992 smolt survival to the winter-run Chinook salmon biological assessment:

- Full scale survival indexes range from 0 to 2.15.
- The fraction diverted at the Cross Channel represents the amount of Sacramento River flowing into the interior Delta.
- The smolts are diverted into the interior Delta in proportion to the flow.
- Georgiana Slough survival indexes are equivalent to factored interior Delta survivals.
- The Smolt Survival Model can be extrapolated to water temperature outside of range of the model input data.

Results of the modeling analyses are shown in Table 23. The operational scenarios are the same as in the CVP-OCAP, and Delta conditions arising from these scenarios were shown in Table 9. The Y refers to water year type (net, above normal, *etc.*), ST refers to beginning-of-year storage, and DEL refers to percentage of project deliveries. PRE is pre-1992 operations, B is alternative B from the NMFS list of winter-run operational scenarios presented at the SWRCB hearings on interim Delta standards.

The numbers represent calculated Delta survival indexes. They do <u>not</u> represent actual survival. The maximum observed survival index in the database has been 2.15. Values in excess of 2.15 are due to the relationship between temperature and survival, which is not constrained by a lower temperature limit; *ie* cooler temperatures increase survival. Although the beneficial impacts of cold water cease at some temperature, perhaps in the high 40s, we did not set a limit for these benefits.

A few general observations can be made about the results in Table 23.

Table 23

CALCULATED DELTA SMOLT SURVIVAL USING 1992 MODEL AND CVP-OCAP OPERATIONAL SCENARIOS

| Y | ST | DEL | PREFEB | TEMFEB | BFEB | PREMAR | TEMMAR | BMAR | PREAPR | TEMAPR | BAPR |
|---|---|---|---|---|---|---|---|---|---|---|---|
| W | HI | 100 | 2.36 | | 2.36 | 1.87 | | 1.71 | 1.01 | | 1.02 |
| W | HM | 100 | 2.36 | | 2.36 | 1.70 | | 1.71 | 1.00 | | 0.97 |
| W | LM | 75 | 2.54 | | 2.54 | 1.73 | | 1.75 | 0.94 | | 0.98 |
| W | LO | 50 | 2.54 | | 2.59 | 1.73 | | 1.75 | 0.94 | | 0.98 |
| A | HI | 100 | 2.34 | | 2.54 | 1.71 | | 1.88 | 0.93 | | 1.20 |
| A | HM | 100 | 2.33 | | 2.72 | 1.73 | | 1.91 | 0.93 | | 1.19 |
| A | LM | 75 | 2.51 | | 2.74 | 1.75 | | 2.01 | 0.71 | | 1.24 |
| A | LO | 50 | 2.33 | | 2.73 | 1.72 | | 1.99 | 0.71 | | 1.24 |
| D | HI | 100 | 2.33 | | 2.91 | 1.36 | | 2.32 | 0.71 | | 1.43 |
| D | HM | 100 | 2.33 | | 2.92 | 1.34 | | 2.34 | 0.71 | | 1.43 |
| D | LM | 75 | 2.33 | | 2.94 | 1.34 | | 2.35 | 0.94 | | 1.43 |
| D | LO | 50 | 2.44 | 2.44 | 2.94 | 1.43 | 1.46 | 2.35 | 1.00 | 1.12 | 1.43 |
| C | HI | 100 | 1.84 | | 3.22 | 1.32 | | 2.41 | 0.85 | | 1.47 |
| C | HM | 100 | 1.84 | 1.85 | 3.22 | 1.31 | 1.31 | 2.39 | 0.90 | 0.98 | 1.46 |
| C | LM | 75 | 1.88 | 1.88 | 3.22 | 1.33 | 1.32 | 2.39 | 1.03 | 1.11 | 1.46 |
| C | LO | 50 | 1.90 | 1.92 | 3.22 | 1.40 | 1.39 | 2.39 | 1.10 | 1.32 | 1.80 |
| E | HI | 100 | 2.12 | 2.15 | 3.55 | 1.75 | 1.83 | 2.65 | 1.14 | 1.22 | 2.20 |
| E | HM | 100 | 2.24 | | 3.55 | 1.75 | | 2.65 | 1.25 | | 2.45 |

- During wet and above normal years, survivals under the pre-1992 and Alternative B scenarios are about the same.
- During dry and critical years, Alt B always resulted in higher survivals compared to pre-1992 (the "base" case).
- As expected, calculated survivals decreased over the three-month period.
- In March and April, survivals for Alternative B increased as water year went from wet to dry. This result was due to a combination of warmer water and the reduced export during the drier years to meet the no-net reverse flow criterion in Alternative B.

The smolt survival model was also used to rate four of the alternatives presented by NMFS in the SWRCB hearings. These alternatives were modeled using flow and diversion information from DWR's studies on closing Georgiana Slough during the 1993 winter-run Chinook salmon outmigration period (Table 24). The base case for these data is 1988.

Table 24

1988 HYDROLOGIC DATA

| | Temperature (°F) | | | Fraction Diverted | | | SWP+CVP Exports | | |
|---|---|---|---|---|---|---|---|---|---|
| Run | FEB | MAR | APR | FEB | MAR | APR | FEB | MAR | APR |
| B88 | 55.4 | 57.0 | 60.0 | 0.63 | 0.68 | 0.64 | 10,216 | 7,438 | 2,872 |
| B | 55.4 | 57.0 | 60.0 | 0.27 | 0.33 | 0.29 | 3,317 | 2,347 | 2,872 |
| C | 55.4 | 57.0 | 60.0 | 0.29 | 0.33 | 0.30 | 3,000 | 3,000 | 3,000 |
| E | 55.4 | 57.0 | 60.0 | 0.00 | 0.00 | 0.00 | 10,179 | 6,624 | 7,042 |
| H | 55.4 | 57.0 | 60.0 | 0.00 | 0.00 | 0.00 | 2,181 | 2,296 | 2,136 |

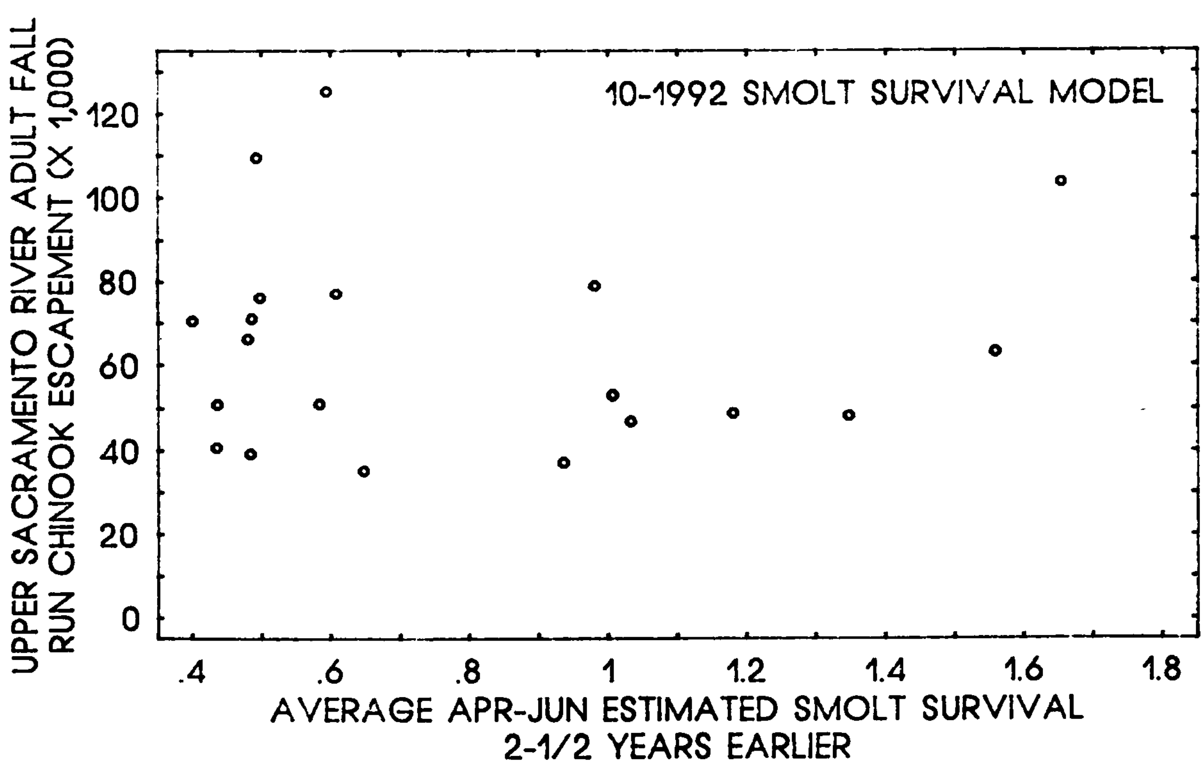
The results of these analyses, Table 25, indicate that Alternative H provides the best calculated survival and the base (actual operating conditions) the worst. Alternative H has both the Cross Channel and Georgiana Slough closed from February 1 through April 30 and average monthly western Delta flows not to exceed –2,000 cfs during the same period. (To be on the safe side, DWR modelers did not allow reverse flows to exceed –1,000 cfs; thus, Alternative H is not the same as envisioned by NMFS.) Alternative E has the same closures but calls for meeting D-1485 salinity standards and with no pumping or reverse flow criteria.

Table 25
RESULTS OF SURVIVAL MODEL USING NMFS ALTERNATIVES

| | BASE 88 | ALT E | ALT B | ALT C | ALT H |
|---|---|---|---|---|---|
| FEB | 1.22 | 1.85 | 2.41 | 2.46 | 3.23 |
| MAR | 1.13 | 1.94 | 2.26 | 2.09 | 2.83 |
| APR | 1.22 | 1.39 | 1.66 | 1.63 | 2.24 |

The model results are to be used with caution. Although they appear to make intuitive sense, some of the statistical components are troublesome. Even with fall run, the model does not appear to be a good predictor of subsequent escapement (Figure 48). (The upper Sacramento River fall run was selected for this analysis because all of the resulting smolts must swim through the Delta on their way to the ocean.) Over the next few months, Interagency Program staff will be conducting further evaluations of the model and data used to develop it.

Figure 48
PLOT OF CALCULATED SALMON SMOLT SURVIVAL DURING APRIL THROUGH JUNE
VERSUS FALL-RUN CHINOOK ESCAPEMENT TO THE UPPER SACRAMENTO RIVER 2-1/2 YEARS LATER



## Direct Losses at the State and Federal Pumps

Although in theory the smolt survival model includes all sources of mortality for Sacramento River outmigrants moving through the Delta, both direct and indirect, it is of interest to examine the number of winter-run estimated to have been lost at the pumps. The following section examines these losses for the 1992 outmigration (when we had the best data) and for the period 1980-1992. We did not use earlier data because of questions regarding its reliability.

Some recent USFWS data provide additional perspective on salvage of juvenile Chinook salmon migrating down the Sacramento River and through the Delta. Over the years the USFWS has made several large releases of marked Chinook salmon in the Sacramento River near Sacramento. Some relevant data from these releases, made when the Delta Cross Channel is open, are shown in Table 26. For purposes of these analyses the relevant data are in the final column of the table, *ie* percent of release salvaged. The percentage ranged from 0.001 to 0.474 with a mean of 0.168.

Table 26
PROPORTION OF FISH RELEASED DURING INTERAGENCY SMOLT SURVIVAL EXPERIMENTS THAT WERE ESTIMATED TO HAVE BEEN SALVAGED AT THE CVP AND SWP FISH FACILITIES
Data Are for Releases Made Above the Delta Cross Channel When It Was Open
(Adapted from DFG 1992)

| Release Date | Release Location | Number Released | Survival Index | Total Salvage | Percent Salvaged |
|---|---|---|---|---|---|
| 04/25/91 | Miller Park | 102,664 | 0.77 | 8 | 0.008 |
| 04/29/91 | Miller Park | 107,608 | 0.48 | 1 | 0.001 |
| 05/07/90 | Miller Park | 48,390 | 0.85 | 6 | 0.012 |
| 05/02/90 | Courtland | 52,612 | 0.84 | 26 | 0.049 |
| 05/05/88 | Miller Park | 102,736 | 0.65 | 486 | 0.474 |
| 05/06/88 | Courtland | 102,480 | 0.76 | 461 | 0.450 |
| 05/01/87 | Courtland | 100,919 | 0.40 | 186 | 0.184 |
| | | | | Mean = | 0.168 |

Since these releases were all made when the Cross Channel gate was open, the percent salvaged should represent the maximum expected. The data are from spring and summer when losses across the Delta may be high. With winter run coming down in colder weather, indirect losses should be much lower and salvage rates higher. Although the difference is unknown, it is reasonable to expect salvage rates for winter run could be twice as high as those for fall run. Even then the rates would be on the order of a fraction of a percent.

Closing the Delta Cross Channel, which is common during typical winter months, would further reduce the percentage recovery, since the only access is through Georgiana Slough. There have been almost no recoveries of marked fish at the salvage facilities from releases made below the Delta Cross Channel (USFWS 1992). Since the Ryde (below Cross Channel) releases were made under a variety of conditions, these data indicate that salmon that move past the Delta Cross Channel do not move back up the San Joaquin River to the pumps.

1992 Take at the CVP and SWP Intakes. In 1992, DFG, DWR, and USFWS made estimates of winter-run take for the February/March period. Since these estimates varied widely, a small group of biologists representing NMFS, USFWS, USBR, DFG, and DWR met on several occasions during the spring and summer of 1992 in an attempt to develop analyses leading to an agreed upon number for 1992 take. The effort was quite productive although agreement was not reached on all factors used in the take estimates. The following discussion largely reflects the results of these meetings.

To calculate take (or loss), the following data and assumptions from the facilities are needed.

- Total number and length of salmon salvaged on a daily basis.
- A system of sorting the salmon by run.
- Estimates of screen efficiency which are derived from fish length and channel velocities.
- Estimates of handling and hauling losses.

After considerable discussion and data analyses the ad hoc group agreed to use the following data and rate estimates for calculations.

Salvage - After about January 15, 1992, the facility operators measured every Chinook salmon captured during the counting period. These data were used to expand actual counts to numbers of Chinook salmon salvaged. Total length, as measured by the operators, was converted to fork length by the DFG equation:

*FLmm = TLmm 0.9056 + 1.6700.*

Screen efficiency - Daily screen efficiencies for winter-run were calculated for the SWP by using velocity and fish length in one of the two following equations, depending on fish size:

*Screening efficiency = 0.630 + (0.0494)(V,fps) for fish <100 mm*
*Screening efficiency = 0.568 + (0.0579)(V,fps) for fish >100 mm*

The calculated efficiencies are for the combined primary and secondary systems. We assumed 75 percent efficiency for the CVP because velocity data were not available.

Prescreening loss rates - For the CVP the agreed upon prescreening loss rate is 15 percent. Although the 15 percent was not experimentally derived it has been used for several years to calculate CVP losses. For the SWP, agreement on a similar loss rate could not be reached. Colder water temperatures, higher pumping, and larger fish led some of us to conclude that during February and March (when most of the winter-run were at the intake) the loss rate should have been lower than the 75 used in calculating losses under terms of the 4-pumps mitigation agreement. As a compromise measure we agreed to provide loss estimates using 50 and 75 percent prescreening loss rates for the SWP. We did agree that more studies are needed to determine if predation in Clifton Court Forebay is affected by such variables as pumping rate, prey size, water temperature, and number of predators.

General pictures of the timing and distribution by race of the Chinook salmon salvaged at the State and federal facilities during the period December 1991 through May 1992 are shown in Figures 49 and 50. Similar information for the marked fish are shown in Figures 51 and 52. The salvage data are summarized in Tables 27 and 28. A few general observations about the data.

- The distributions at the facilities do not resemble those seen either at Miller Park or Chipps Island. For example, the percentage catch or salvage by race at Miller Park, SWP, and CVP are:

| | Miller Park | SWP | CVP |
|---|---|---|---|
| Fall | 91.7 | 20.5 | 20.2 |
| Spring | 3.8 | 20.0 | 54.3 |
| Winter | 2.5 | 16.1 | 5.0 |
| Late Fall | 2.0 | 43.2 | 20.7 |

  The percentages are somewhat more similar if the spring and fall runs are combined, which may better reflect suspected recent interbreeding between the two runs.

- There were no salmon salvaged in December and no winter-run salvaged in January at either facility. The percentages and number/acre-foot of total winter-run salvaged by month are:

| | SWP | | CVP | |
|---|---|---|---|---|
| Month | % of Total Salvage | Number per Acre-Foot | % of Total Salvage | Number per Acre-Foot |
| December | 0 | 0 | 0 | 0 |
| January | 0 | 0 | 0 | 0.0001 |
| February | 21.7 | 0.0023 | 7.0 | 0.0012 |
| March | 70.8 | 0.0041 | 63.8 | 0.0061 |
| April | 7.1 | 0.0020 | 28.2 | 0.0066 |
| May | 0.4 | 0.0002 | 0.4 | 0.0002 |

Figure 49
TOTAL CHINOOK SALVAGE, DECEMBER 1991 THROUGH MAY 1992, BY RUN

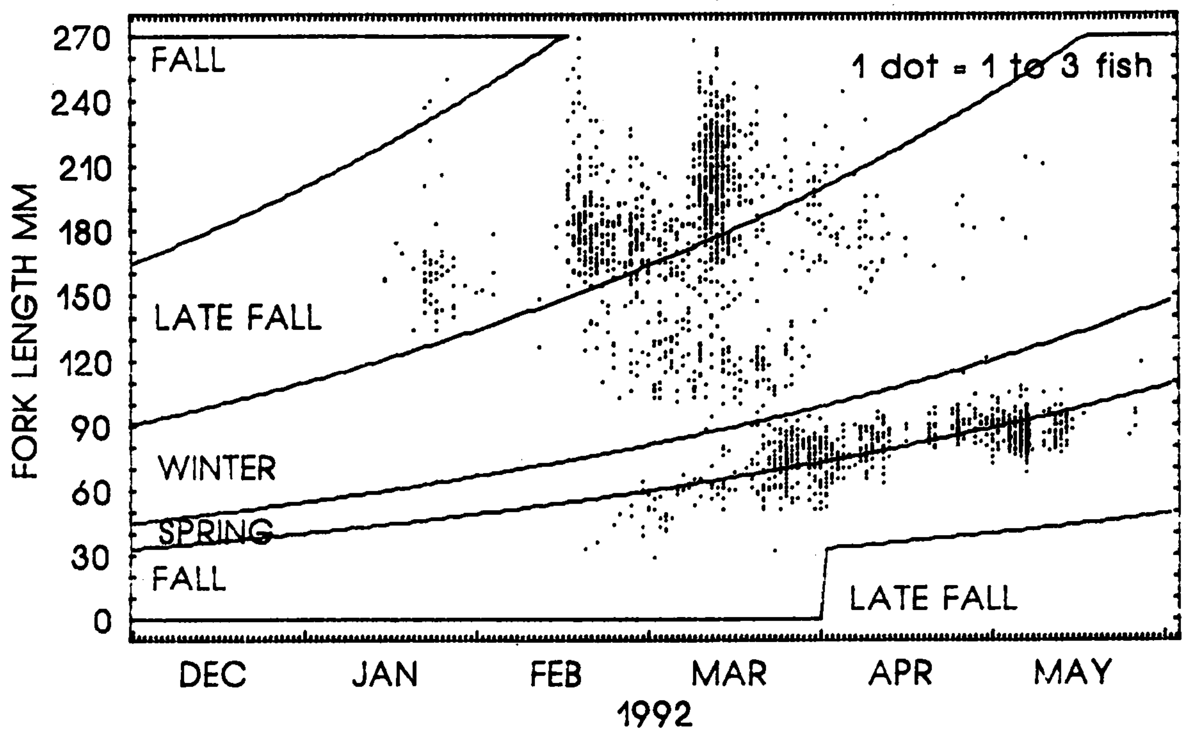



Figure 50
TOTAL CVP SALVAGE, DECEMBER 1991 THROUGH MAY 1992, BY RUN

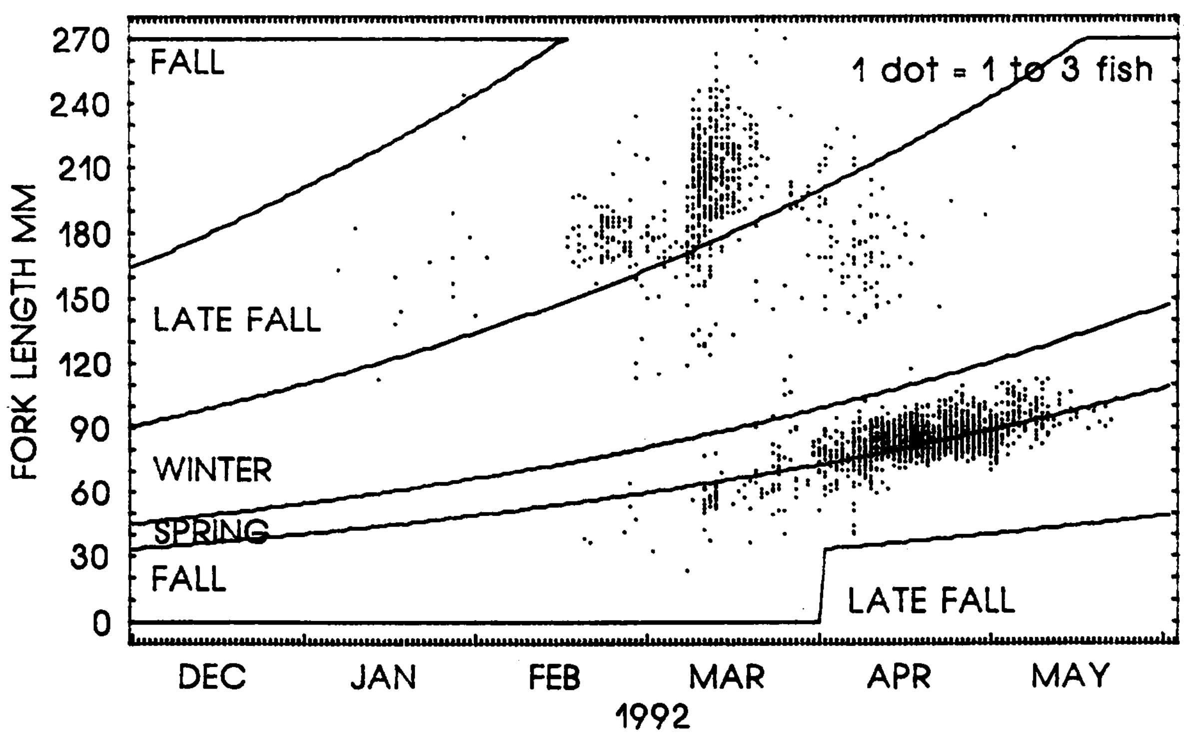


Figure 51
ADIPOSE FIN-CLIPPED CHINOOK SALMON SALVAGED AT THE SWP,
DECEMBER 1991 THROUGH MAY 1992, BY RUN

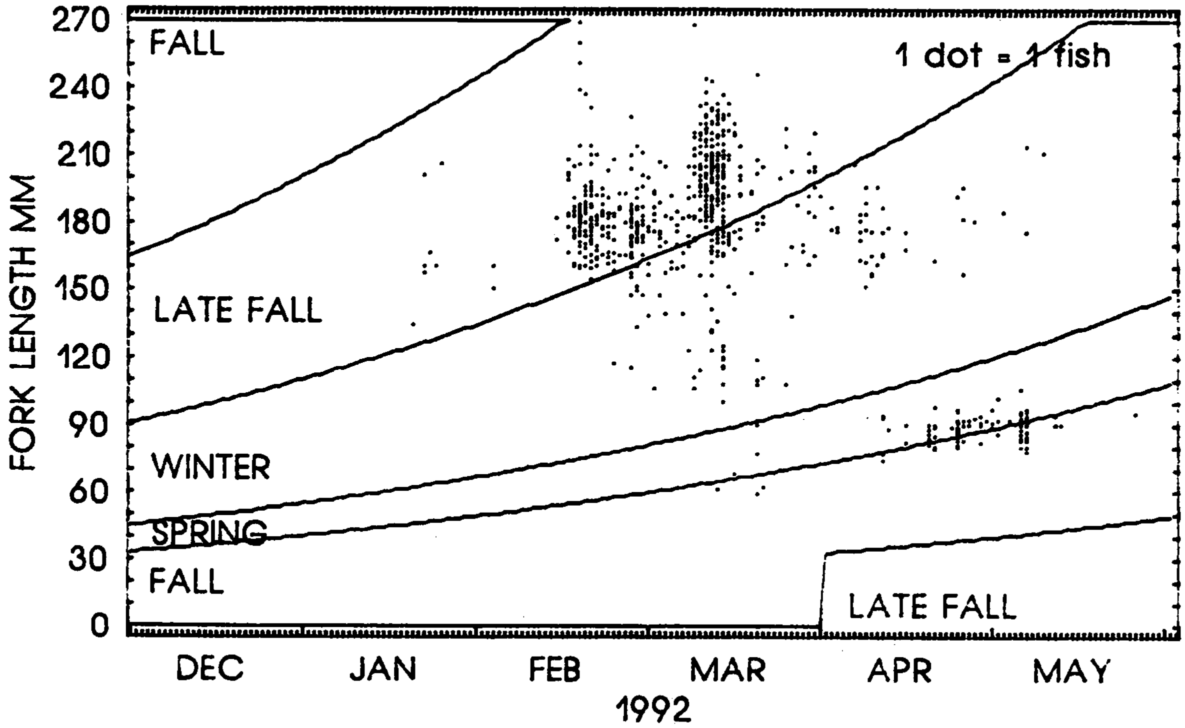



Figure 52
ADIPOSE FIN-CLIPPED CHINOOK SALMON SALVAGED AT THE CVP,
DECEMBER 1991 THROUGH MAY 1992, BY RUN

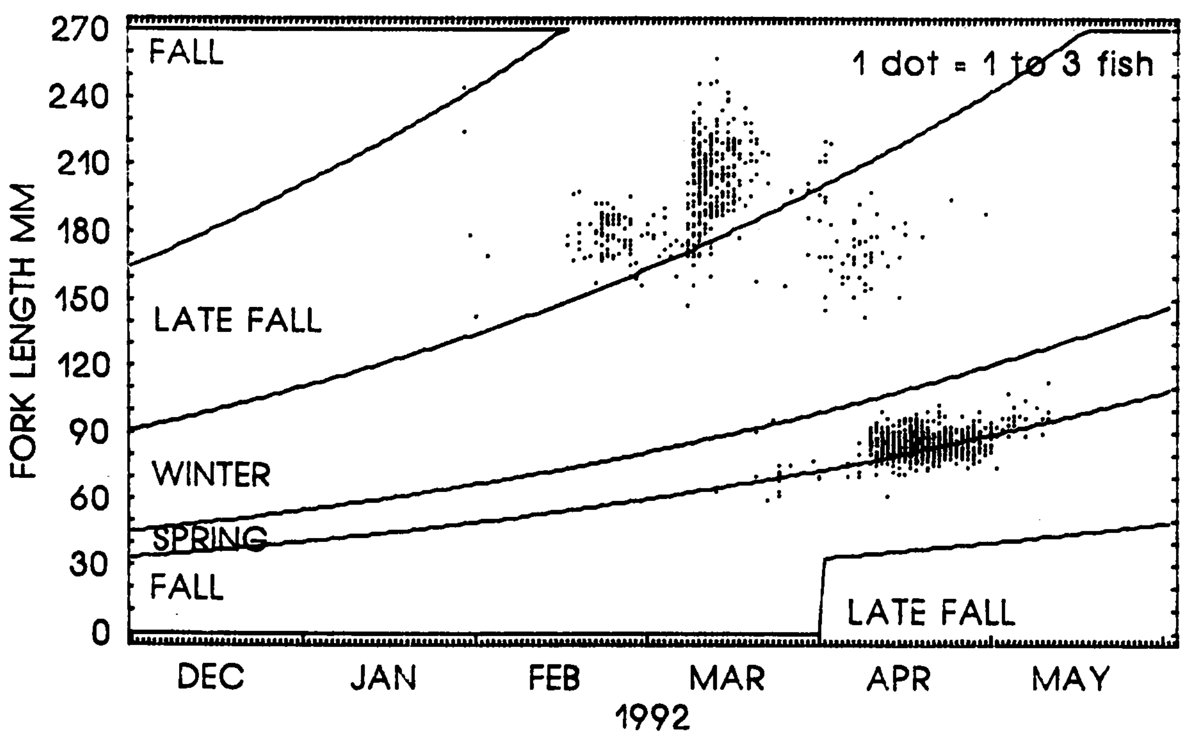


Table 27

EXPANDED FOUR RACES OF CHINOOK SALMON SALVAGED AT THE SWP AND CVP DELTA FISH FACILITIES

The races were categorized using DFG daily length interval criteria derived from DFG bimonthly length intervals. The special length salvage dataset was used; therefore the expansion involved only the fraction of time sampled. This salvage dataset represents the DFG data edited by DWR, although the data are still subject to revision.

| | | State Water Project | | Central Valley Project | |
|---|---|---|---|---|---|
| | | Expanded Winter Run | Expanded Chinook | Expanded Winter Run | Expanded Chinook |
| January 1992 | Wild | 0 | 203 | 0 | 48 |
| | Clipped | 0 | 26 | 0 | 48 |
| | Unknown | 0 | 100 | 12 | 84 |
| | Total | 0 | 329 | 12 | 180 |
| February 1992 | Wild | 310 | 1197 | 72 | 468 |
| | Clipped | 159 | 2347 | 72 | 2184 |
| | Unknown | 0 | 0 | 24 | 120 |
| | Total | 469 | 3544 | 168 | 2772 |
| March 1992 | Wild | 1018 | 4080 | 834 | 6479 |
| | Clipped | 537 | 2528 | 615 | 9349 |
| | Unknown | 41 | 95 | 84 | 192 |
| | Total | 1596 | 6703 | 1533 | 16020 |
| April 1992 | Wild | 27 | 660 | 175 | 5833 |
| | Clipped | 116 | 342 | 478 | 7761 |
| | Unknown | 0 | 0 | 24 | 189 |
| | Total | 143 | 1002 | 677 | 13783 |
| May 1992 | Wild | 0 | 837 | 8 | 736 |
| | Clipped | 7 | 88 | 0 | 80 |
| | Unknown | 0 | 0 | 0 | 0 |
| | Total | 7 | 925 | 8 | 816 |
| Cumulative 1992 | Wild | 1355 | 6977 | 1089 | 13564 |
| | Clipped | 819 | 5331 | 1165 | 19422 |
| | Unknown | 41 | 195 | 144 | 585 |
| | Total | 2215 | 12503 | 2398 | 33571 |

- The percentage of salvaged Chinook by race that were tagged was:

| | SWP | CVP |
|---|---|---|
| Fall | 9.5 | 60.3 |
| Spring | 15.9 | 55.5 |
| Winter | 39.6 | 53.3 |
| Late Fall | 58.5 | 71.2 |

Historical yearly winter-run salvage data for both facilities are summarized in Table 29. The winter salvage numbers are based on the April 1992 DFG size classification system and, except for 1992, on the monthly intervals. If daily length data were available it is likely that all winter-run estimates before 1992 would be lower than shown.

Table 29
ESTIMATED ANNUAL SALVAGE OF ALL CHINOOK AND WINTER-RUN SALMON AT THE SWP AND CVP DELTA FACILITIES, 1981-1992

| | State Water Project | | Central Valley Project | |
|---|---|---|---|---|
| Year | Winter | Total | Winter | Total |
| 1981 | 17,588 | 66,577 | 3,218 | 30,759 |
| 1982 | 40,677 | 84,834 | 8,621 | 28,066 |
| 1983 | 506 | 30,092 | 40,289 | 63,653 |
| 1984 | 7,013 | 28,997 | 29,216 | 95,429 |
| 1985 | 4,348 | 31,592 | 11,470 | 58,683 |
| 1986 | 19,319 | 167,737 | 14,540 | 504,863 |
| 1987 | 5,204 | 45,590 | 5,491 | 51,247 |
| 1988 | 15,834 | 55,817 | 6,629 | 31,603 |
| 1989 | 10,544 | 60,599 | 6,914 | 19,764 |
| 1990 | 8,780 | 25,609 | 174 | 2,352 |
| 1991 | 3,109 | 39,167 | 748 | 31,226 |
| 1992 | 2,208 | 11,482 | 2,378 | 32,719 |

The total winter-run salvage for each facility from 1981 through 1992 is surprisingly similar — 135,130 for the SWP and 128,550 for the CVP, or an average of about 12,000 per year. There were, of course, considerable annual variations, and the year-by-year salvage numbers are not similar. Plotting total annual CVP winter-run salvage versus SWP winter-run salvage indicated there was no relationship ($r^2 = 0.03$). If predation rates are as used in loss computations, one would expect salvage at the CVP to be about 3 to 4 times that at the SWP. This assumes equal pumping and equal concentrations of salmon in the water entering the facilities with the exception of a large difference in 1986 salvage, total numbers of salmon salvaged at the two facilities are quite similar.

Another way to look at the salmon salvage data is to plot percentage of winter-run of the total salvage (Figure 53). Although the period of record is relatively short, there is no apparent trend in the fraction. The downward trend in winter adult stock should have resulted in a lower fraction of winter-run at the facilities. Interestingly enough, over the period the record the average fraction of winter-run in the total salvage was essentially the same for both facilities at about 21.5 percent. This fraction is surprisingly high given that the facilities salvage mostly San Joaquin salmon, with the USBR salvaging an even higher fraction of San Joaquin than the State. This again points out that there are problems in using the size criteria.

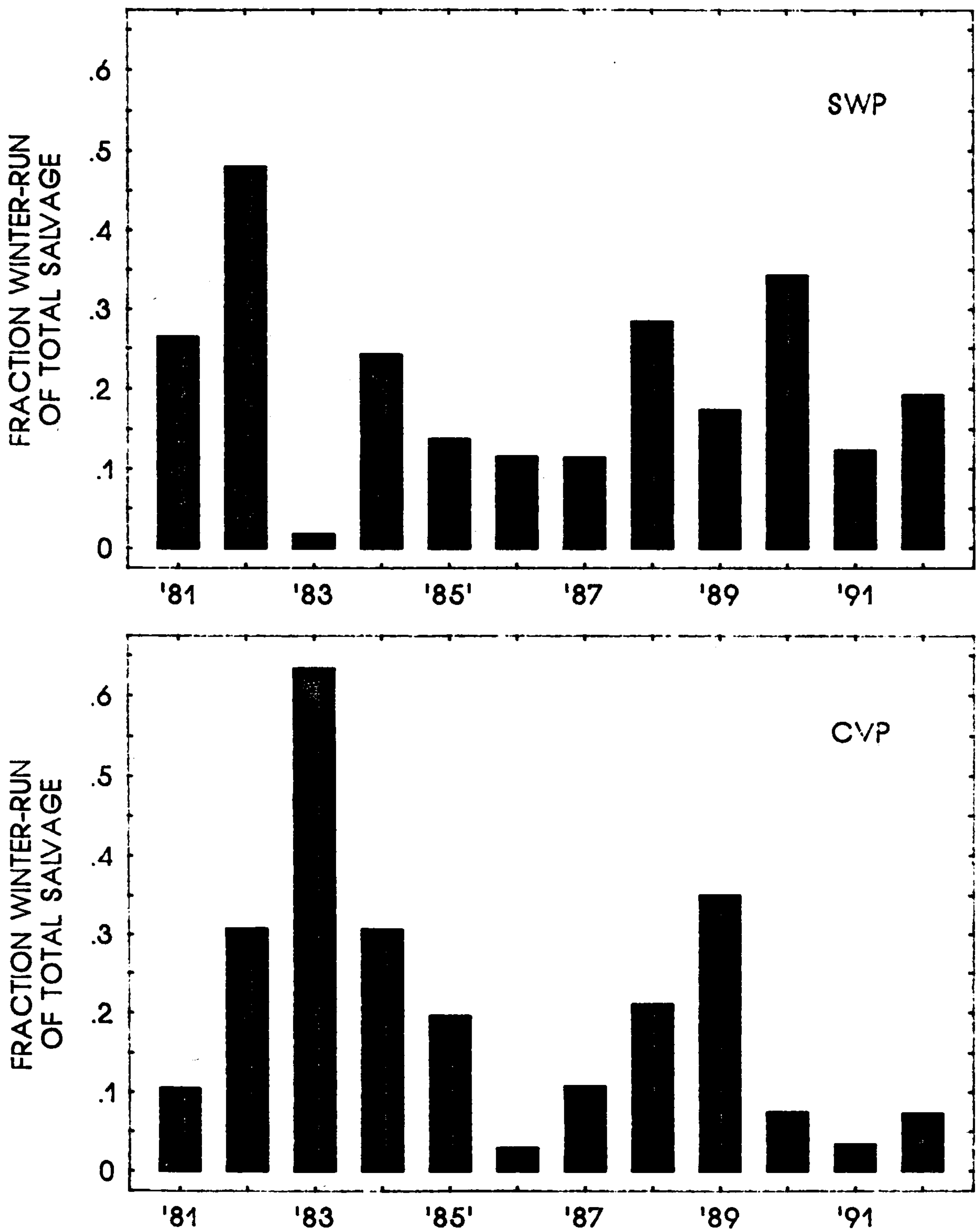
Table 28
FOUR RACES OF CHINOOK SALMON SALVAGED AT THE
SWP AND CVP DELTA FISH FACILITIES
Races were determined using DFG daily length interval criteria derived from DFG bimonthly length intervals.
This salvage dataset represents DFG data edited by DWR, although the data are still subject to revision.

| | | State Water Project | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fall Run | Spring Run | Winter Run | Late-Fall Run | >270mm | Total |
| January 1992 | Wild | 3 | 0 | 0 | 44 | 0 | 47 |
| | Clipped | 0 | 0 | 0 | 7 | 0 | 7 |
| | Unknown | 0 | 0 | 0 | 14 | 0 | 14 |
| | Total | 3 | 0 | 0 | 65 | 0 | 68 |
| February 1992 | Wild | 11 | 2 | 31 | 75 | 0 | 119 |
| | Clipped | 0 | 0 | 14 | 230 | 0 | 244 |
| | Unknown | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 11 | 2 | 45 | 305 | 0 | 363 |
| March 1992 | Wild | 109 | 187 | 163 | 231 | 0 | 690 |
| | Clipped | 3 | 3 | 82 | 293 | 0 | 381 |
| | Unknown | 0 | 0 | 6 | 8 | 0 | 14 |
| | Total | 112 | 190 | 251 | 532 | 0 | 1085 |
| April 1992 | Wild | 46 | 110 | 6 | 4 | 0 | 166 |
| | Clipped | 12 | 50 | 35 | 1 | 1 | 99 |
| | Unknown | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 58 | 160 | 41 | 5 | 1 | 265 |
| May 1992 | Wild | 220 | 56 | 0 | 0 | 0 | 276 |
| | Clipped | 26 | 14 | 4 | 0 | 0 | 44 |
| | Unknown | 0 | 0 | 0 | 0 | 0 | 0 |
| | Total | 246 | 70 | 4 | 0 | 0 | 320 |
| Cumulative 1992 | Wild | 389 | 355 | 200 | 354 | 0 | 1298 |
| | Clipped | 41 | 67 | 135 | 531 | 1 | 775 |
| | Unknown | 0 | 0 | 6 | 22 | 0 | 28 |
| | Total | 430 | 422 | 341 | 907 | 1 | 2101 |

CVP and SWP Direct Entrainment 1980-1992. The 1992 draft biological assessment contained information related to the total Chinook salmon and winter-run salvaged at the State and federal facilities during the period 1981 through 1991. Data before 1981 were not used because necessary length information was not available from DFG. The information was updated for the present assessment by:

- Adding 1992,
- Converting all salvaged fish from total length to fork length, and
- Using the newest (April 1992) version of the DFG size interval classification system to classify the winter-run by race.

Figure 53
FRACTION OF WINTER-RUN EXPANDED SALVAGE OF TOTAL EXPANDED SALVAGE, JANUARY THROUGH APRIL, 1981-1992



To remove the potential impacts of differences in total amount of water pumped, the annual average number of winter-run Chinook salvaged per thousand acre-feet pumped during January through April over time has been plotted in Figure 54. There is little apparent difference salvage per unit volume at the two facilities and no discernible trend over time.

The months in which maximum salvage of Chinook salmon (number/acre-foot) occurred at the facilities varied considerably among water years and between facilities (Table 29). Although it is difficult to detect a pattern in the relative rankings, one could conclude that March and April are the months in which density of winter-run-sized fish was highest. The high ranking for April and May at the CVP intakes does not seem to be in line with accepted outmigration patterns.

For the CVP, more than half of all the races were tagged; percentages that are much higher than expected based on known hatchery releases. The high percentages of tagged winter run are surprisingly high in that there were probably several times more wild winter-run than hatchery. To avoid undue killing of possible hatchery winter run, we were able to read only two of tagged salmon falling into the winter-run category. These two salmon, which died accidentally during handling at the federal facility, were identified as fall-run yearlings released from the Merced River Fish Facility. The percentage of tagged late-fall-run is also high given that only one-third of the 1992 brood year production from Coleman was tagged and there should have been a substantial number of wild late-fall-run juveniles.

Calculated winter-run losses for 1992 are shown in Table 30 for the SWP and Table 31 for the CVP. Not specifically shown are the losses for the period April 9 through April 30, 1992. In an April amendment to the February 14, 1992 Biological Opinion, NMFS stipulated that no more than 400 winter- run could be taken from April 9 through April 30. The actual calculated take was 355 Chinook salmon fitting into the winter-run size interval. The losses used a 75 percent predation loss rate for Clifton Court Forebay and 15 percent for the CVP intake.

Again using the 75 percent predation rate for the SWP and 15 percent for the CVP, the total calculated 1992 take was 10,411. Reducing the Clifton Court Forebay predation rate from 75 percent to 50 percent reduces the take by more than 50 percent to 4,782 Chinook salmon that fit into the winter-run size category.

As mentioned earlier, many members of the committee working on 1992 loss estimates were not convinced that we should move away from the 75 percent predation rate in Clifton Court Forebay. Since the predation rate drives the loss estimate, it is important to summarize some of the arguments that pointed to a lower rate for February-March period.

Figure 54
EXPANDED SALVAGED WINTER-RUN PER
THOUSAND ACRE-FEET OF EXPORT PUMPING, JANUARY THROUGH APRIL, 1981-1992

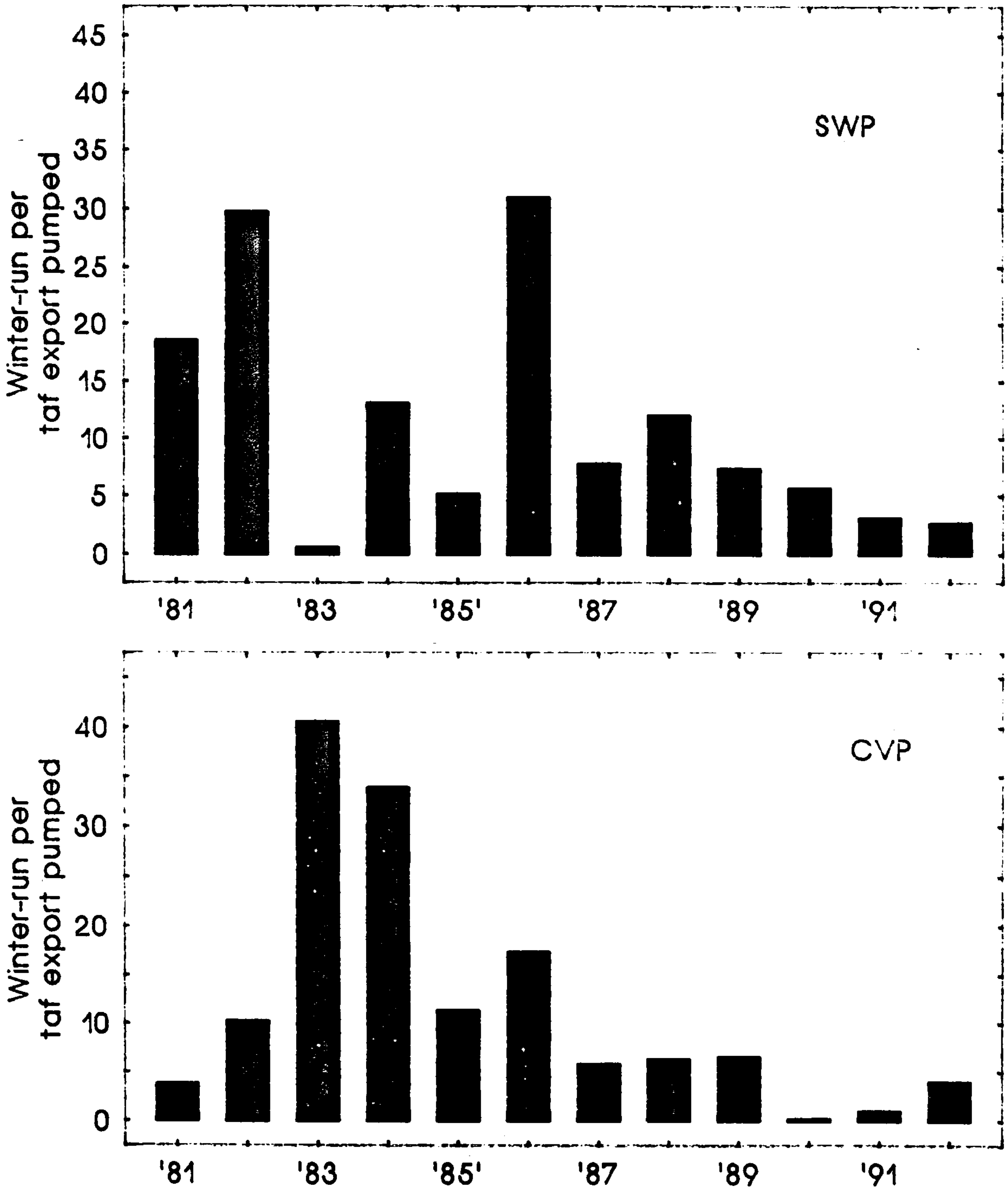


Table 30

ESTIMATES OF THE NUMBER OF CHINOOK AND WINTER-RUN CHINOOK DIRECT LOSSES AT THE SWP ASSUMING 25, 50, AND 75 PERCENT PRE-SCREENING PREDATION RATES

Expanded Chinook and winter-run Chinook salvage was estimated using the special lengths dataset and DFG daily winter-run length intervals. Daily screen efficiencies were calculated for all Chinook and winter-run Chinook. Comparable CVP numbers were not calculated because there are no data available to calculate primary screen efficiency.

| | Estimated Loss Using Predation Rate of: 25% | 50% | 75% |
|---|---|---|---|
| January 1992 | | | |
| Chinook | 102 | 317 | 963 |
| Winter Run | 0 | 0 | 0 |
| February 1992 | | | |
| Chinook | 2557 | 5608 | 14760 |
| Winter Run | 343 | 749 | 1967 |
| March 1992 | | | |
| Chinook | 4700 | 10401 | 27505 |
| Winter Run | 1072 | 2406 | 6408 |
| April 1992 | | | |
| Chinook | 761 | 1642 | 4286 |
| Winter Run | 118 | 249 | 641 |
| May 1992 | | | |
| Chinook | 704 | 1519 | 3963 |
| Winter Run | 6 | 13 | 33 |
| Cumulative 1992 | | | |
| Chinook | 8825 | 19489 | 57007 |
| Winter Run | 1540 | 3417 | 9049 |

Table 31

ESTIMATES OF THE NUMBER OF CHINOOK AND WINTER-RUN CHINOOK DIRECT LOSSES AT THE CVP ASSUMING 75 PERCENT SCREENING EFFICIENCY AND 15 PERCENT PRE-SCREENING PREDATION RATES

Expanded Chinook and winter-run Chinook salvage was estimated using the special lengths dataset and DFG daily winter-run length intervals.

| | Estimated Expanded Salvage Rate | Estimated Number Prescreen @ 75% Eff | Estimated Number Preforebay @ 15% Pred | Estimated Direct Loss |
|---|---|---|---|---|
| January 1992 | | | | |
| Chinook | 180 | 240 | 282 | 102 |
| Winter Run | 12 | 16 | 19 | 7 |
| February 1992 | | | | |
| Chinook | 2772 | 3696 | 4348 | 1576 |
| Winter Run | 168 | 224 | 264 | 96 |
| March 1992 | | | | |
| Chinook | 16020 | 21360 | 25129 | 9109 |
| Winter Run | 1533 | 2044 | 2405 | 872 |
| April 1992 | | | | |
| Chinook | 13783 | 18377 | 21620 | 7837 |
| Winter Run | 677 | 903 | 1062 | 385 |
| May 1992 | | | | |
| Chinook | 816 | 1088 | 1280 | 464 |
| Winter Run | 8 | 11 | 13 | 5 |
| Cumulative 1992 | | | | |
| Chinook | 33571 | 44761 | 52659 | 19088 |
| Winter Run | 2398 | 3198 | 3763 | 1365 |

- Pumping rate — The 75 percent value is based on the average of three tests that were conducted at average pumping rates ranging from about 2,000 to 4,000 cfs. In 1992 another experiment was conducted at an average pumping rate of about 500 cfs. The four data points are plotted in Figure 55 and a least square regression line fitted ($r^2$=0.95). Extrapolating to the 6,400 cfs pumping that occurred in February and March 1992, the expected predation would be about 45 percent. A lower predation rate at high pumping makes biological sense in that residence time, and exposure time, is reduced.

- Temperature — Using data on perciform fish from Windell (1978) found, as expected, that the evacuation time (an index of digestion rate and feeding) varies with temperature. At 10°F the average number of days it took to clear the gut was about 44 days, which decreased to 20 days at 20°F. This follows quite well the van't Hoff rule of doubling the metabolic needs of a poikilotherm for each 10°C rise in temperature. During February and March 1992, Delta water temperatures were in the range of 9 to 16°C (data from Freeport, Figure 56.) DFG's 1992 Biological Assessment and Opinion on the striped bass planting program also concluded that striped bass predation on juvenile salmonids is reduced during the colder months.

- Number of predators — The previous predation studies were conducted when there were higher adult striped bass populations than DFG estimates to be present in 1992 (from 1.5 to 2.0 million adults to a million or less at present). The expectation would be that there would now be fewer sub-adult striped bass in the forebay than when adult population levels were higher. Earlier DFG tagging studies suggested that the forebay striped bass population varied seasonally, with lower numbers in midwinter (reference). In addition, 1991 and 1992 had an active predator removal program in the forebay.

  In 1992, DFG used a modified Peterson mark/recapture technique to estimate striped bass abundance on two occasions in the forebay — once during February/March and the second during April/May. The two estimates were in close agreement (142,023 in February/March and 162,281 in April/May) and were higher than expected and even higher than in previous years. Although there are fairly wide confidence intervals around the estimates, based on these data it appears a large share of the 2-year-old striped bass in the estuary are in Clifton Court Forebay. More data are needed to determine if the estimates are reasonable.

- Prey size — Winter-run Chinook salmon entering the forebay are generally larger than hatchery salmon used in previous predation studies. Larger prey should be better able to avoid predators.

- Turbidity — Since striped bass are sight feeders, increased turbidity should reduce predator effectiveness. During storms, and high flows such as occurred this past February and March, turbidity in the Delta is generally near its annual maximum.

Even without issues related to predation, there are several inconsistencies in the salvage data which raise questions regarding the validity of the estimates. The following are a few of these inconsistencies.

- We know exactly how many marked and unmarked hatchery Chinook salmon were released in the Sacramento River. Assuming that survival rates of these various releases were approximately equal, one would expect that the salvage, or losses, at facilities of those marked would be about the same proportion as the relative size of the release groups. The release groups were:

Figure 55
ESTIMATED CLIFTON COURT FOREBAY PREDATION RATES AT VARIOUS PUMPING RATES

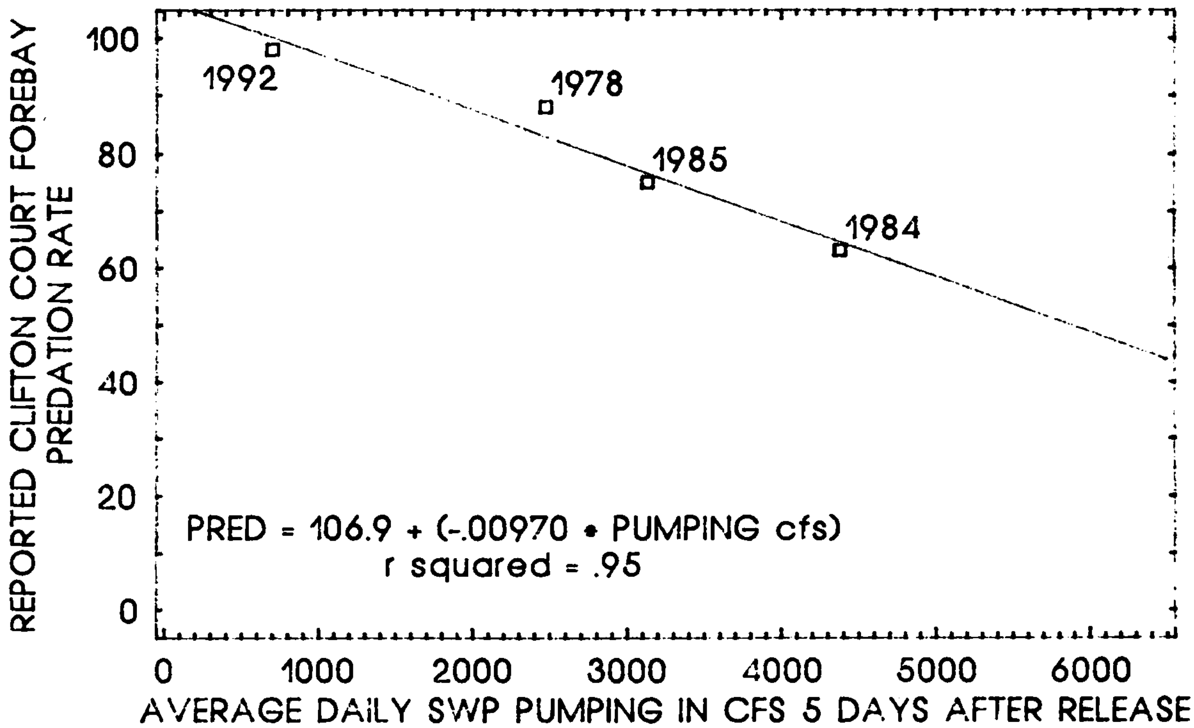
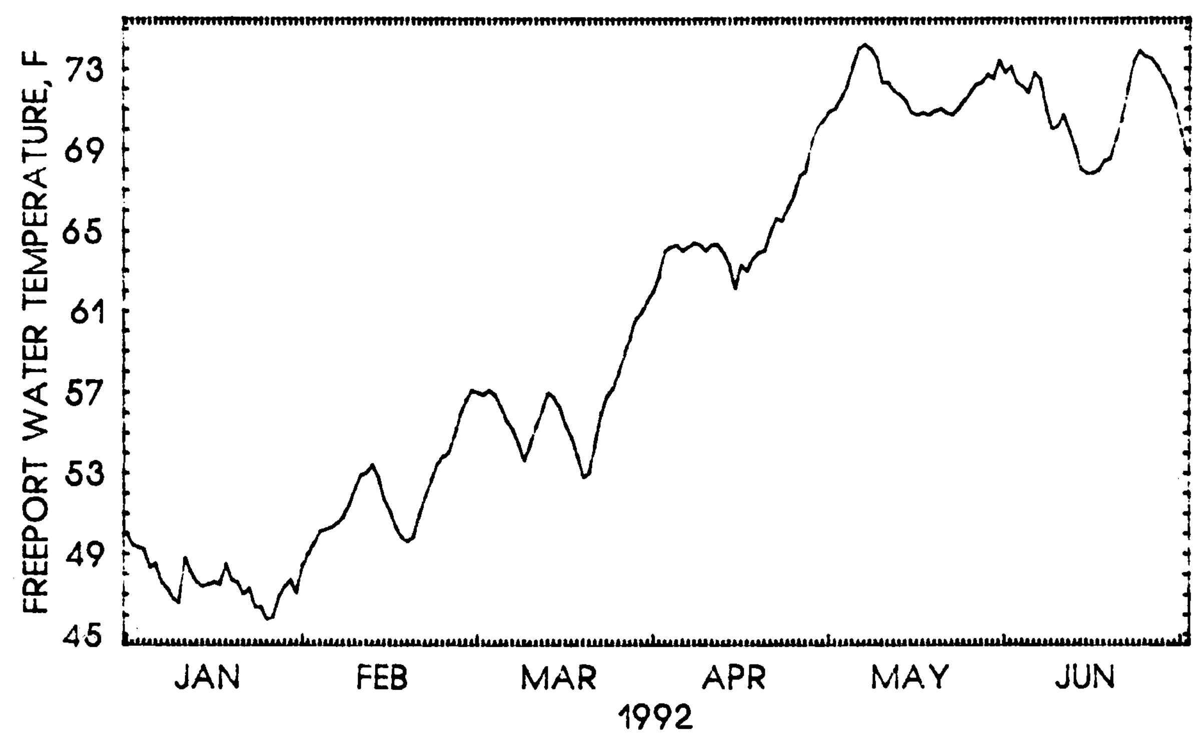



Figure 56
MEAN DAILY WATER TEMPERATURE IN THE SACRAMENTO RIVER AT FREEPORT, JANUARY 1 THROUGH MAY 20, 1992



| | |
|---|---|
| Winter-run Chinook (information provided by Jim Smith, USFWS) | Source: Coleman National Fish Hatchery<br>Release date: January 21, 1992<br>Number marked: 11,582<br>Release location: Near Redding |
| Late-fall-run Chinook (information provided by Jim Smith, USFWS) | Release date: January 3 and 6, 1992<br>Total number released: About 300,000<br>Release location: Hatchery on Battle Creek<br>Number tagged of total: 119,145 |
| Spring-run Chinook (information provided by Don Schlicting, DFG) | Release date: March 1992<br>Release location: Clear Creek<br>Total number released: 205,208<br>Number of total that were tagged: 100,000±<br>Size distribution: Average 66 mm;<br>Range 55 to 75 mm |

Of the tagged fish the number released by race is:

| | |
|---|---|
| Late Fall - | 119,145 |
| Spring - | 100,000 |
| Winter - | 11,582 |

All salmon had the same external mark.

Expected and observed ratios from salvage for the three marked groups are:

| | Late Fall | Spring | Winter |
|---|---|---|---|
| Expected | 1 | 1 | 0.1 |
| Observed | 1 | 13 | .25 |

The marked spring-run are underrepresented and the winter-run over-represented in the salvage. Since the winter-run and late-fall were about the same size at release, and were released at about the same time and location, survival to and through the Delta should be about equal.

- The apparent growth rates of the hatchery winter-run and winter-run were considerably different. Based on visual inspections of data from Figure 29 and Figures 57 and 58, on the average the winter-run about doubled in size between early January and march, whereas the late-fall-run increased in length by less than 50 percent. It is likely that the DFG curves overestimate the growth of the larger salmon, since their size is not changing as rapidly as the curves predict. This conclusion is supported by the observation that two fall-run salmon from the Merced Fish Facility were in the fall-run interval in November and in the winter-run interval when recaptured in April.
- The percentage of hatchery winter-run salmon was about twice as high as expected at both facilities.

Figure 57
LENGTH FREQUENCY OF LATE-FALL-RUN AND WINTER-RUN CHINOOK
SALVAGED AT THE SWP, JANUARY 1 THROUGH MAY 31, 1992

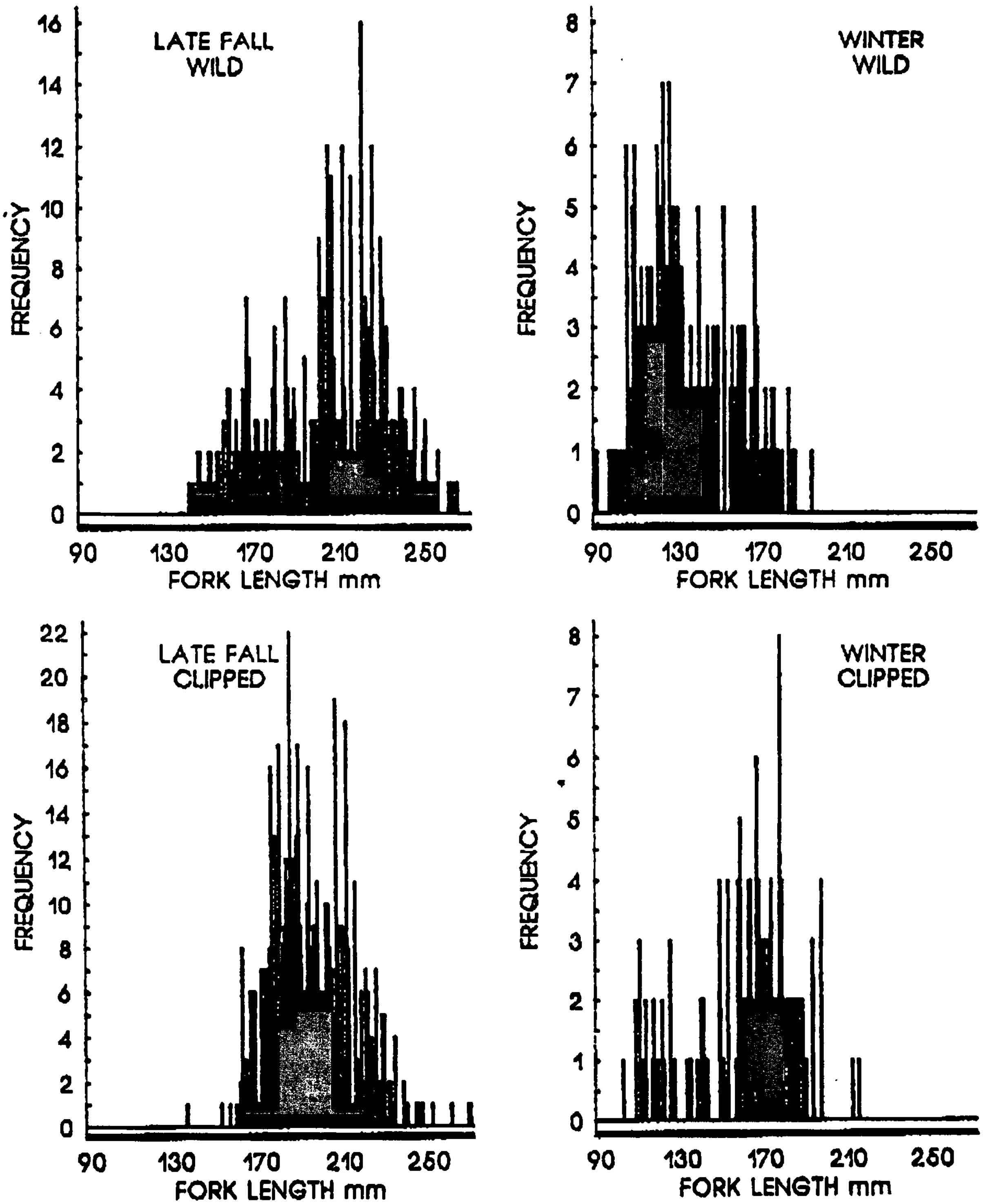
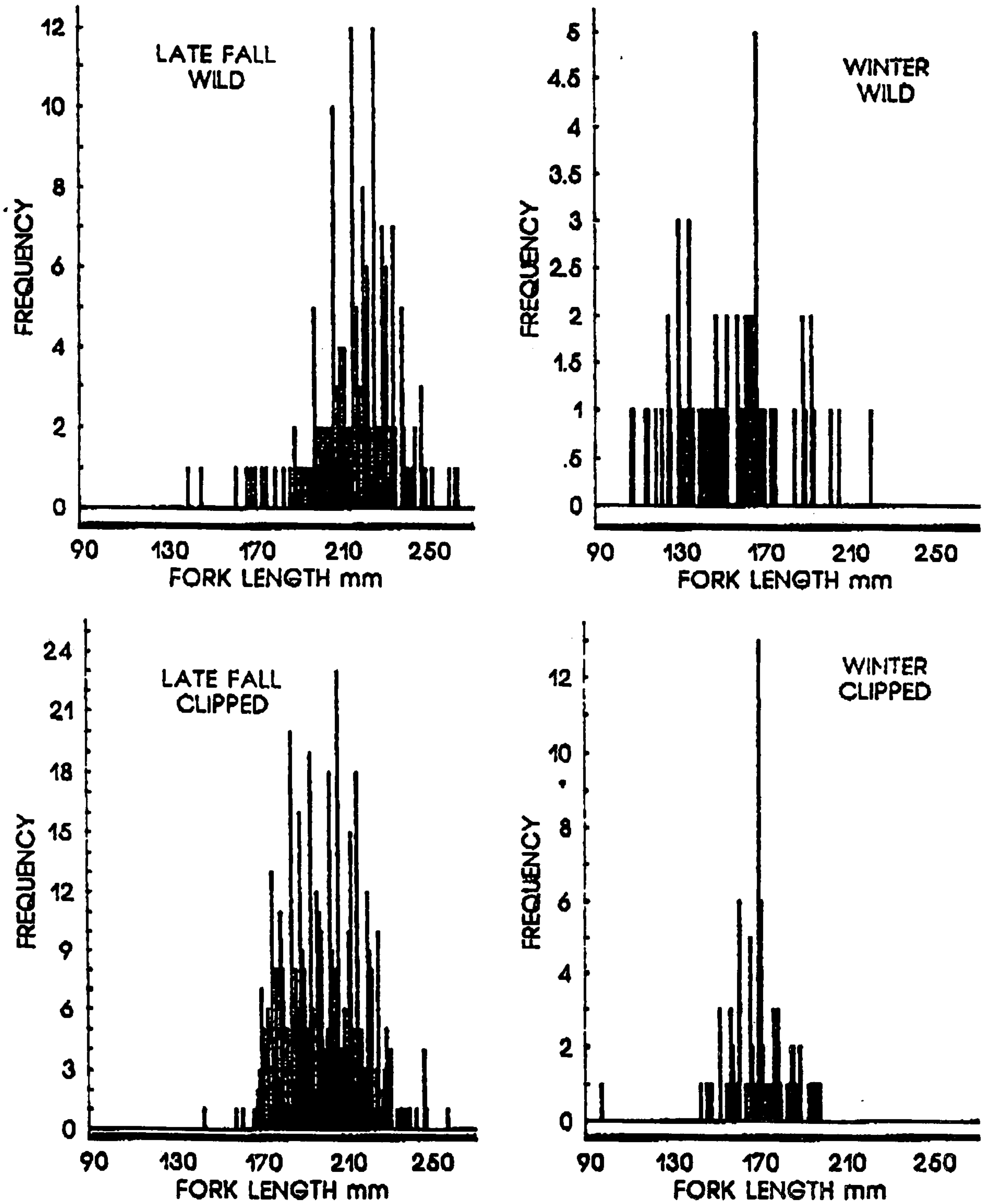


Figure 58
LENGTH FREQUENCY OF LATE-FALL-RUN AND WINTER-RUN CHINOOK
SALVAGED AT THE CVP, JANUARY 1 THROUGH MAY 31, 1992



## Salinity Control Gates

As described earlier, the control gates, which went into operation in 1988, are used to tidally pump low salinity water from the Sacramento River to freshen the interior channels of Suisun Marsh.

The control gates are generally operated from October 1 through May 31 of drier years to meet D-1485 salinity standards. On March 1, 1992, they were placed in the down position and left closed until March 24, 1992. From March 24 until April 30 landowners in the Marsh could only divert from screened diversions. Since only the Roaring River intake was screened, most club managers were unable to divert water during a critical period for vegetation management. Without the February/March rains curtailing gate operation for extended periods would have had serious impacts on the Suisun Marsh plant and animal community, including rare, threatened, and endangered species.

Although there has been relatively little effort devoted to determining the impact of the gates on juvenile operation, or the importance of Montezuma Slough as a migration corridor for salmon outmigrants there are three sets of information which bear on these topics. There are some data on potential predator concentrations around the structure and a theoretical analysis by DFG on the importance of the slough in salmon migrations. The third data set, from USFWS testimony at the 1992 SWRCB hearings, integrates both predation impacts and migration corridor.

DFG has conducted studies of predator abundance before and after the control gates were installed. Raquel (1992) summarized these data which showed that the combined squawfish and striped bass catch rate in 1991 (with project) was 1.9 fish/hour compared to a 1987 preproject catch rate of 1.4 fish/hour. Over the period there was a decline in squawfish catch and an increase in striped bass catch. The data were not analyzed statistically to determine if the preproject and post-project catch/unit effort are different.

In February 1992 in a letter to Jim Lecky (NMFS), Pete Chadwick (DFG) analyzed the possible impact of the Montezuma Slough diversion on winter-run salmon. This analysis, the main text of which is included below, concluded that impacts of the diversion would be low but that there were several unknowns.

> **"Does operation of the gates increase the number of salmon migrating through Montezuma Slough in relation to the normal tidal action?**
>
> "The answer to this question needs to start with a description of the physical change caused by gate operation. Salinity in the marsh channels is reduced by allowing normal tidal action during ebb tide, but closing the gates during flood tide. Hence the block of water which enters the slough is moved downstream rather quickly during each successive ebb tide rather than being pushed back and forth by each ebb and flood tide.

"Actually in Montezuma Slough during low Delta outflows, a typical average velocity is 1,800 cfs during ebb tide and 2,100 cfs during flood tide. Thus a net upstream flow of 300 cfs would occur under normal tidal action in this example. Because gate operation causes flood tide flows to be 0, it would change net velocity to a downstream flow of 1,800 cfs.

"How do fish behave in response to these differences between gate operation and normal tidal action? The only definite applicable fact is that tagging results clearly demonstrate that salmon migrate downstream much more rapidly than net flows would transport them. Thus they must either actively swim downstream or find some way to hold their geographic locations during flood tide or some combination of those two strategies. It seems unlikely that they can actually make downstream progress during flood tide, even if they swim into the current.

"Given all of the above, the most logical conclusion is that the same number of salmon enter Montezuma Slough under both modes of operation, since actual downstream transport is limited to ebb tide and ebb tide flows are not affected by gate operation.

"Under gate operation, the salmon which enter the Slough presumably get moved downstream relatively rapidly by a combination eliminating flood tide and active downstream swimming. Under normal tidal operation movement through the Slough is likely slower, and unless salmon have a way to maintain their geographic location during flood tide, some would be carried back out into the Sacramento River. Considering the known active downstream movement, the fraction carried back out into the Sacramento River is presumably small.

"The only actual evidence to help answer this question comes from marked fall-run salmon released at Ryde on the Sacramento River and recovered at Chipps Island. Survival indices are available for 9 groups released pre-project from 1984-1988 and two groups released during normal tidal operation in 1989 after the gates were installed. Survival indices are also available for three groups released when the gates were operating during 1989 and 1990. The temperature corrected survival index averaged 0.61 (range 0.16-1.28) during normal tidal action and 1.35 (range 1.19-1.62) during gate operation. If gate operation had caused a large increase in the number of salmon passing through Montezuma Slough, it would have tended to decrease apparent survival to Chipps Island rather than the increase which was observed. Factors other than gate operation could change survival, so the results are not definitive.

"Given all of the above, I see no logical reason or evidence to indicate that gate operation would increase the number of salmon migrating downstream through Montezuma Slough.

**"Does the survival of salmon in Montezuma Slough differ under gate operation and normal tidal flow?**

"One potential source of mortality is predation near the control structure. Sampling from 1987 through 1991 indicates an increase in the abundance of predators after the structure was put in place. This is not surprising since predators generally tend to concentrate around structures. Thus the structure may well have increased local predation, but I can think of no logical reason for believing that predation would differ depending on whether gate operation or normal gate operation was occurring.

"Another source of mortality is losses in diversions from the Slough. The only reason I can think of for such losses to differ between modes of operation is that less diversion might occur if the slough were too salty for effective marsh management. That would be more likely to occur during normal tidal action. Obviously screening diversions would reduce mortality and the largest diversion was screened as part of the project.

"Another factor potentially affecting mortality is speed of migration. Presumably the faster fish migrate through the Slough, the less exposure would occur to the various factors causing mortality. The rationale discussed in answering the previous question, suggests that gate operation would cause faster migration and thus less mortality.

"We have no actual evidence of the relative rates of mortality.

**"What proportion of salmon outmigrants go through Montezuma Slough?**

"At low flows a substantial portion of this net Delta outflow goes through Montezuma Slough. For example, total Delta outflow this spring, will probably be in the range of 4,000 cfs to 7,000 cfs. Of that about 1,800 cfs will be moving through Montezuma Slough if the gates are operating. It is difficult to believe, however, that fish can perceive differences in net flow which is the difference between flows integrated over ebb and flood tides rather than a flow occurring at some time. Also, the transport rationale described in answering the first question is contrary to a hypothesis that net flow determines the proportion of salmon migrating through Montezuma Slough.

"A better indication of the proportion of migrants using Montezuma Slough may be the magnitude of ebb tidal flow in the main channel and Montezuma Slough. The average ebb tidal flow in the main channel is on the order of 200,000 cfs or about 2 orders of magnitude grater than the average ebb flow in Montezuma Slough. This suggests that only a very small fraction of the outmigrants use Montezuma Slough.

"A few miles downstream from Montezuma Slough at Chipps Island, salmon tend to be least abundant on the south side of the river. This probably reflects salmon being more numerous in the Sacramento River than in the San Joaquin River. Since the two rivers join immediately upstream of Montezuma Slough and Montezuma Slough is on the Sacramento side, Montezuma Slough may transport a disproportionate share of the population. Given the different tidal flows, however, it seems likely that less than 5% of the salmon outmigrants use Montezuma Slough.

**"How does survival through Montezuma Slough compare to survival in the main channel through Suisun Bay?**

"Again, no measurements of relative survival are available. A general consensus is survival is probably greater in the main channel than in Montezuma Slough. The fact that Montezuma Slough is a longer route with more diversions and a number of side channels leads to that consensus.

**"Do the gates affect the passage of upstream migrant salmon through Montezuma Slough?**

"Maximum velocities through the control structure are about 3 fps and average about 1.8 fps. This contrasts with sustained swimming speeds of about 4 to 10 fps for adult salmon and design velocities of 4 to 6 fps for salmon passage through culverts. For this reason, no one expected salmon to have any difficulty migrating through the gates when they are operating. Hence the expectation has been that salmon would be delayed for up to 6 hours during flood tide when the gates are operating but that they would easily pass through during ebb tide when velocities would range from essentially 0 to 3 fps.

"Observations, however, during sampling for predators within a few hundred yards upstream and downstream of the control structure from 1987 through 1991, raise questions about whether this expectation has been met. Biologists doing that work have captured 1-3 adult salmon each spring both upstream and downstream from the control structure both before the structure was installed and after installation when the stoplogs were out and the gates were open. They report sighting other salmon escaping from their nets, which have a mesh size too small for optimum capture of adult salmon. In contrast, they have neither taken or observed any salmon when the gates were in operation during 1990 and 1991.

"The actual number of observations are so small that it is difficult to know whether there observations reflect a real difference. If the difference is real, its significance is uncertain. It could be that salmon don't enter Montezuma Slough at all when the gates are in operation, or it could be that they are holding up someplace below the barrier. Either conclusion seems surprising, given the nature of the structure and what is known about salmon migration.

**"What studies could provide evidence on the most significant unknowns about impacts?**

"The highest priority is gathering evidence on the relative number of salmon using the main channel and Montezuma Slough. The relative abundance of salmon in the main channel is being measured each spring, so this requires only comparable sampling in Montezuma Slough.

"Another useful study would be measuring the survival of marked salmon released at Chipps Island and in Montezuma Slough. The logical recovery point is in Carquinez Strait. This has a substantially lower priority than the first study, unless the first one documents a much higher percentage of migrants using Montezuma Slough than I have hypothesized.

"Better sampling of adults is clearly warranted. This should include sampling with more appropriate nets near the structure and probably sonic tagging salmon captured near the west end of the Slough and observing their movements.

**"What can be concluded from the various questions I have proposed?**

"Clearly there are uncertainties as to the actual impacts of the Suisun Marsh Salinity Control Structure on winter-run salmon. I believe the most logical inferences which can be drawn from the physical data and the general biology of salmon, are that only a small portion of the winter-run migrate through Montezuma Slough, that that fraction is not increased by gate operation (as contrasted to allowing normal tidal operation), and that mortality is more likely to be decreased than increased by gate operation. Some very limited evidence supports the second contention.

"On the other hand, the most logical inference is that closing the control structure would exclude salmon from Montezuma Slough and increase their survival, since survival in the main channel is likely greater than in Montezuma Slough. If the proportion migrating through the Slough is small as hypothesized, this would have little consequence for the population. I also acknowledge that I have a major philosophical reservation about such a management strategy. It in effect would take advantage of the existence a structure built to mitigate a major impact of water development in a way which would negate its purpose during the most important time of the year.

"As for the potential delays on adult migrants, I would hesitate to recommend management measures based on the meager evidence, uncertainties as to its real meaning and its being so at odds with considerable experience with salmon behavior at potential barriers."

In response to the concern that gate operation would draw winter run and other salmonids into Montezuma Slough, the USFWS staff made numerous trawls in the Slough during April and May 1992 when the gates were operating full bore. During the same period, they were also trawling at Chipps Island. The two trawl data sets were used to estimate the percentage of Chinook salmon entering Montezuma Slough. A similar study was conducted in 1987 before the Salinity Control Structure was in place.

The 1992 results, Table 32, were almost identical to those from 1987. In both cases, only a small percentage (average of 0.7 percent) of Chinook salmon apparently entered Montezuma Slough. Perhaps more importantly the percentage was the same with and without the gates operating.

Based on theoretical and empirical evidence gate operation does not impact winter-run juveniles and operational conditions should not be included in subsequent biological opinions.

### Contra Costa Canal

The CVP's Contra Costa Canal, oldest of the CVP/SWP Delta diversions, diverts approximately 120,000 acre-feet/year from Rock Slough at diversion rates varying from about 150 to 255 cfs (Figure 21). Concerns related to winter-run salmon impacts of the CCC's Rock Slough intake are being handled in consultations regarding Contra Costa Water District's proposed Los Vaqueros Project.

Table 32
MIDWATER TRAWL CATCHES AT CHIPPS ISLAND AND MONTEZUMA SLOUGH,
EXPANDED FOR TIME AND CHANNEL SIZE, AND
PERCENTAGE OF FISH DIVERTED INTO MONTEZUMA SLOUGH FOR 1987 AND 1992

| 1987 | | | | |
|---|---|---|---|---|
| Date | Chipps Island Expanded Catches | Montezuma Slough Expanded Catches | Total Expanded Catches | % Fish Diverted to Montezuma Slough |
| 4/06<br>4/07 | 658<br>– | –<br>0 | 658 | 0.00 |
| 4/08<br>4/09 | 1711<br>– | –<br>0 | 1711 | 0.00 |
| 4/14<br>4/15 | –<br>6974 | 40<br>– | 7014 | 0.57 |
| 4/16<br>4/18 | –<br>8158 | 60<br>– | 8218 | 0.73 |
| 4/21 | 10658 | 100 | 10758 | 0.93 |
| 4/23 | 25658 | 60 | 25718 | 0.23 |
| 4/28 | 24342 | 100 | 24442 | 0.41 |
| 4/29 | 22632 | 260 | 22892 | 1.14 |
| 4/30 | 43289 | 560 | 43849 | 1.28 |
| 5/01 | 30132 | 400 | 30532 | 1.31 |
| 5/02 | 46316 | 460 | 46776 | 0.98 |
| 5/03 | 67895 | 260 | 68155 | 0.38 |
| 5/04 | 38947 | 300 | 39247 | 0.76 |
| 5/05 | 47632 | 260 | 47892 | 0.54 |
| 5/06 | 45526 | 660 | 46186 | 1.43 |
| 5/07 | 58816 | 340 | 59156 | 0.57 |
| 5/08 | 55526 | 140 | 55666 | 0.25 |
| 5/09 | 27368 | 440 | 27808 | 1.58 |
| 5/10 | 59474 | 100 | 59574 | 0.17 |
| 5/11 | 35789 | 0 | 35789 | 0.00 |
| 5/12 | 30526 | 240 | 30766 | 0.78 |
| 5/13 | 43421 | 360 | 43781 | 0.82 |
| 5/14 | 20921 | 260 | 21181 | 1.22 |
| 5/15 | 15132 | 140 | 15272 | 0.92 |
| 5/19 | 35789 | 0 | 35789 | 0.00 |
| 5/21 | 19474 | 340 | 19814 | 1.72 |
| 5/26 | 4342 | 60 | 4402 | 1.36 |
| 5/28 | 5000 | 140 | 5140 | 2.72 |

Table 32 (continued)
MIDWATER TRAWL CATCHES AT CHIPPS ISLAND AND MONTEZUMA SLOUGH
EXPANDED FOR TIME AND CHANNEL SIZE AND
PERCENTAGE OF FISH DIVERTED INTO MONTEZUMA SLOUGH FOR 1987 AND 1992

| 1992 | | | | |
|---|---|---|---|---|
| Date | Chipps Island Expanded Catches | Montezuma Slough Expanded Catches | Total Expanded catches | % Fish diverted to Montezuma Slough |
| 4/20 | 104737 | 200 | 104937 | 0.19 |
| 4/21 | 146974 | 620 | 147594 | 0.42 |
| 4/22 | 215789 | 720 | 216509 | 0.33 |
| 4/23 | 155263 | 1560 | 156823 | 0.99 |
| 4/24 | 123553 | 620 | 124173 | 0.50 |
| 4/27 | 77105 | 1220 | 78325 | 1.56 |
| 4/29 | 83684 | 1100 | 84784 | 1.30 |
| 4/30 | 68816 | 360 | 69176 | 0.52 |
| 5/01 | 95395 | 960 | 96355 | 1.00 |

## North Bay Aqueduct

To meet project entitlements in Napa and Solano Counties, in 1987 DWR began pumping from Barker Slough through the North Bay Aqueduct. Although scheduled annual deliveries were expected to be about 67,000 acre-feet, pumping has averaged about 50 cfs (50 cfs for 365 days would be about 36,000 acre-feet) during the past two years (Figure 26).

In response to fisheries concerns, DWR constructed a state-of-the-art positive barrier fish screen at the Barker Slough intake. The screen consists of a series of flat stainless steel wedge wire panels with a slot width of 3/32-inch. The design approach velocity is 0.5 feet per second. This slot width will exclude all salmon from being diverted and the low approach velocity prevents them from being impinged on the screens. The screens are routinely cleaned to prevent head loss across the screen face which would result in increased approach velocity. Screen design and maintenance procedures were developed in cooperation with DFG and the final design was approved by DFG.

As part of DWR's Corps of Engineers permit for the North Bay intake, DWR contracted with DFG and U.C. Davis to conduct pre- and post-installation fisheries monitoring. The results of these surveys have been documented by DFG in two file reports (DFG 1989 and 1990). The post-project monitoring is continuing.

Because of its location, physical feature, and focus on striped bass concerns, DFG and U.C. Davis used egg and larva nets, otter trawls, and gill nets to obtain fish samples for analysis. Samples for both pre- and post-project were collected twice in February, June, and October of each year. These gear are not particularly effective for juvenile salmon.

In the pre-installation sampling (February 1986 through February 1988) two adult Chinook salmon and no juveniles were captured. In the post-project sampling (June 1988 through June 1990) 4 of the 1,636 fish caught were Chinook salmon. The salmon ranged in size from 43 to 845 millimeters.

Although data are scarce, the relatively remote location of intake from the Sacramento River, the low pumping rate, and the presence of a state-of-the-art fish screen should result in little or no impact on juvenile winter-run salmon.

## Coordinated Operation Agreement

The Coordinated Operation Agreement provides the opportunity for mitigation and avoidance of project impacts on winter run salmon. Through the COA accounts DWR can loan water to the USBR which can help retain cold water in Shasta Reservoir for temperature control in the upper Sacramento River. DWR uses Lake Oroville releases to meet in-basin and Delta outflow needs during certain months. USBR balances their COA account in subsequent months by increasing releases from Shasta and Folsom while the SWP reduced flows from Lake Oroville.

Table 33 contains the COA balances for the past four years and shows that in 1988 and 1989 significant "exchanges" of water were made between the two projects. For example, during the period July 1988 and November-August 1989, the USBR "borrowed" water from DWR and wound up with a balance of 185,000 acre-feet. In September and October of 1989 they returned the water. Although it is not possible to quantify benefits to winter run salmon, in some years the benefits can be substantial.

Table 33
COORDINATED OPERATION AGREEMENT BALANCES
(In Thousands of Acre-Feet)

| | 1987 | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|
| January | * | * | -131 | -6 | 38 |
| February | * | -13 | -180 | 36 | 0 |
| March | * | -39 | * | 33 | * |
| April | -33 | 3 | * | 7 | -4[c] |
| May | -17 | 45 | -100 | -83 | 27[c] |
| June | -18 | 104 | -40 | -103 | 25[c] |
| July | -12 | -16 | -165 | -89 | 74[c] |
| August | -29 | -57 | -185 | -68 | 211[c] |
| September | 0 | -57 | -136 | -13 | |
| October | 3 | -69 | -84 | 9 | |
| November | 0 | -94[a] | -7 | 41 | |
| December | * | -144[b] | 23 | 28 | |

* Not in Balanced Conditions
Sign Convention: – Means USBR owes DWR
a As of 11/26; last day of balanced conditions.
b Balanced conditions effective from 12/3 through 12/25.
c Not adjusted for effects of Governor's Drought Water Bank.

## Flow

In their analyses of survival of Sacramento River fall-run salmon through the Delta, Kjelson *et al* concluded that flow *per se* was not a controlling factor. Flow did enter into the equation as the fraction of Sacramento River flow diverted through the Delta Cross Channel. Flow also may be important in the late spring as a factor influencing water temperature in the river above Sacramento and thus will affect survival to the Delta.

## Reverse Flows

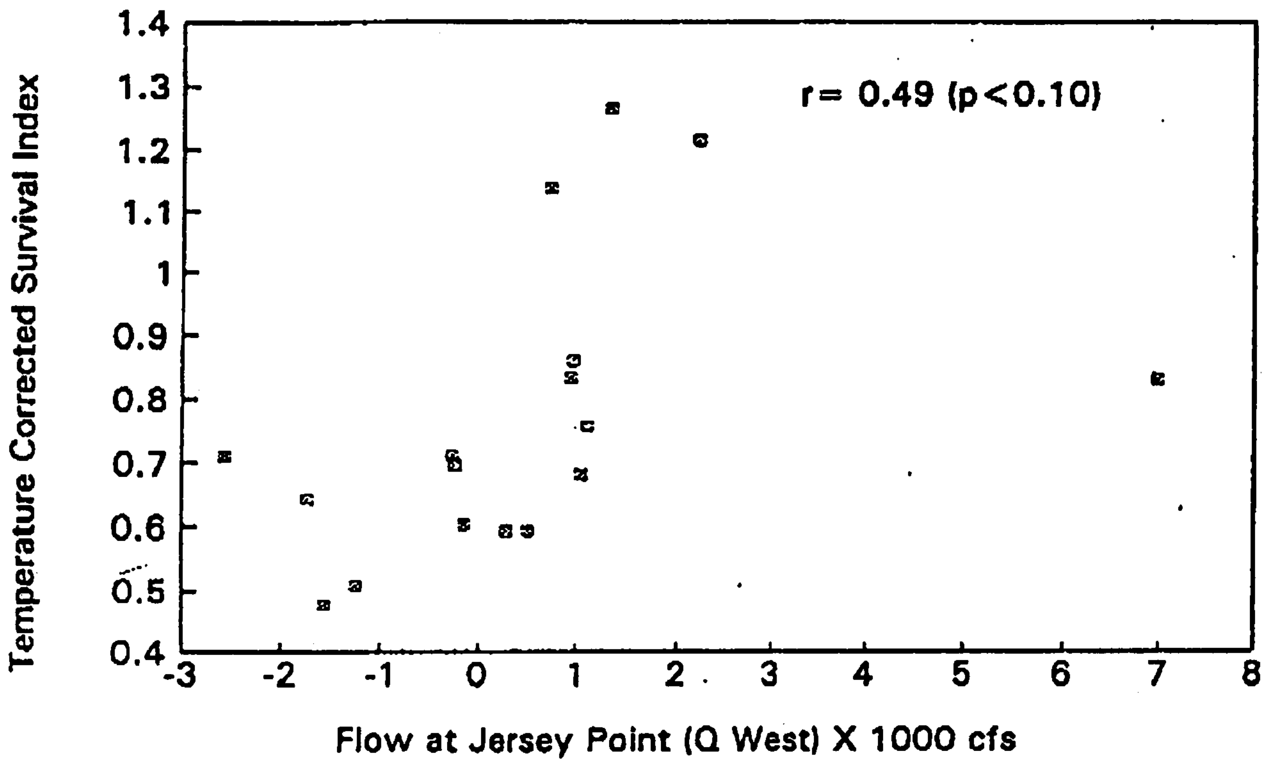
It has been difficult to assess the impact of flow reversals in the lower San Joaquin River on winter run salmon. As mentioned earlier, western Delta flow does not enter into the smolt survival regression model in any of the reaches. Recoveries at the Delta pumps of tagged fish released below the Cross Channel has been low during periods when flow reversals were occurring. Regressing Antioch flow versus salmon salvage or spawning stock two years later did not yield significant relationships. Finally, in the western Delta, tidal flows overwhelm river flows during the dry periods when flow reversals typically occur. It isn't clear how a juvenile salmon can use these relatively small residual flows in their migratory movement. Due to tidal effects, reverse flows are not transport flows; *ie* fish are not carried along with net flows. At this location the salmon should be using other guidance cues to find their way to the ocean.

The USFWS presented testimony regarding reverse flow at the 1992 SWRCB hearings to help develop interim standards to protect the Bay/Delta. Their detailed information is contained in USFWS WRINT-7. In essence the Service correlated residual survival (observed survival minus predicted survival at 61°F) with reverse flow for the Ryde reach. Their regression relationship is shown in Figure 59.

To obtain a significant relation, the Service deleted data from two years, 1983 and 1986, with the rationale that these were wet and they were trying to develop a dry year relation. As shown in the figure, the range of reverse flows in the regression is limited, basically from -2000 to +2000 cfs. The regression is driven by the high survivals at flows of 1000 to 2000 cfs. One of the major concerns with this analysis is the reverse flows used are calculated values based on Delta inputs and depletions. Since the calculations do not take tidal effects into account, the flows used do not represent how water was actually moving in the lower San Joaquin River during the 5-day averaging period used in the regression.

The USFWS subsequently used a Ryde survival versus reverse flow regression equation to develop another version of the smolt survival model excluding 1983 and 1986. Incorporating reverse flow into the regression prevents incorporating water temperature (residual survival after reverse flow is not correlated to water temperature). Survival in the interior Delta still uses temperature and exports as the driving factors. The Sacramento to Walnut Grove reach equation was the same as used in the 1989 Smolt Survival model.

Figure 59
TEMPERATURE-CORRECTED SURVIVAL FOR FISH RELEASED AT RYDE BETWEEN 1984 AND 1992 VERSUS FLOW AT JERSEY POINT ON THE SAN JOAQUIN RIVER
(From USFWS 1992)




The USFWS smolt survival model was used to calculate survival indexes for the same NMFS alternatives as the updated DWR smolt survival model. The results are:

| | BASE | NMFS ALTERNATIVES | | | |
|---|---|---|---|---|---|
| | 1988 | E | H | C | B |
| FEB | 0.32 | -1.90 | 0.59 | 1.03 | 1.09 |
| MAR | 0.56 | -0.70 | 0.59 | 0.89 | 1.07 |
| APR | 0.56 | -0.88 | 0.56 | 0.86 | 0.99 |

Their are still many unresolved issues related to the reverse flow question. This should be an area of active research by the Interagency Ecological Studies Program.

## Delta Cross Channel Gates

Although impacts of the Delta Cross Channel are covered in the salmon smolt model, a few words about their impacts may be useful here.

Salmon migrating down the Sacramento River when the Delta Cross Channel gates are open can be diverted into the central Delta with the flow. (They also can be diverted into Georgiana Slough.) With fall-run salmon, Kjelson *et al* have found that through-Delta survival is affected by water temperature, percent diverted through the Cross Channel, and combined CVP/SWP pumping. Similar studies have not been conducted for winter-run salmon.

Temperature appears to be an especially important factor in determining fall-run smolt survival. Since the estimated peak of winter-run migration (January through March) occurs during cold weather, temperature should not be a problem. Overall Delta survival for winter-run salmon should be better for the winter run than for the fall run. Also, during this period lower internal Delta agricultural diversions and lower predation rates should help lead to good Delta survival.

There are some strong indications that the Kjelson *et al* equations may underestimate the benefits of low temperatures to juvenile salmon and overestimate the benefit of closing the Delta Cross Channel when temperatures are low. For example, the data in Table 34 were obtained from the 1988 USFWS annual report.

Table 34
FALL-RUN SMOLT SURVIVAL INDICES IN THE SACRAMENTO RIVER DELTA
DURING SPRING 1987 AND 1988
UNDER LOW, MEDIUM, AND HIGH TEMPERATURE CONDITIONS

| Release Site | Delta Cross Channel | Low Temperature (61-63°F)* | Medium Temperature (66-67°F)** | High Temperature (73-76°)*** |
|---|---|---|---|---|
| Sacramento | Open | 0.65 | No Release | 0.09 |
| Courtland | Open | 0.72 | 0.40 | 0.02 |
| | Closed | 0.70 | 0.67 | 0.17 |
| Ryde | Open | 1.28 | 0.88 | 0.34 |
| | Closed | 0.94 | 0.85 | 0.40 |

* Release site temperature range in May 1988.
** Release site temperature range in May 1987.
***Release site temperature range in June 1987.

At low water temperatures, closing the Cross Channel gates did not benefit survival of fall-run smolts released above or below the Delta Cross Channel. On the other hand, closing the gates did increase survival for fish released above the Cross Channel when temperatures were moderate to high.

Results of an experiment conducted in April 1991 with fall-run salmon provide additional support for the contention that closing the Cross Channel gates may not provide significant benefits during low water temperatures. This study was selected because the water temperature was near conditions that exist when winter-run salmon are present. On April 25, as part of the Interagency Program, the USFWS released about 100,000 tagged fall-run hatchery salmon into the Sacramento River at Miller Park. Relevant conditions at the time of release were:

| | |
|---|---|
| Water Temperature | 61°F |
| Combined CVP/SWP Exports | About 6,000 cfs |
| Estimated Flow, San Joaquin River at Antioch | –1,000 cfs |
| Estimated Flow, Sacramento River at Freeport | 7,000 cfs |
| Delta Cross Channel Gates | Both Open |

This experiment represents a mix of potential good and bad conditions. The temperature was near optimum for salmon survival and in about the range expected in January through March. However, streamflow was low, exports were moderate, and there was reverse flow in the lower San Joaquin River.

Expanded coverage of the salvage at the State and Federal facilities resulted in recovery of 1 out of 100,000 of the tagged fish at the SWP and none at the CVP. Expanding the tag recovered to salvage involves multiplying the number recovered by the reciprocal of the sampling time divided by the total minutes pumped during that day. For example, if the sampling time was 10 minutes and the pumps were on for 720 minutes, one recovery would represent a salvage of 72 fish. The survival index to Chipps Island during this study was relatively good, at 0.77.

The experiment was repeated in May with slightly warmer temperatures (64°F at release), less exports, positive flow at Antioch, and the Cross Channel gates still open. The survival index of 0.48 was significantly less than the 0.77 obtained in April.

### South Delta Temporary Barriers

In mid-April 1992, DWR installed a temporary barrier at the head of Old River to help protect juvenile Chinook salmon migrating from the San Joaquin River. Mark/recapture studies demonstrated that although overall survival of San Joaquin smolts was low in 1992, the barrier appeared to result in increased survival.

Evaluating impacts of the barrier installation on winter-run Chinook salmon is more difficult. There are no experimental data to help determine if the barrier affects Chinook salmon coming down the Sacramento River and diverted into the interior Delta. Mathematical modeling results indicate installation of a barrier at the head of Old River has minimal effect on movement of water from the mouth of the Mokelumne toward Stockton. If this is the case, then there is no apparent way in which barrier installation could adversely impact winter-run salmon.

In a preliminary analysis of potential impacts of the barrier, Coulston (1992) concluded there could be a minor impact. The data used in this assessment were from mathematical modeling using tracers injected into the model to help follow the direction of transport. It is unlikely that salmon would move in a manner similar to diffusive material such as salt.

Coulston's analyses were done under the assumption that the Delta Cross Channel gates were open. If they were closed, then the potential for the barrier impacting winter-run Chinook salmon would be even less than he postulated.

## Impacts on Adults

There is basically no information on adult movement through the Delta and how project operation affects this movement. In that adult salmon are probably being guided by olfactory responses in their migration through the estuary to their natal streams, there is some concern that present circulation patterns may confuse adult migrants. Since the historical Delta was a myriad of interconnected channels and flooded wetlands, finding their way through the Delta has always been difficult.

## Use of DFG's Salmon Classification System

At present, we have only the size interval system that can be used to classify juvenile salmon by race. Analysis of the available data indicates the system probably greatly overestimates the number of winter-run salmon in CVP and SWP salvage and trawl sampling. This conclusion has been developed after examination of the large amount of information analyzed for this assessment. The problem, not unexpected, is that a general growth curve does not capture the large amount of natural variability present in wild, and even hatchery, salmon populations. This variation can be seen in the plots of salmon catch and salvage presented earlier. In several instances, the sizes of what appeared to be a cohort of outmigrating smolts produced a solid line from one race to another — in this case, from winter run to late-fall run. The system will have no applicability for sorting the spring run from the fall run in that there was always a solid band of smolts between the two races.

Several observations support the conclusion that the system does not provide accurate estimates of the numbers of winter-run Chinook salmon collected or taken. These include:

- The lack of correlation between winter run catches at the two facilities. If the system provides accurate estimates, one would expect some relationship.
- The failure of winter run catch-per-unit-effort to decrease in the Chipps Island trawl as the spawning stock decreased.
- The large deviation in the ratios of the four races at the salvage facilities from what would be expected based on parent spawning stocks and run timing in the Sacramento River.
- Identification of several tagged fish that were originally classified as fall run.
- Information developed by DFG (1992) comparing size intervals of hatchery fish and salvaged fish showing that many of the salmon classified as winter run were more likely to be fall run.

Some of the problems mentioned above will disappear in 1993 if the proposal to sacrifice most of the hatchery marked salmon at the facilities and trawling is enacted. For example, at the facilities in 1992, almost half of the winter run take was from marked salmon.

# CUMULATIVE IMPACTS

Several projects and actions can cumulatively interact with CVP and SWP Delta operations to affect winter-run Chinook salmon. It is beyond the scope of this assessment to analyze the cumulative impacts of these projects and actions; however, brief descriptions may be helpful in providing a perspective on how they may interact with Delta operations.

## Georgiana Slough Barrier

The 1992 Biological Opinion on CVP/SWP operation included closure of Georgiana Slough as a conservation measure. Also, in the 1992 SWRCB hearings on interim Bay/Delta standards, NMFS included an alternative that called for closing the slough during February, March, and April and meeting current D-1485 standards. Since this alternative appeared to provide a level of protection acceptable to NMFS and resulted in the least water cost to the projects, DWR decided to pursue installation of the barrier for the 1993 outmigration season.

As of the end of October 1992, DWR is continuing to plan for barrier installation; however, the installation period is February and Marcy only, due to concerns about other fish, including the fall run on the San Joaquin system. Planning for the temporary rock barrier includes provisions for rapid removal in case of flooding and two relatively small culverts at the base of the barrier. These culverts will allow sufficient water to enter Georgiana Slough to maintain water quality and to provide for passage of any adult salmon that may wind up on the downstream side of the barrier.

Although planning is continuing, installation will depend on conditions in the 1993 biological assessment. The presence of the barrier can increase flow reversal, depending on pumping and flow in the San Joaquin River. It would appear that keeping downstream migrants in the mainstem of the Sacramento River results in the greatest survival; however, there are as yet unquantifyable concerns about reverse flow impacts. An alternative action would be to install the barrier, allow pumping, and monitor salmon abundance in the lower San Joaquin. If it were determined that significant numbers of juveniles were moving toward the pumps under this scenario, pumping curtailments would be enacted. Implementation of this alternative requires an extensive monitoring program in the lower river and timely reporting of results to management agencies.

## Los Vaqueros Project

Contra Costa Water District is proposing to construct and operate an offstream storage reservoir, which will result in increased diversions from the Delta. The District has prepared environmental documentation and a biological assessment for the project. There is also formal consultation with NMFS related to winter-run salmon concerns.

From a cumulative standpoint, the project will cause additional diversions from the Delta, some of which are likely to occur during the months in which winter-run salmon are present. Calculation of reverse flows has a term for internal Delta demand and a new diversion in the southern Delta results in an incremental increase in reverse flow at any given CVP/SWP pumping rate.

## Proposed Additions to the State Water Project

The Department of Water Resources has several proposals for projects to complete the State Water Project. Each of these projects has environmental documentation and will entail formal consultation with NMFS and DFG on winter-run salmon and with DFG and USFWS on other listed species. Following is an annotated list of these projects.

### South Delta

This project, by itself, is mainly to improve circulation in the southern Delta by a combination of barriers and dredging. Alternatives being looked at include expansion of Clifton Court Forebay. South Delta also calls for lifting the current Corps of Engineers constraint on pumping.

### North Delta

Planning for the northern Delta involves providing for additional flood protection and diversion off the Sacramento River. North Delta planning is temporarily on hold pending the results of environmental documentation called for as part of the Governor's proposed Bay/Delta Oversight Council.

### Kern Fan

The objective of the Kern Fan project is to divert water from the Delta during high-flow periods for storage below ground in Kern County. The stored water would be pumped for delivery during water shortages. As proposed, the diversions would occur during the time when winter-run outmigrants are common in the Delta.

### Los Banos Grandes

The Los Banos Grandes project is similar to the Kern Fan project, except that storage would be above ground in the offstream Los Banos Grandes reservoir.

### Coastal Branch Extension

The Coastal Branch Extension is an approved project that will not result in increased diversion from the Delta. To meet the water needs of the South Coast area, the project involves allocation of a portion of existing SWP supplies to new users.

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# Appendix 1

# RESTORATION GOALS AND UP-RIVER FACTORS CONTROLLING WINTER-RUN CHINOOK SALMON ABUNDANCE

## RESTORATION GOALS AND UP-RIVER FACTORS CONTROLLING WINTER RUN CHINOOK SALMON ABUNDANCE

The U.S. Fish and Wildlife Service has formally identified restoration goals for Chinook salmon in the upper Sacramento River. Those goals are to restore Chinook salmon stocks to levels of the 1950s (adult catch plus escapement of 673,000 fall Chinook, 50,000 late-fall Chinook, 80,000 winter Chinook, and 130,000 spring Chinook) (USFWS, 1982).

The California Department of Fish and Game has established higher restoration goals as, shown in Table 2.

**Table 2**
**California Department of Fish and Game's Restoration Goals for Production of Adult Chinook Salmon from the Upper Sacramento River (figures in thousands of salmon)**

| Stock | Escapement[a] | Stock Catch | Ratio of Catch to Escapement | Total |
|---|---|---|---|---|
| Fall | 300 | 600 | 2:1 | 900 |
| Late fall | 25 | 50 | 2+:1[b] | 75 |
| Winter | 70 | 42 | 0.6:1 | 112 |
| Spring | 70 | 105 | 1.5:1 | 175 |

[a]Escapement equals number of spawners plus number harvested in river.
[b]Although the catch:escapement ratio for Sacramento River late-fall run Chinook salmon has not been ascertained, it is estimated to be substantially higher than the ratio for fall run.
Source: California Department of Fish and Game, 1990.

Prior to the winter run Chinook being listed as a threatened species by the Federal Government in 1989, a task force composed of natural resource professionals and interest groups was established to develop and review actions to restore the depressed populations of winter run Chinook. That group developed this restoration goal:

> "The goal is to restore the Sacramento River winter run Chinook salmon throughout their range as a naturally sustained stock capable of withstanding natural and man-made perturbations while maintaining harvestable surpluses. The Winter run Task Force believes that the goal will have been achieved when the three-year running average of naturally spawning fish reaches or exceeds 40,000. During the period of restoration, no additional projects or water diversions detrimental to the population should occur. All actions including

habitat restoration, flow augmentation, water quality, as well as water temperature and fish passage improvement, artificial production, and reduction of direct mortalities from fish screens, dewatering of redds, and predation shall be actively pursued by all responsible agencies." (Rawstron, 1988).

In 1988, a ten-point cooperative agreement was made between the U. S. Bureau of Reclamation, U. S. Fish and Wildlife Service, National Marine Fisheries Service, and California Department of Fish and Game to implement actions to improve the status of winter run Chinook salmon in the Sacramento River Basin. Specific actions to be taken by the contributing parties are summarized from the agreement:

- Raise the Red Bluff Diversion Dam gates from December 1 to April 1. USBR will operate the gates so that the timing for raising the gates will be designed to optimize the maximum practical benefits for upstream migrating winter run Chinook salmon. The parties will develop fish passage alternatives to raising the gates.

- Develop a water temperature control solution for warm water years in the Sacramento River. USBR is to develop and implement operational solutions to temperature control problems associated with Shasta Dam releases. This will include installation of a device to control the depth of water released from the dam.

- Correct the Spring Creek pollution problems. USBR, under a funding agreement with the Environmental Protection Agency, will develop the water management portion of the Spring Creek pollution control program. Pollution problems are associated with acid drainage from Iron Mountain Mine, located in the Spring Creek watershed.

- Restore spawning habitat in the Redding area of the Sacramento River. CDFG will develop and fund a winter run Chinook salmon spawning habitat restoration program.

- Correct salmon-related problems at the Anderson-Cottonwood Irrigation District Diversion Dam. CDFG has already begun efforts to replace the diversion dam with an alternative method of supplying water to the district.

- Restrict in-river harvest of winter run Chinook salmon.

- Develop a winter run Chinook salmon propagation program at Coleman National Fish Hatchery.

- Modify the Keswick fish trap to prevent mortality to winter run Chinook salmon. USBR began modification to the fish trap in 1986.

- Develop measures to control squawfish predation at Red Bluff Diversion Dam.

- Continue and expand studies on winter run salmon. The parties will fund, develop, and implement studies to identify additional management actions to improve the status of winter run Chinook salmon in the Sacramento River.

A variety of activities to benefit winter run Chinook salmon are currently underway. NMFS has organized the Winter run Chinook Salmon Restoration Team, which includes representatives from the cooperative agreement parties as well as from the California Department of Water Resources, U. S. Army Corps of Engineers, Pacific Fishery Management Council, American Fisheries Society, and United Anglers of California. As of November 1, 1991, the team had not met to discuss and evaluate recovery efforts.

USBR completed the Red Bluff Diversion Dam Fish Passage Action Program in 1988 to improve upstream passage of adult salmon and survival of downstream migrating juveniles. For the past five years, USBR has raised the diversion dam gates during the nonirrigation season to benefit winter run migration.

USBR also completed the Tehama-Colusa Canal Diversion fish screening facilities in 1990 to eliminate fish entrainment into the Tehama-Colusa and Corning irrigation canals and to reduce predation at the dam.

USBR, DWR, and CDFG have begun adding spawning gravels to the upper Sacramento River, and USFWS has initiated a winter run Chinook salmon artificial propagation program.

The Environmental Protection Agency is in the process of implementing pollution control measures for the Iron Mountain Mine.

The California State Legislature enacted legislation (Senate Bill 1086) initiating the development of an upper Sacramento River fisheries and riparian habitat management plan. The plan was completed in 1989 and cooperating agencies are seeking funding for these restoration projects.

Actions have been taken by the California Fish and Game Commission and the Pacific Marine Fisheries Council to reduce commercial and recreational catches by anglers. The following are brief descriptions of these actions.

Before 1987, the Department of Fish and Game estimated that the in-river fishery resulted in about 8.7 percent of the adult winter run salmon being harvested. In 1987 the following regulation was adopted to decrease this take.

> "Prohibit salmon fishing year-round upstream from the Deschutes Bridge; from February 1 through June 30 between Deschutes Bridge and Red Bluff Diversion Dam; from February 1 through April 30 between Red Bluff Diversion Dam and Hamilton City; from February 1 through March 31 between Hamilton City and Knights Landing; and open to fishing all year below Knights Landing. The bag limit is three trout or salmon in combination, but no more than two salmon per angler per day."

Implementing this regulation resulted in the take being reduced to an estimated 1.2 percent in 1987; 4.2 percent in 1988; and 3.1 percent in 1989.

In 1989 an additional restriction prohibited the harvest of salmon in: (1) the Sacramento River from the Deschutes Bridge downstream to Red Bluff Diversion Dam from Saturday nearest November 15 through August 15, and (2) the Sacramento River from Red Bluff Diversion Dam downstream to Carquinez Bridge from Saturday nearest November 15 through July 31. This restriction was intended to reduce the take to near zero.

## Ocean Commercial and Recreational Harvest

The Pacific Fisheries Management Council, through its Ocean Salmon Management Plan, develops fishing regulations that balance salmon resource protection with providing catch for commercial, recreational, and native American fishermen. A proportion of those fish harvested in the ocean off California are winter run salmon. In April 1990, the Management Council requested the National Marine Fisheries Service to enter into consultation regarding 1990 and 1991 fishing regulations. In October 1990, NMFS requested formal consultation for the 1991 fishing regulations. A biological opinion and incidental take permit under Section 7 of the Endangered Species Act was issued on March 1, 1991 for 1991 and future salmon regulations. The NMFS opinion stipulated that consultation would be reinitiated if conditions changed significantly or if new information became available. In summary, the March 1, 1991 biological opinion conveyed the following information related to the ocean fishery.

- Winter run Chinook salmon probably leave the ocean from early November through mid-May, with the peak occurring in February through early March.

- Ocean impact rate (catch plus those killed by the fishery) is about 35 percent.

- Early migration from the ocean and small size relative to other Sacramento River Chinook salmon runs contribute to this comparatively small impact rate.

- For every fish caught in the ocean fishery, it was estimated that two escape to the river.

- The 1990 ocean fishery may have impacted (caught or killed) 249 adult winter run salmon.

- Most winter run adults are caught below Point Arena.

Although the opinion recognized that the ocean commercial and recreational fishery was not a major cause of the observed decline, NMFS stipulated two conditions in issuing its incidental take permit:

- The PMFC not approve a proposed early opening before May 1 of the commercial fishery below Point Arena.

- The PMFC close the ocean recreational fishery for two weeks at beginning and end of proposed (normal) season.

### Estimated Annual Spawning Population of Winter run Chinook Salmon

The best estimates of winter run Chinook escapement have been obtained by counts of salmon passing through the fish ladders at Red Bluff Diversion Dam. Estimated numbers of winter run adults have been recorded from 1967 to the present. The maximum number of winter run adults passing the diversion dam was 117,808 in 1969 and the minimum was 190 fish in 1991 (Table 3). The average annual number of winter Chinook passing the diversion dam was 24,062 for 1967 through 1990.

**Table 3**
**Winter Run Chinook Salmon Counts at the Red Bluff Diversion Dam**

| Year | Number of Fish | Year | Number of Fish |
|---|---|---|---|
| 1967 | 57,306 | 1980 | 1,156 |
| 1968 | 84,414 | 1981 | 20,041 |
| 1969 | 117,808 | 1982 | 1,242 |
| 1970 | 40,409 | 1983 | 1,831 |
| 1971 | 53,089 | 1984 | 2,663 |
| 1972 | 37,133 | 1985 | 3,962 |
| 1973 | 24,079 | 1986 | 2,094 |
| 1974 | 21,897 | 1987 | 1,997 |
| 1975 | 23,430 | 1988 | 2,094 |
| 1976 | 35,096 | 1989 | 533 |
| 1977 | 17,214 | 1990 | 441 |
| 1978 | 24,862 | 1991 | 190 |
| 1979 | 2,364 | Mean | 24,062 |

The marked decline in numbers passing the dam in 1979 and 1980 was the result of drought in 1976 and 1977 (Figure 4). Because most winter run salmon return as 3-year-old fish, the impact of such losses is evident for many years into the future, making it difficult for the runs to rebound to previous population levels. The last strong year class, which was in 1981, failed to return in large numbers during 1984. The reason for this low return is unknown, but is assumed to be the result of the 1982 and 1983 El Niño event, which created poor rearing conditions for salmon in the ocean.

The winter run spawning populations have remained at low levels (<4,000) since 1982 and have decreased to well below 1,000 in 1989, 1990, and 1991. Reasons for these declines are unknown but are presumed to be attributable to direct and indirect adverse conditions induced by the drought.

For the past five years, the Red Bluff Diversion Dam gates have been out of water during the nonirrigation season (about December through March) and the fish ladders were inoperable. Free-flow conditions were present at the diversion dam during this time, salmon passage was unimpeded past the dam. Without the fish ladders in operation, enumeration of salmon passing the dam was not possible, so CDFG employed an alternative method of estimating each year's winter Chinook run size. This method assumes that each year's timing is the same as that exhibited for 1982 through 1986. After counts are conducted following dam gate closure at the onset of the irrigation season and the fish ladders are operational, an estimate of the entire year's run size is calculated by extrapolating actual fish counts to encompass the entire period when counts could not be conducted using the historical run timing pattern. For example, if the diversion dam does not go back into operation until April 1, when approximately two-thirds of the winter run is estimated to have passed the dam, and 1,000 winter run salmon pass the dam after April 1, the run size would be estimated to be about 3,000 fish.

## Hatchery Production

Several Chinook salmon hatcheries have been constructed and operated in the Sacramento-San Joaquin drainage to mitigate for water project impacts. Foremost among these hatcheries are the Coleman National Fish Hatchery (USFWS), Feather River Hatchery (DWR/DFG), American River Hatchery (USBR/DFG), and the Merced River Fish Facility (DFG).

Although these hatcheries produce all four races of Chinook salmon, they focus on the fall run with present annual production being several million fall run fish. Coleman NFH rears late fall and as of last year winter run with all their production being released in the upper River during ost years. The Feather River Hatchery produces fall run and spring run with the planting size and location being quite variable (Table __). Amrican River fall run are generally planted in the spring as smolts in the estuary near the Carquinez Strait. Finally, fall run salmon produced at the Merced River Fish Facility are planted as fry, smolts, and yearlings at various locations in the San Joaquin River drainage (Table __).

This information is included because, as will be seen later, the presence of hatchery-reared fish at the State and federal salvage facilities as well as in various sampling programs can confuse the process of sorting winter run from other races.

## FACTORS INFLUENCING WINTER RUN CHINOOK SALMON POPULTION SIZEe

Red Bluff Diversion Dam was constructed in 1964 and went into operation in August 1966 to provide water for the Tehama-Colusa and Corning irrigation canals. Fishery resource problems associated with operation of the diversion dam include:

- Delay and blockage in upstream migration.
- Increased predation on juvenile salmon in Lake Red Bluff and areas directly downstream from the dam.
- Direct injury to juveniles passing under the dam gates or through the fish bypass system.

Red Bluff Diversion Dam has been shown to affect upstream salmon migration by delaying fish passage to the upper river. Between 1979 and 1981, winter run salmon were radio-tagged and their movements monitored in the area of the diversion dam (Hallock et al., 1982). Results of that study showed that radio-tagged migrants were delayed from 1 to 40 days and an average of 18 days (Hallock and Fisher, 1985). The researchers determined that the period of delay directly below the dam was related to flow levels between 4,000 and 16,000 cubic feet per second -- the greater the flow the longer the delay. Data for water flow through Red Bluff Diversion Dam between 1967 and 1983 showed that average monthly flows ranged from 12,743 to 23,535 cfs during January through May (Hallock and Fisher, 1985). This corresponds to the period when most of the spawning winter run Chinook would attempt to pass the diversion dam. Delays in winter Chinook spawning runs may increase prespawning mortality, reduce fecundity or egg viability, or cause the winter run Chinook to spawn in areas below the dam where water temperatures and habitat may not be suitable.

As stated previously, for the past five years, the Red Bluff Diversion Dam gates have been removed from the water during the nonirrigation season (about December through March). Free-flow conditions were present at the dam during this period, and salmon passage was unimpeded. It is estimated that this period encompasses about the first two-thirds of the upstream migration for winter run Chinook. Those passing after April 1 (or when the gates go back into place) have to pass the dam via the fish ladders. Overall, the measure of raising the dam gates during the nonirrigation season is believed to have been beneficial for winter run, because it allows a greater proportion of a given run to access the best spawning habitat upstream of the dam.

Downstream migrating juveniles that are delayed in Lake Red Bluff have an increased chance of being preyed upon by both piscivorous and avian predators. Vogel and Smith (1987) reported that radio-tagged juvenile steelhead salmon were preyed upon by cormorants while moving through Lake Red Bluff; similar predation may occur on winter run Chinook juveniles.

Studies have not been conducted on mortality of winter run juveniles passing though Red Bluff Diversion Dam. However, these types of studies have been performed for other anadromous salmonids. For example, studies by CDFG have indicated that survival of out-migrating juvenile fall run Chinook salmon released downstream of the dam exhibited a 46 percent greater survival rate than those released upstream of the dam. Results of these studies also indicate that losses occur for juvenile salmon passing the dam in spring as well as in winter, so winter run juveniles probably suffer similar mortalities to the fall run Chinook (Hallock and Fisher, 1985).

Young salmon passing the dam are faced with the turbulence below the dam, which can disorient the fish and increase predation effectiveness. Conditions for squawfish predation on juvenile winter run salmon are optimal during summer and fall (Garcia, 1989). The river is typically low, with seasonably high temperatures and low turbidity, which could increase the efficiency of squawfish predation. Significant numbers of squawfish have been observed directly below Red Bluff Diversion Dam during late summer and early fall, when juvenile winter run salmon may begin to migrate downstream (Garcia, 1989). In addition, large numbers of predatory striped bass are known to accumulate downstream of the dam during the fall months, when juvenile winter run are present.

## Sacramento River Temperatures

Chinook salmon spawning success in the Sacramento River is determined by the length of the river reach that possesses cold water (≤ 56°F). In most years, the area of suitable spawning habitat (with respect to water temperature) is located upstream of Red Bluff Diversion Dam. Hallock and Fisher (1985) found that downstream of Red Bluff Diversion Dam water temperatures were suitable for salmon egg incubation in only 4 of 18 years studied (1967 through 1984). This indicates that optimal spawning and incubating temperatures below the dam would be unlikely during any given year.

The optimal spawning reach above Red Bluff Diversion Dam may also incur water temperature problems under certain conditions. Water temperatures between Keswick Dam and Red Bluff Diversion Dam are affected by the following factors (Resources Agency of California, 1989):

- Ambient air temperature

- Tributary inflows
- Volume of water released from Keswick Dam
- Ratio of Spring Creek Power Plant to Lake Shasta releases
- Total storage at Shasta and Clair Engle Lakes
- Depth of water released from Shasta Lake

During dry years with low reservoir storage, water temperatures can exceed 58°F in the upper reaches and result in significant egg and fry mortality.

## Irrigation Diversions

Irrigation diversions can affect both adult upstream migrants and juvenile downstream migrants. There are over 300 unscreened irrigation diversions on the Sacramento River between Redding and the Feather River (RAC, 1989). Cumulatively, these unscreened diversions could cause large losses of winter run Chinook fry, because the fry are rearing in the Sacramento River during a significant portion of the irrigation season (i.e., July through November). An estimated 10 million juvenile salmonids are lost to unscreened diversions annually (RAC, 1989).

As of 1988, only the Anderson-Cottonwood Irrigation District diversion at Redding, the Tehama-Colusa Canal at Red Bluff Diversion Dam, and the Glenn-Colusa Irrigation District diversion at Hamilton City have fish screening facilities (RAC, 1989). However, not all of the screened facilities offer adequate protection to migrating Chinook salmon. In addition to the loss of downstream migrating juveniles, adults may enter many of the unscreened outfalls of irrigation canals, where they can become stranded or attempt to spawn in unsuitable habitat.

### Anderson-Cottonwood Irrigation District

The Anderson-Cottonwood Irrigation District dam is a 450-foot-long flashboard structure constructed in 1917 to divert water from the Sacramento River at Redding. Factors affecting winter run salmon production related to the operation of the dam are:

- Inadequate fish passage.
- Reduced Sacramento River flows from Keswick Dam in response to ACID operations.

- Dewatering of redds constructed by salmon forced to spawn below the dam (result of reduced flow directly below the dam).

The dam is equipped with a fish ladder, but it was designed in the 1920s and is inefficient (CDFG, 1990). The fish ladder does not provide adequate flows for fish attraction. The ladder entrance is positioned at a 90-degree angle to the dam, which can result in direct mortality of fish attempting to enter the ladder or delay adult migration to the point that winter run Chinook may be forced to spawn below the dam (CDFG, 1990).

The Anderson-Cottonwood Irrigation District flashboards are usually in place from April to October (RAC, 1989). Operation of the dam requires that water released from Keswick Dam be reduced during installation, removal, or adjustment of the flashboards (RAC, 1989). Flows from Keswick Dam must be reduced for 3 to 4 days to make these adjustments (CDFG, 1990). These periods of lowered flows may cause increased water temperature in the mainstem Sacramento River, adding to mortality of winter run salmon eggs incubating in redds during this time. The reduced flows may also result in dewatered redds downstream of the dam and cause egg mortality. CDFG is currently devising an alternative method for supplying the district with water.

Tehama-Colusa and Corning Irrigation Canals

The headworks for the Tehama-Colusa Canal are at Red Bluff Diversion Dam. Water entering the headworks supplies both Tehama-Colusa Canal and Corning Canal, which is about 1/2 mile from the intake. Both canals convey irrigation water, and Tehama-Colusa Canal also provides water to national wildlife refuges and the Tehama-Colusa Fish Facilities.

Problems historically associated with operation of Tehama-Colusa Canal and Corning Canal are:

- Entrainment of downstream migrating juvenile salmon into Tehama-Colusa Canal.

- Entrainment of juveniles into Corning Canal pumps.

- Increased predation on juveniles as they exit the Tehama-Colusa Canal bypass system into the Sacramento River.

In 1966, a louver fish screening system was placed at the headworks to prevent entrainment of downstream migrating juveniles into the canal. This system operated until 1990, when it was replaced with a state-of-the-art fish screening system. Yearly entrainment of downstream migrants into Tehama-Colusa Canal from 1982 to 1987 was estimated to be between 0.2 and 0.6

million salmon. Physical injury to downstream migrants passing through the headworks bypass system was 1.6 to 4.1 percent during this same period (Vogel et al., 1988).

A series of 32 new rotary-drum screens and fish bypass system have been installed at the TCC headworks and began operation in the spring of 1990. It is believed that the problem of entrainment of juvenile salmon has been greatly reduced or eliminated. The impact of predation at the fish bypass outlet has yet to be determined.

Glenn-Colusa Irrigation District

The Glenn-Colusa Irrigation District diversion on the Sacramento River is located about 3-1/2 miles north of Hamilton City. The diversion is on an oxbow of the Sacramento River that is about 1-1/2 miles long and contains about 25 percent of the total Sacramento River flow during the summer months (Cramer et al., 1990).

Downstream migrant juvenile Chinook salmon are being lost at the diversion. Recent evaluations at the California Department of Fish and Game's fish screen at this diversion have indicated that losses may range from 9 to 72 percent of the juvenile salmon entering the diversion's intake channel (Cramer, 1990). Losses of salmon fry migrating past the fish screens may be particularly severe (Ward, 1989). Primary causes of these losses are believed to be a combination of:

* • Entrainment of downstream migrating juveniles into the canal.

- Impingement of juveniles on the existing fish screens.

- Predation of juveniles in the oxbow channel.

In 1972, rotary-drum fish screens were installed by the California Department of Fish and Game to prevent entrainment of downstream migrating juvenile salmon into the canal. However, since the installation of the screens, the hydraulics of the river have changed in the oxbow, resulting in a reduced elevation of the river by about 3 feet (RAC, 1989). This reduced water level has, in turn, reduced the effective screening area of the drums and increased the water velocity through the screens. The increased velocity has resulted in impingement of juveniles on the drum screens. Another problem is that the screens were not designed with the proper mesh size to effectively screen small salmon or trout fry. Fish smaller than 1-3/4 inches (45 mm) can pass through the screens.

The total loss of all downstream salmonid juveniles at the Glenn-Colusa Irrigation District is estimated by California Department of Fish and Game to have been about 7 million fish annually (RAC, 1989).

In August 1991, a suit was filed in federal court by the National Marine Fisheries Service to require Glenn-Colusa Irrigation District to reduce its pumping level to protect downstream migrant winter run salmon. The federal court mandated that the district reduce pumping to 1,100 cfs to comply with present fish screening criteria of the California Department of Fish and Game (0.33 feet per second through-screen velocity). Glenn-Colusa Irrigation District subsequently obtained alternative water supplies from Tehama-Colusa Canal (U. S. Bureau of Reclamation) and Black Butte Reservoir. (Access to this latter source required the district to pursue a federal court-ordered water transfer from USBR.) Neither of these alternative water supplies may be secure for the district's future use.

## Toxins

The greatest risk of toxins to winter run Chinook salmon occurs as a direct result of acid mine drainage from Iron Mountain Mine, located in Shasta County about 9 miles northwest of Redding. The mine was mined periodically for copper, gold, iron, pyrite, silver, and zinc from the 1860s until 1963.

Iron Mountain Mine has been associated with water quality degradation and impacts on aquatic resources in nearby drainages during much of its history. Impacts include numerous fish kills in the upper Sacramento River and have been attributed primarily to contamination of surface waters with acid mine drainage that has a low pH and high concentrations of cadmium, copper, and zinc.

The greatest risk of acid mine drainage to winter run Chinook is during the wet season (November through March in most years). This is the period when the most acid mine drainage is discharged into the Sacramento River and when the highest number of uncontrolled spills from Spring Creek Reservoir enter the Sacramento River just above Keswick Dam. Spring Creek Reservoir receives contaminated water from Spring Creek, Boulder Creek, and Slickrock Creek, all of which pass within the Iron Mountain Mine boundaries. This is also the period when Lake Shasta is refilled and the availability of dilution water is low.

Winter run juveniles are at a particular risk from Iron Mountain Mine acid mine drainage because they may be in the upper Sacramento River when uncontrolled spills from Spring Creek Reservoir have occurred (Table 4). This is also the time adult winter run salmon are likely to be in the Sacramento River immediately downstream of Keswick Dam and may be susceptible to lethal conditions.

**Table 4**
**Uncontrolled Spills from Spring Creek Reservoir**

| Start of Spill (date) | Length of Spill (days) | Volume of Spill (acre-feet) |
|---|---|---|
| 12/22/64 | 7 | 5,159 |
| 1/13/69 | 10 | 5,195 |
| 1/9/78 | 14 | 15,248 |
| 2/6/78 | 2 | 355 |
| 3/28/79 | 2 | 22 |
| 2/19/80 | 2 | 496 |
| 1/30/81 | 4 | 194 |
| 3/22/81 | 3 | 1,065 |
| 11/24/81 | 3 | 30 |
| 1/26/83 | 4 | 1,662 |
| 3/1/83 | 4 | 5,177 |
| 2/15/86 | 4 | 3,457 |
| 3/25/89 | 43 | 2,535 |

Note: Information obtained from U. S. Bureau of Reclamation, Central Valley Operations- Report of Operations, 1967-1990.

## Loss of Spawning Gravel

Construction of Shasta and Keswick dams has reduced or eliminated the recruitment of spawning gravel to the main-stem Sacramento River below the dams. Most spawning gravel recruitment in the upper Sacramento River is now derived from bank erosion, tributaries, and chute cutoffs (CDFG, 1990). Controlled dam releases are limiting the amount of gravel recruitment from stream banks. Many tributaries entering the Sacramento River below the dams are now mined for gravel.

Although spawning habitat is not believed to limit winter run Chinook at this time because of currently depressed run sizes, replenishment of good spawning gravel in the uppermost reaches of the Sacramento River will likely enhance winter run recovery efforts. For example, about 10 percent of the entire 1987 winter run utilized the severely gravel-depleted, 3-mile river reach from Keswick Dam to the Anderson-Cottonwood Irrigation District dam (Vogel and Taylor, 1987).

To compensate for the historical loss of spawning gravel, the California Department of Fish and Game and the Department of Water Resources have been involved in a spawning gravel replenishment project in the upper reaches of the Sacramento River since 1978 (Ralph Hinton, DWR, personal communication). Gravel was placed during 1978, 1979, 1986, and 1988 through 1991 (John Elko, DWR, personal communication). All gravel replenishment has been initiated during periods that would minimize the impact on Chinook spawning and the outmigration of juveniles. This has typically been from January 1 to March 31 and from September 1 to October 1.

The Department of Water Resources has placed approximately 95,000 cubic yards of gravel in the upper Sacramento River during 1990 and will place 6,300 cubic yards of gravel at the mouth of Salt Creek (about one mile downstream of Keswick Dam) in 1991.

# Appendix 2

# TABLE II, DECISION 1485
# WATER QUALITY STANDARDS
# FOR THE
# SACRAMENTO-SAN JOAQUIN DELTA AND
# SUISUN MARSH

## Table II
## DECISION 1485
## WATER QUALITY STANDARDS
## FOR THE SACRAMENTO–SAN JOAQUIN DELTA AND SUISUN MARSH [1/]

| BENEFICIAL USE PROTECTED and LOCATION | PARAMETER | DESCRIPTION | YEAR TYPE [2/] | VALUES |
|---|---|---|---|---|
| **MUNICIPAL and INDUSTRIAL** | | | | |
| Contra Costa Canal Intake at Pumping Plant No. 1 | Chloride | Maximum Mean Daily $Cl^-$ in mg/l | All | 250 |
| Contra Costa Canal Intake at Pumping Plant No. 1 or Antioch Water Works Intake on San Joaquin River | Chloride | Maximum Mean Daily 150 mg/l Chloride for at least the number of days shown during the Calendar Year. Must be provided in intervals of not less than two weeks duration. (% of Year shown in parenthesis) | | Number of Days Each Calendar Year Less than 150 mg/l Chloride |
| | | | Wet | 240 (66%) |
| | | | Ab. Normal | 190 (52%) |
| | | | Bl. Normal | 175 (48%) |
| | | | Dry | 165 (45%) |
| | | | Critical | 155 (42%) |
| City of Vallejo Intake at Cache Slough | Chloride | Maximum Mean Daily $Cl^-$ in mg/l | All | 250 |
| Clifton Court Forebay Intake at West Canal | Chloride | Maximum Mean Daily $Cl^-$ in mg/l | All | 250 |
| Delta Mendota Canal at Tracy Pumping Plant | Chloride | Maximum Mean Daily $Cl^-$ in mg/l | All | 250 |

| BENEFICIAL USE PROTECTED and LOCATION | PARAMETER | DESCRIPTION | YEAR TYPE | 0.45 EC April 1 to Date Shown | EC from Date Shown [3/] to Aug. 15 |
|---|---|---|---|---|---|
| **AGRICULTURE** | | | | | |
| *WESTERN DELTA* | | | | | |
| Emmaton on the Sacramento River | Electrical Conductivity | Maximum 14-day Running Average of Mean Daily EC in mmhos | Wet | Aug. 15 | — |
| | | | Ab. Normal | July 1 | 0.63 |
| | | | Bl. Normal | June 20 | 1.14 |
| | | | Dry | June 15 | 1.67 |
| | | | Critical | — | 2.78 |
| Jersey Point on the San Joaquin River | Electrical Conductivity | Maximum 14-day Running Average of Mean Daily EC in mmhos | Wet | Aug. 15 | — |
| | | | Ab. Normal | Aug. 15 | — |
| | | | Bl. Normal | June 20 | 0.74 |
| | | | Dry | June 15 | 1.35 |
| | | | Critical | — | 2.20 |
| *INTERIOR DELTA* | | | | | |
| Terminous on the Mokelumne River | Electrical Conductivity | Maximum 14-day Running Average of Mean Daily EC in mmhos | Wet | Aug. 15 | — |
| | | | Ab. Normal | Aug. 15 | — |
| | | | Bl. Normal | Aug. 15 | — |
| | | | Dry | Aug. 15 | — |
| | | | Critical | — | 0.54 |
| San Andreas Landing on the San Joaquin River | Electrical Conductivity | Maximum 14-day Running Average of Mean Daily EC in mmhos | Wet | Aug. 15 | — |
| | | | Ab. Normal | Aug. 15 | — |
| | | | Bl. Normal | Aug. 15 | — |
| | | | Dry | June 25 | 0.58 |
| | | | Critical | — | 0.87 |

## Table II
## DECISION 1485
## WATER QUALITY STANDARDS
## FOR THE SACRAMENTO–SAN JOAQUIN DELTA AND SUISUN MARSH [1]

| BENEFICIAL USE PROTECTED and LOCATION | PARAMETER | DESCRIPTION | YEAR TYPE [2] | VALUES |
|---|---|---|---|---|
| **FISH AND WILDLIFE** | | | | |
| • *STRIPED BASS SPAWNING* | | | | |
| *Prisoners Point on the San Joaquin River* | *Electrical Conductivity* | *Average of mean daily EC for the period not to exceed* | *All* | *April 1 to May 5*<br>*0.550 mmhos* |
| *Chipps Island* | *Delta Outflow Index in cfs* | *Average of the daily Delta outflow index for the period, not less than* | *All* | *April 1 to April 14*<br>*6700 cfs* |
| *Antioch Waterworks Intake on the San Joaquin River* | *Electrical Conductivity* | *Average of mean daily EC for the period, not more than* | *All* | *April 15 to May 5*<br>*1.5 mmhos* |
| *Antioch Waterworks Intake* | *Electrical Conductivity (Relaxation Provision — replaces the above Antioch and Chipps Island Standard whenever the projects impose deficiencies in firm supplies [5])* | *Average of mean daily EC for the period, not more than the values corresponding to the deficiencies taken (linear interpolation to be used to determine values between those shown)* | *All — whenever the projects impose deficiencies in firm supplies [5]* | *Total Annual Imposed Deficiency MAF — April 1 to May 5 EC in mmhos:*<br>0 — 1.5<br>0.5 — 1.9<br>1.0 — 2.5<br>1.5 — 3.4<br>2.0 — 4.4<br>3.0 — 10.3<br>4.0 or more — 25.2 |
| • *STRIPED BASS SURVIVAL* | | | | |
| *Chipps Island* | *Delta Outflow Index in cfs* | *Average of the daily Delta outflow index for each period shown not less than* | | *May 6–31 / June / July* |
| | | | *Wet* | 14,000 / 14,000 / 10,000 |
| | | | *Ab. Normal* | 14,000 / 10,700 / 7,700 |
| | | | *Bl. Normal* | 11,400 / 9,500 / 6,500 |
| | | | *Subnormal Snowmelt* | 6,500 / 5,400 / 3,600 |
| | | | *Dry [6]* | 4,300 / 3,600 / 3,200 |
| | | | *Dry [7] or Critical* | 3,300 / 3,100 / 2,900 |
| • *SALMON MIGRATIONS* | | | | |
| *Rio Vista on the Sacramento River* | *Computed net stream flow in cfs* | *Minimum 30-day running average of mean daily net flow* | | *Jan. / Feb. 1–Mar. 15 / Mar. 16–June 30* |
| | | | *Wet* | 2.500 / 3,000 / 5,000 |
| | | | *Ab. Normal* | 2,500 / 2,000 / 3,000 |
| | | | *Bl. Normal* | 2,500 / 2,000 / 3,000 |
| | | | *Dry or Critical* | 1,500 / 1,000 / 2,000 |
| | | | | *July / Aug. / Sept. 1–Dec. 31* |
| | | | *Wet* | 3,000 / 1,000 / 5,000 |
| | | | *Ab. Normal* | 2,000 / 1,000 / 2,500 |
| | | | *Bl. Normal* | 2,000 / 1,000 / 2,500 |
| | | | *Dry or Critical* | 1,000 / 1,000 / 1,500 |
| • *SUISUN MARSH* | | | | *Jan.–May / Oct.–Dec.* |
| *Chipps Island at O&A Ferry Landing* | *Electrical Conductivity* | *Maximum 28-day running average of mean daily EC* | *Wet* | 12.5 mmhos / 12.5 mmhos |
| | | | *Ab. Normal* | 12.5 mmhos / 12.5 mmhos |
| | | | *Bl. Normal* | 12.5 mmhos / 12.5 mmhos |
| | | | *Dry or Critical* | 12.5 mmhos / 15.5 mmhos |
| | | *(The 15.6 mmhos EC Standard applies only when project water users are taking deficiencies in scheduled water supplies [8] otherwise the 12.5 mmhos EC remains in effect.)* | | |
| *Chipps Island* | *Delta Outflow Index in cfs* | *Average of the daily Delta outflow index for each month, not less than values shown* | *Wet* | *February–May*<br>*10,000 cfs* |
| | | | *Subnormal Snowmelt* | *February–April*<br>*10,000 cfs* |
| | | *Minimum daily Delta outflow index for 60 consecutive days in the period* | *Ab. Norm. and Bl. Norm.* | *January–April*<br>*12,000 cfs* |

Table II
DECISION 1485
WATER QUALITY STANDARDS
FOR THE SACRAMENTO-SAN JOAQUIN DELTA AND SUISUN MARSH[1]

| BENEFICIAL USE PROTECTED and LOCATION | PARAMETER | DESCRIPTION | YEAR TYPE[2] | VALUES |
|---|---|---|---|---|
| **FISH AND WILDLIFE** | | | | |
| • SUISUN MARSH | | | | |
| Chipps Island (continued) | Delta Outflow Index in cfs | Average of the daily Delta outflow index for each month, not less than values shown | All (if greater flow not required by above standard)—whenever storage is at or above the minimum level in the flood control reservation envelope at two out of three of the following: Shasta Reservoir, Oroville Reservoir, and CVP storage on the American River | Jan.–May<br>6,600 cfs |
| Collinsville on Sacramento River (C–2)<br>Miens Landing on Montezuma Slough (S–64)<br>Montezuma Slough at Cutoff Slough (S–48)<br>Montezuma Slough near mouth<br>Suisun Slough near Volanti Slough (S–42)<br>Suisun Slough near mouth (S–31)<br>Goodyear Slough south of Pierce Harbor (S–35)<br>Cordelia Slough above S. P. R.R. (S–32) | Electrical Conductivity | The monthly average of both daily high tide values not to exceed the values shown (or demonstrate that equivalent or better protection will be provided at the location) | All – To become effective Oct. 1, 1984 | Month / EC in mmhos<br>Oct. 19.0<br>Nov. 15.5<br>Dec. 15.5<br>Jan. 12.5<br>Feb. 8.0<br>Mar. 8.0<br>Apr. 11.0<br>May 11.0 |
| • OPERATIONAL CONSTRAINTS | | | | |
| Minimize diversion of young striped bass from the Delta | Diversions in cfs | The mean monthly diversions from the Delta by the State Water Project (Department) not to exceed the values shown. | All | May June July<br>3,000 3,000 4,600 |
| | | The mean monthly diversions from the Delta by the Central Valley Project (Bureau), not to exceed the values shown | All | May June<br>3,000 3,000 |
| Minimize diversion of young striped bass into Central Delta | | Closure of Delta cross channel gates for up to 20 days but no more than two out of four consecutive days at the discretion of the Department of Fish and Game upon 12 hours notice | All – whenever the daily Delta outflow index is greater than 12,000 cfs | April 16–May 31 |
| Minimize cross Delta movement of Salmon | | Closure of Delta Cross Channel gates (whenever the daily Delta outflow index is greater than 12,000 cfs) | All | Jan. 1–April 15 |

# Table II
# DECISION 1485
# WATER QUALITY STANDARDS
# FOR THE SACRAMENTO-SAN JOAQUIN DELTA AND SUISUN MARSH 1/

## FISH PROTECTIVE FACILITIES

Maintain appropriate records of the numbers, sizes, kinds of fish salvaged and of water export rates and fish facility operations.

## STATE FISH PROTECTIVE FACILITY

The facility is to be operated to meet the following standards to the extent that they are compatible with water export rates:

(a) King Salmon — from November through May 14, standards shall be as follows:
   (1) Approach Velocity — 3.0 to 3.5 feet per second
   (2) Bypass Ratio — maintain 1.2:1.0 to 1.6:1.0 ratios in both primary and secondary channels
   (3) Primary Bay — not critical but use Bay B as first choice
   (4) Screened Water System — the velocity of water exiting from the screened water system is not to exceed the secondary channel approach velocity. The system may be turned off at the discretion of the operators.

(b) Striped Bass and White Catfish — from May 15 through October, standards shall be as follows:
   (1) Approach Velocity — in both the primary and secondary channels, maintain a velocity as close to 1.0 feet per second as is possible
   (2) Bypass Ratio
      (i) When only Bay A (with center wall) is in operation maintain a 1.2:1.0 ratio
      (ii) When both primary bays are in operation and the approach velocity is less than 2.5 feet per second, the bypass ratio should be 1.5:1.0
      (iii) When only Bay B is operating the bypass ratio should be 1.2:1.0
      (iv) Secondary channel bypass ratio should be 1.2:1.0 for all approach velocities.
   (3) Primary Channel — use Bay A (with center wall) in preference to Bay B
   (4) Screened Water Ratio — if the use of screened water is necessary, the velocity of water exiting the screened water system is not to exceed the secondary channel approach velocity
   (5) Clifton Court Forebay Water Level — maintain at the highest practical level.

## TRACY FISH PROTECTIVE FACILITY

The secondary system is to be operated to meet the following standards, to the extent that they are compatible with water export rates:

(a) The secondary velocity should be maintained at 3.0 to 3.5 feet per second whenever possible from February through May while salmon are present

(b) To the extent possible, the secondary velocity should not exceed 2.5 feet per second and preferably 1.5 feet per second between June 1 and August 31, to increase the efficiency for striped bass, catfish, shad, and other fish. Secondary velocities should be reduced even at the expense of bypass ratios in the primary, but the ratio should not be reduced below 1:1.0

(c) The screened water discharge should be kept at the lowest possible level consistent with its purpose of minimizing debris in the holding tanks

(d) The bypass ratio in the secondary should be operated to prevent excessive velocities in the holding tanks, but in no case should the bypass velocity be less than the secondary approach velocity.

## FOOTNOTES

1/ Except for flow, all values are for surface zone measurements. Except for flow, all mean daily values are based on at least hourly measurements. All dates are inclusive.

2/ Footnote 2 is set forth on next sheet.

3/ When no date is shown in the adjacent column, EC limit in this column begins on April 1.

4/ If contracts to ensure such facilities and water supplies are not executed by January 1, 1980, the Board will take appropriate enforcement actions to prevent encroachment on riparian rights in the southern Delta.

5/ For the purpose of this provision firm supplies of the Bureau shall be any water the Bureau is legally obligated to deliver under any CVP contract of 10 years or more duration, excluding the Friant Division of the CVP, subject only to dry and critical year deficiencies. Firm supplies of the Department shall be any water the Department would have delivered under Table A entitlements of water supply contracts and under prior right settlements had deficiencies not been imposed in that dry or critical year.

6/ Dry year following a wet, above normal or below normal year.

7/ Dry year following a dry or critical year.

8/ Scheduled water supplies shall be firm supplies for USBR and DWR plus additional water ordered from DWR by a contractor the previous September, and which does not exceed the ultimate annual entitlement for said contractor.

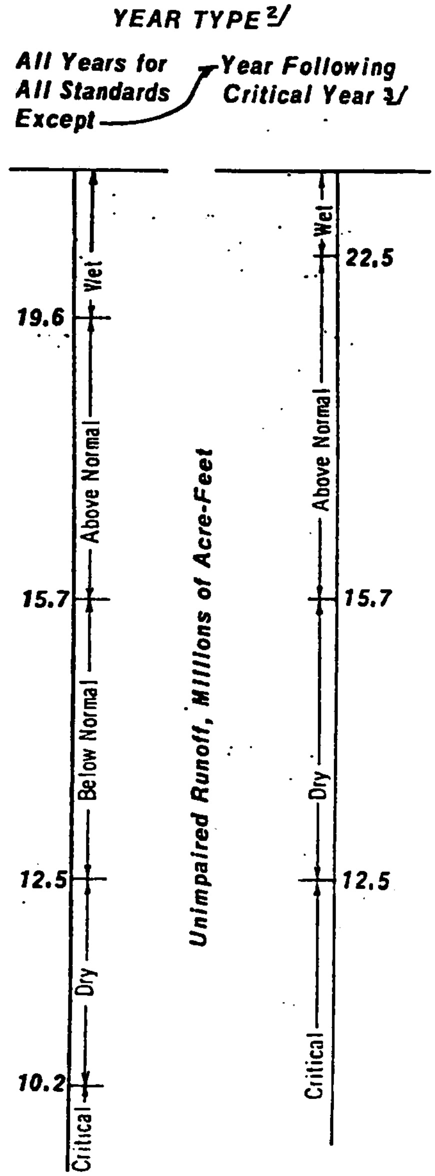
NOTE: EC values are mmhos/cm at 25°C.

# FOOTNOTE 2 OF TABLE II

## YEAR CLASSIFICATION

Year classification shall be determined by the forecast of Sacramento Valley unimpaired runoff for the current water year *(October 1 of the preceding calendar year through September 30 of the current calendar year)* as published in California Department of Water Resources Bulletin 120 for the sum of the following locations: Sacramento River above Bend Bridge, near Red Bluff; Feather River, total inflow to Oroville Reservoir; Yuba River at Smartville; American River, total inflow to Folsom Reservoir. Preliminary determinations of year classification shall be made in February, March and April with final determination in May. These preliminary determinations shall be based on hydrologic conditions to date plus forecasts of future runoff assuming normal precipitation for the remainder of the water year.

| *YEAR TYPE* | *RUNOFF, MILLIONS OF ACRE-FEET* |
|---|---|
| Wet 1/ | equal to or greater than 19.6 (except equal to or greater than 22.5 in a year following a critical year). 3/ |
| Above Normal 1/ | greater than 15.7 and less than 19.6 (except greater than 15.7 and less than 22.5 in a year following a critical year). 3/ |
| Below Normal 1/ | equal to or less than 15.7 and greater than 12.5 (except in a year following a critical year). 3/ |
| Dry | equal to or less than 12.5 and greater than 10.2 (except equal to or less than 15.7 and greater than 12.5 in a year following a critical year). 3/ |
| Critical | equal to or less than 10.2 (except equal to or less than 12.5 in a year following a critical year). 3/ |

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1/ *Any otherwise wet, above normal, or below normal year may be designated a subnormal snowmelt year whenever the forecast of April through July unimpaired runoff reported in the May issue of Bulletin 120 is less than 5.9 million acre-feet.*

2/ *The year type for the preceding water year will remain in effect until the initial forecast of unimpaired runoff for the current water year is available.*

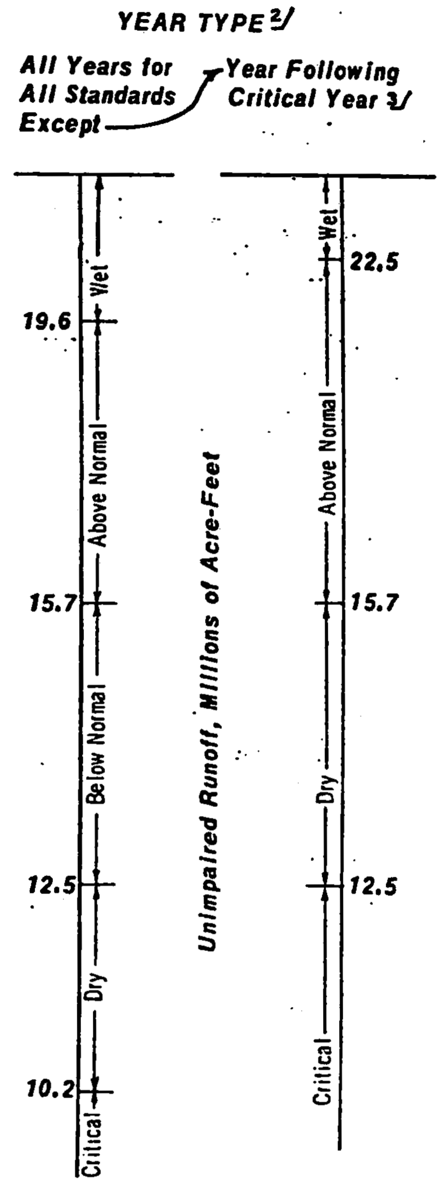
3/ *"Year following critical year" classification does not apply to Agricultural, Municipal and Industrial standards.*

# FOOTNOTE 2 OF TABLE II

## YEAR CLASSIFICATION

Year classification shall be determined by the forecast of Sacramento Valley unimpaired runoff for the current water year *(October 1 of the preceding calendar year through September 30 of the current calendar year)* as published in California Department of Water Resources Bulletin 120 for the sum of the following locations: Sacramento River above Bend Bridge, near Red Bluff; Feather River, total inflow to Oroville Reservoir; Yuba River at Smartville; American River, total inflow to Folsom Reservoir. Preliminary determinations of year classification shall be made in February, March and April with final determination in May. These preliminary determinations shall be based on hydrologic conditions to date plus forecasts of future runoff assuming normal precipitation for the remainder of the water year.

| *YEAR TYPE* | *RUNOFF, MILLIONS OF ACRE-FEET* |
|---|---|
| Wet 1/ | equal to or greater than 19.6 (except equal to or greater than 22.5 in a year following a critical year). 3/ |
| Above Normal 1/ | greater than 15.7 and less than 19.6 (except greater than 15.7 and less than 22.5 in a year following a critical year). 3/ |
| Below Normal 1/ | equal to or less than 15.7 and greater than 12.5 (except in a year following a critical year). 3/ |
| Dry | equal to or less than 12.5 and greater than 10.2 (except equal to or less than 15.7 and greater than 12.5 in a year following a critical year). 3/ |
| Critical | equal to or less than 10.2 (except equal to or less than 12.5 in a year following a critical year). 3/ |

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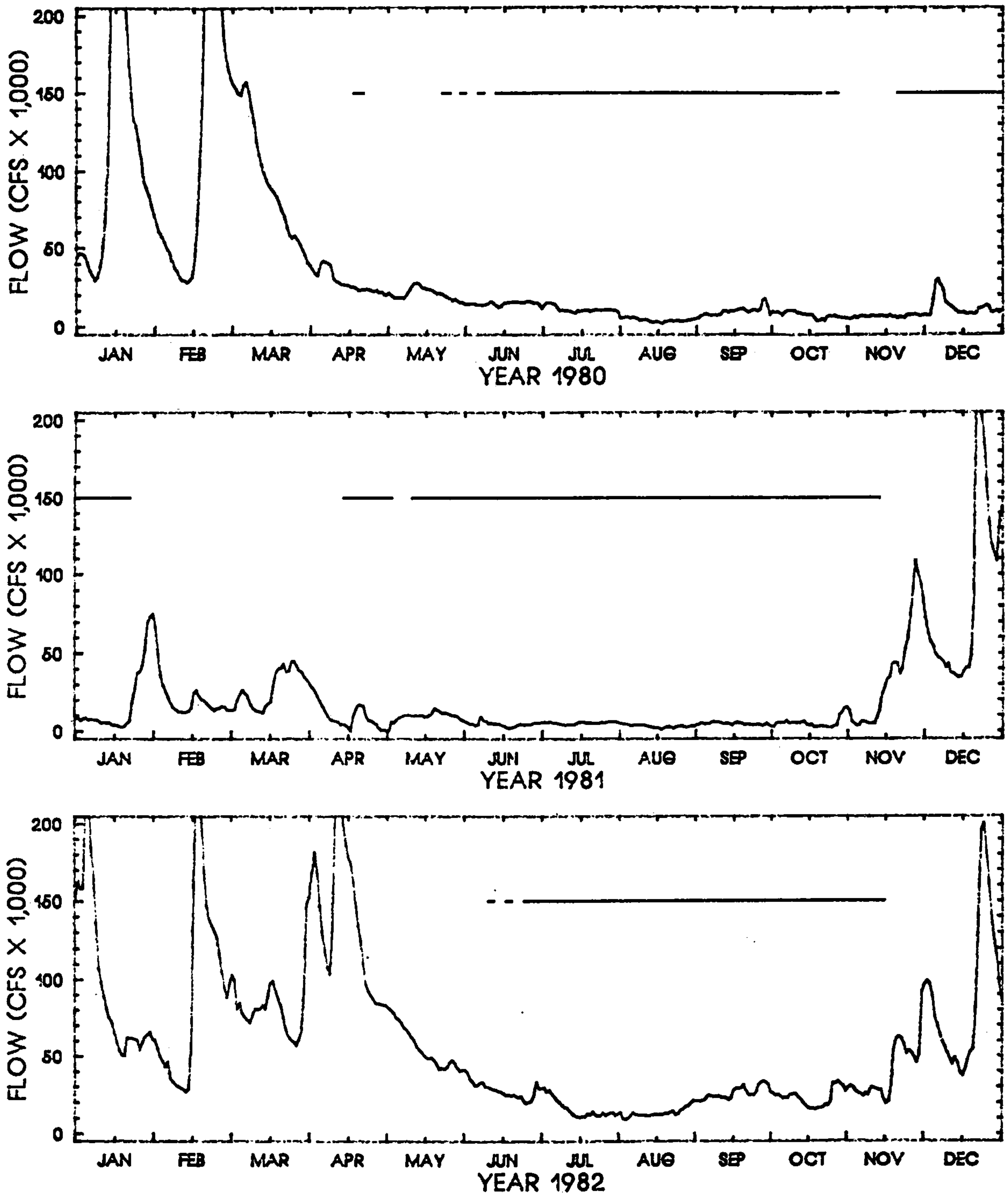
1/ *Any otherwise wet, above normal, or below normal year may be designated a subnormal snowmelt year whenever the forecast of April through July unimpaired runoff reported in the May issue of Bulletin 120 is less than 5.9 million acre-feet.*

2/ *The year type for the preceding water year will remain in effect until the initial forecast of unimpaired runoff for the current water year is available.*

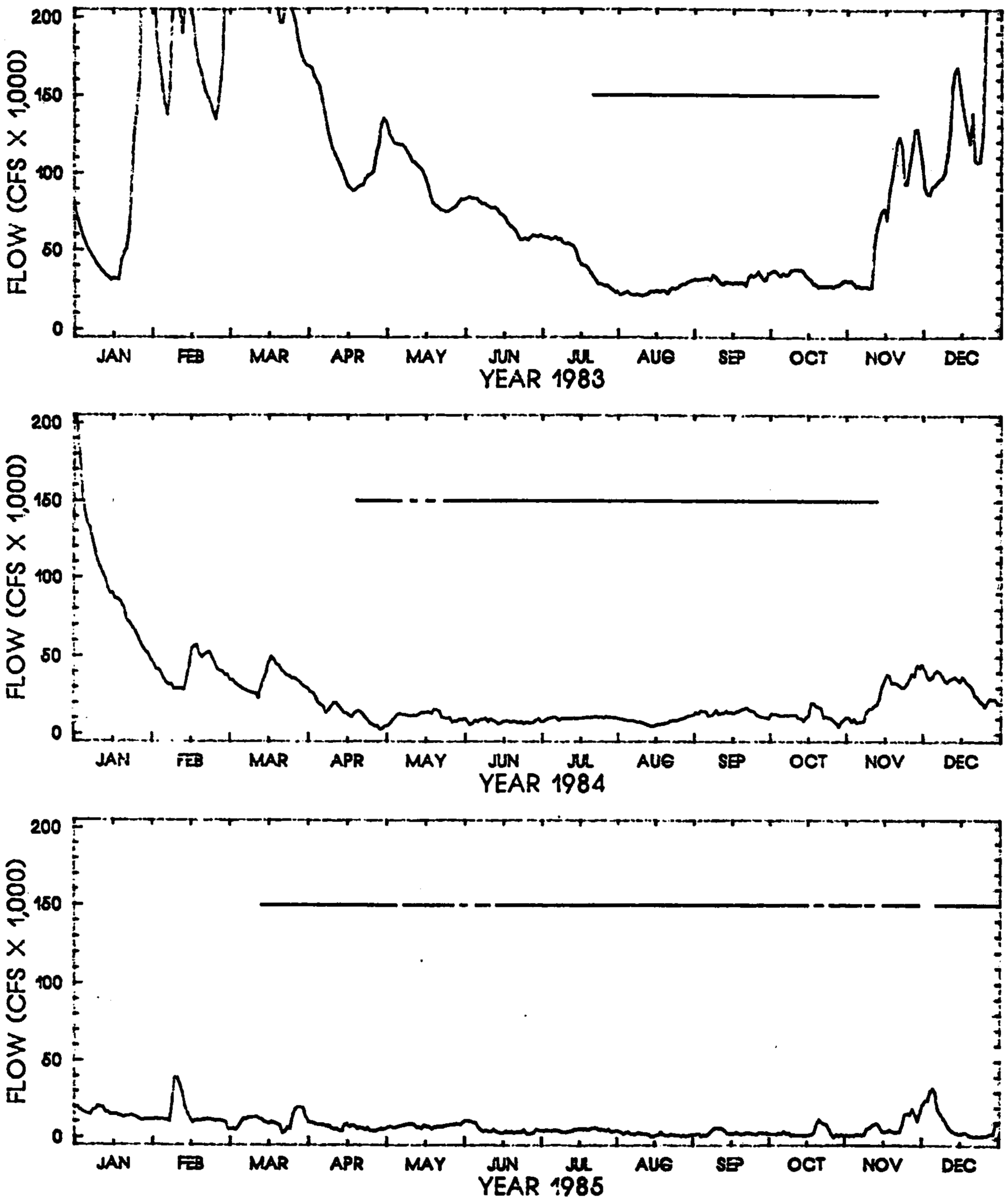
3/ *"Year following critical year" classification does not apply to Agricultural, Municipal and Industrial standards.*

# Appendix 3

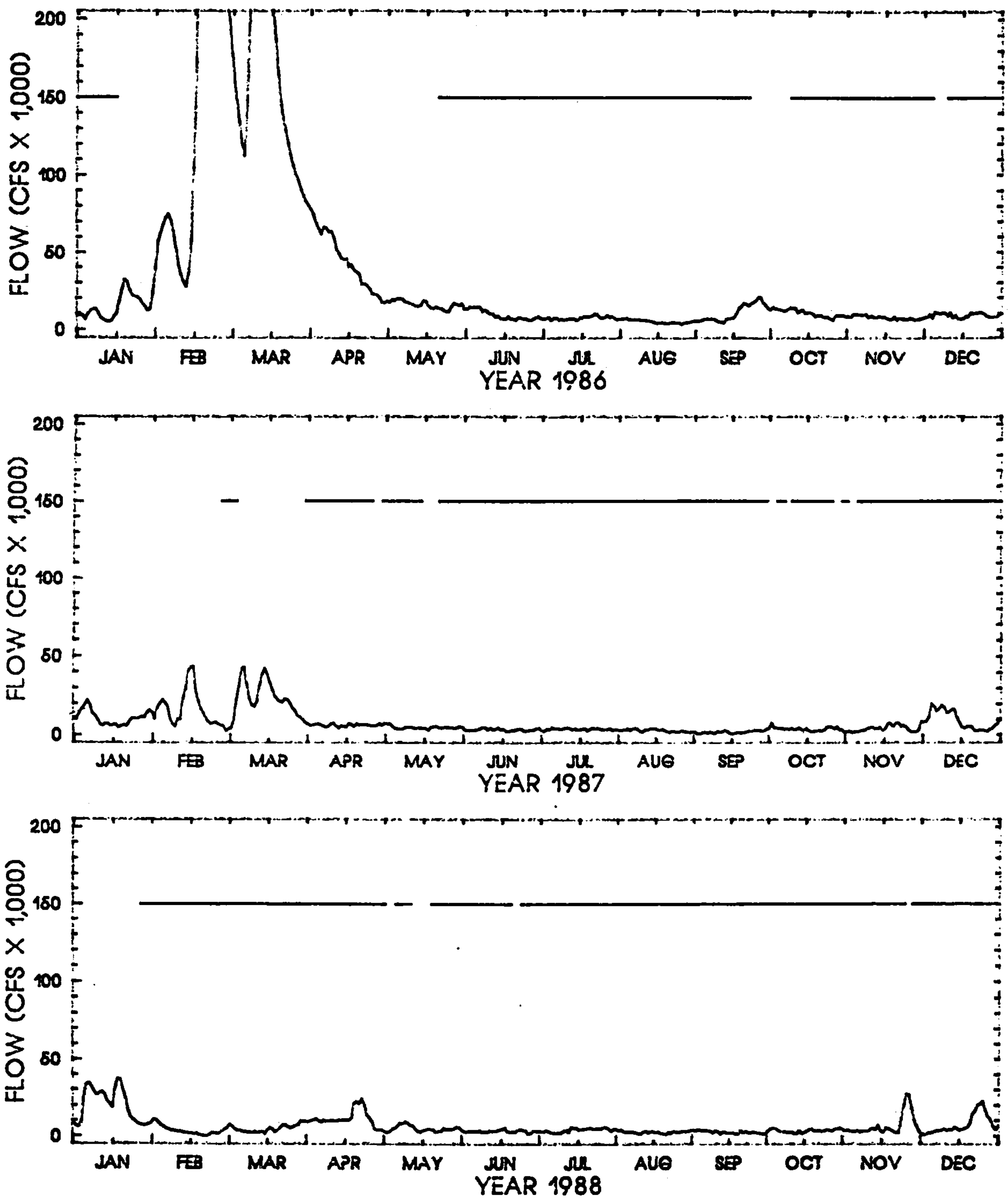
# PLOTS OF
# SACRAMENTO RIVER DAILY FLOWS



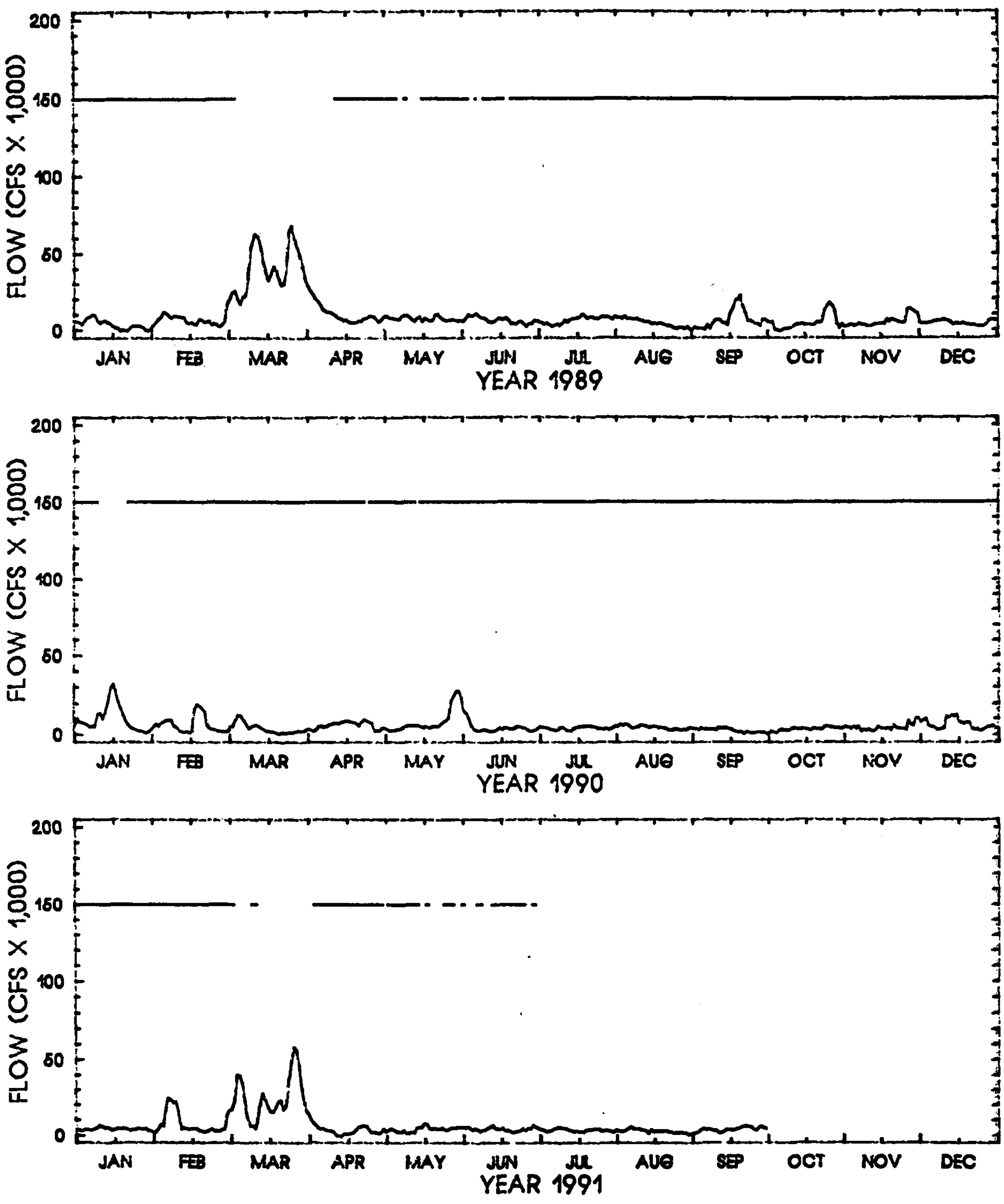

Sacramento River daily flow at Freeport and Delta Cross Channel gate operations from 1980 thru 1991, taken from CDWR DAYFLOW publication. A dot near the 150,000 cfs line indicates gates open.




Sacramento River daily flow at Freeport and Delta Cross Channel gate operations from 1980 thru 1991, taken from CDWR DAYFLOW publication. A dot near the 150,000 cfs line indicates gates open.




Sacramento River daily flow at Freeport and Delta Cross Channel gate operations from 1980 thru 1991, taken from CDWR DAYFLOW publication. A dot near the 150,000 cfs line indicates gates open.




Sacramento River daily flow at Freeport and Delta Cross Channel gate operations from 1980 thru 1991, taken from CDWR DAYFLOW publication. A dot near the 150,000 cfs line indicates gates open.

# Appendix 4

# SALMON LENGTH FREQUENCIES FROM THE UNITED STATES FISH AND WILDLIFE SERVICE MONTEZUMA SLOUGH TRAWLING, 4/7/87 THROUGH 5/28/87

APPENDIX 4. Salmon length frequencies from the United States Fish and Wildlife Service Montezuma Slough trawling 4/7/87 through 5/28/87.

| DATE | LENGTH | FREQ | DATE | LENGTH | FREQ | DATE | LENGTH | FREQ |
|---|---|---|---|---|---|---|---|---|
| 04/14/87 | 62. | 1 | 05/02/87 | 97. | 1 | 05/09/87 | 78. | 2 |
| 04/16/87 | 62. | 1 | 05/03/87 | 78. | 2 | 05/09/87 | 81. | 1 |
| 04/16/87 | 97. | 1 | 05/03/87 | 80. | 1 | 05/09/87 | 82. | 1 |
| 04/21/87 | 62. | 1 | 05/03/87 | 81. | 1 | 05/09/87 | 83. | 1 |
| 04/21/87 | 82. | 1 | 05/03/87 | 82. | 1 | 05/09/87 | 85. | 1 |
| 04/21/87 | 91. | 1 | 05/03/87 | 84. | 2 | 05/09/87 | 88. | 1 |
| 04/23/87 | 74. | 1 | 05/03/87 | 85. | 1 | 05/09/87 | 91. | 1 |
| 04/23/87 | 79. | 1 | 05/04/87 | 67. | 1 | 05/10/87 | 80. | 1 |
| 04/28/87 | 68. | 1 | 05/04/87 | 74. | 1 | 05/10/87 | 83. | 1 |
| 04/28/87 | 75. | 1 | 05/04/87 | 75. | 1 | 05/10/87 | 90. | 1 |
| 04/28/87 | 80. | 1 | 05/04/87 | 77. | 1 | 05/12/87 | 68. | 1 |
| 04/29/87 | 74. | 1 | 05/04/87 | 80. | 2 | 05/12/87 | 72. | 1 |
| 04/29/87 | 75. | 1 | 05/04/87 | 84. | 1 | 05/12/87 | 74. | 1 |
| 04/29/87 | 76. | 1 | 05/04/87 | 91. | 1 | 05/12/87 | 77. | 1 |
| 04/29/87 | 79. | 1 | 05/04/87 | 94. | 1 | 05/12/87 | 78. | 1 |
| 04/29/87 | 81. | 2 | 05/05/87 | 73. | 1 | 05/12/87 | 80. | 1 |
| 04/29/87 | 83. | 1 | 05/05/87 | 74. | 2 | 05/12/87 | 83. | 1 |
| 04/29/87 | 95. | 1 | 05/05/87 | 75. | 1 | 05/13/87 | 70. | 1 |
| 04/30/87 | 67. | 1 | 05/05/87 | 78. | 1 | 05/13/87 | 75. | 1 |
| 04/30/87 | 74. | 2 | 05/05/87 | 79. | 1 | 05/13/87 | 77. | 2 |
| 04/30/87 | 75. | 1 | 05/05/87 | 86. | 1 | 05/13/87 | 78. | 3 |
| 04/30/87 | 76. | 3 | 05/05/87 | 92. | 1 | 05/13/87 | 79. | 2 |
| 04/30/87 | 83. | 1 | 05/06/87 | 69. | 2 | 05/13/87 | 80. | 1 |
| 04/30/87 | 84. | 2 | 05/06/87 | 71. | 2 | 05/13/87 | 82. | 1 |
| 04/30/87 | 85. | 1 | 05/06/87 | 74. | 1 | 05/14/87 | 70. | 1 |
| 04/30/87 | 86. | 1 | 05/06/87 | 75. | 3 | 05/14/87 | 75. | 2 |
| 04/30/87 | 87. | 2 | 05/06/87 | 76. | 3 | 05/14/87 | 77. | 1 |
| 04/30/87 | 90. | 1 | 05/06/87 | 77. | 3 | 05/14/87 | 81. | 1 |
| 04/30/87 | 94. | 1 | 05/06/87 | 78. | 2 | 05/14/87 | 88. | 1 |
| 04/30/87 | 95. | 1 | 05/06/87 | 79. | 1 | 05/14/87 | 89. | 1 |
| 05/01/87 | 74. | 1 | 05/06/87 | 85. | 2 | 05/14/87 | 91. | 1 |
| 05/01/87 | 78. | 1 | 05/06/87 | 86. | 1 | 05/15/87 | 72. | 1 |
| 05/01/87 | 80. | 2 | 05/07/87 | 67. | 1 | 05/15/87 | 75. | 2 |
| 05/01/87 | 81. | 1 | 05/07/87 | 70. | 1 | 05/15/87 | 80. | 1 |
| 05/01/87 | 82. | 2 | 05/07/87 | 71. | 1 | 05/21/87 | 72. | 1 |
| 05/01/87 | 84. | 1 | 05/07/87 | 75. | 1 | 05/21/87 | 74. | 1 |
| 05/01/87 | 85. | 1 | 05/07/87 | 79. | 3 | 05/21/87 | 75. | 1 |
| 05/01/87 | 90. | 1 | 05/07/87 | 85. | 1 | 05/21/87 | 76. | 1 |
| 05/01/87 | 91. | 1 | 05/07/87 | 88. | 1 | 05/21/87 | 82. | 1 |
| 05/01/87 | 92. | 1 | 05/07/87 | 95. | 1 | 05/21/87 | 85. | 1 |
| 05/02/87 | 77. | 1 | 05/08/87 | 70. | 1 | 05/21/87 | 87. | 1 |
| 05/02/87 | 79. | 2 | 05/08/87 | 76. | 1 | 05/21/87 | 89. | 1 |
| 05/02/87 | 81. | 1 | 05/08/87 | 79. | 1 | 05/21/87 | 90. | 2 |
| 05/02/87 | 82. | 1 | 05/08/87 | 81. | 1 | 05/26/87 | 78. | 1 |
| 05/02/87 | 83. | 3 | 05/09/87 | 70. | 1 | 05/26/87 | 89. | 1 |
| 05/02/87 | 84. | 1 | 05/09/87 | 71. | 1 | 05/28/87 | 85. | 2 |
| 05/02/87 | 85. | 1 | 05/09/87 | 73. | 1 | 05/28/87 | 90. | 1 |
| 05/02/87 | 90. | 1 | 05/09/87 | 75. | 1 | 05/28/87 | 100. | 1 |
| 05/02/87 | 91. | 2 | 05/09/87 | 77. | 1 | | | |

# Appendix 5

# FIGURES AND TABLES RELATED TO DEVELOPMENT OF THE DELTA SMOLT SURVIVAL MODEL

TABLE 1.

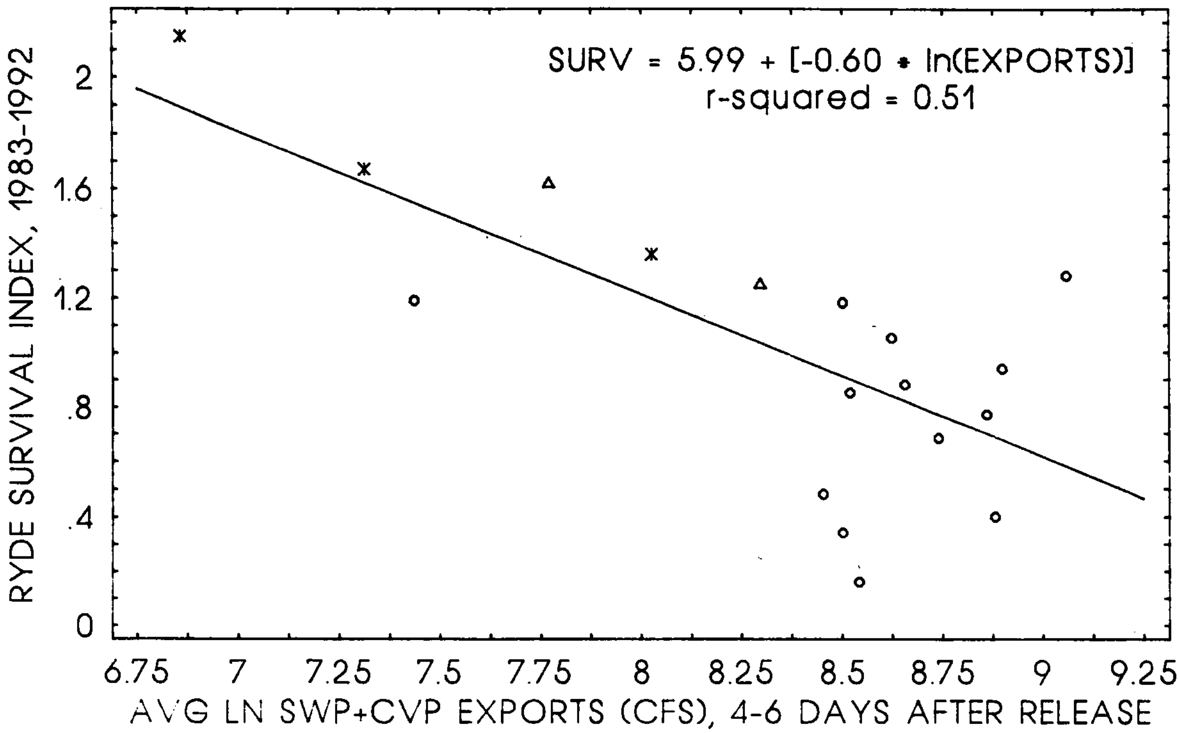
| RELS | RELDATEB | TRAWL SURVIVAL | JULIAN DAY | TEMPFREE | WEST4_6 | WEST_CI | EXP4_6 | LNEXP4_6 | EXP3_9 | LNEXP3-9 |
|---|---|---|---|---|---|---|---|---|---|---|
| isle | 05/20/83 | 1.18 | 140 | 62.5 | 33746. | 35026. | 4925. | 8.50208 | 4634. | 8.441175 |
| ryde | 06/13/84 | 1.05 | 165 | 66.8 | 1223. | 1108. | 5563. | 8.623893 | 5508. | 8.613956 |
| ryde | 05/11/85 | 0.77 | 131 | 61.3 | -99. | -147. | 7042. | 8.859648 | 7221. | 8.884748 |
| ryde | 05/30/86 | 0.68 | 150 | 72. | 6978. | 6964. | 6243. | 8.739216 | 5931. | 8.687948 |
| ryde | 04/29/87 | 0.85 | 119 | 67.4 | 2112. | 1046. | 5012. | 8.51959 | 5335. | 8.582045 |
| ryde | 05/02/87 | 0.88 | 122 | 67.5 | 221. | 511. | 5746. | 8.65626 | 5244. | 8.56484 |
| ryde | 05/04/88 | 0.94 | 125 | 63.9 | 524. | 285. | 7321. | 8.898502 | 8024. | 8.990192 |
| ryde | 05/07/88 | 1.28 | 128 | 59.9 | -517. | -271. | 8596. | 9.059052 | 8607. | 9.060331 |
| ryde | 06/22/88 | 0.4 | 174 | 73.4 | -2326. | -2569. | 7185. | 8.879751 | 6052. | 8.708144 |
| ryde | 06/25/88 | 0.34 | 177 | 72.9 | -1012. | -1736. | 4919. | 8.50086 | 4919. | 8.50086 |
| ryde | 05/03/89 | 1.19 | 123 | 62.1 | 3663. | 253. | 1696. | 7.436028 | 3149. | 8.05484 |
| ryde | 06/02/89 | 0.48 | 153 | 68.7 | -75. | -828. | 4687. | 8.452548 | 5812. | 8.66768 |
| ryde | 06/16/89 | 0.16 | 167 | 70. | -2771. | -1378. | 5124. | 8.541691 | 4853. | 8.487352 |
| ryde | 05/09/90 | 1.618294 | 129 | 68.9 | 2074. | 828. | 2368. | 7.769801 | 3174. | 8.062748 |
| ryde | 05/31/90 | 1.2461 | 151 | 62.15 | 1954. | 945. | 4014. | 8.297544 | 3897. | 8.267962 |
| ryde | 04/06/92 | 1.36 | 97 | 64.2 | 11. | 1328. | 3062. | 8.026824 | 1969. | 7.585281 |
| ryde | 04/14/92 | 2.15 | 105 | 62.1 | 1391. | 1028. | 951. | 6.857514 | 936. | 6.841616 |
| ryde | 04/27/92 | 1.67 | 118 | 69.3 | 725. | 737. | 1499. | 7.312553 | 1991. | 7.596392 |

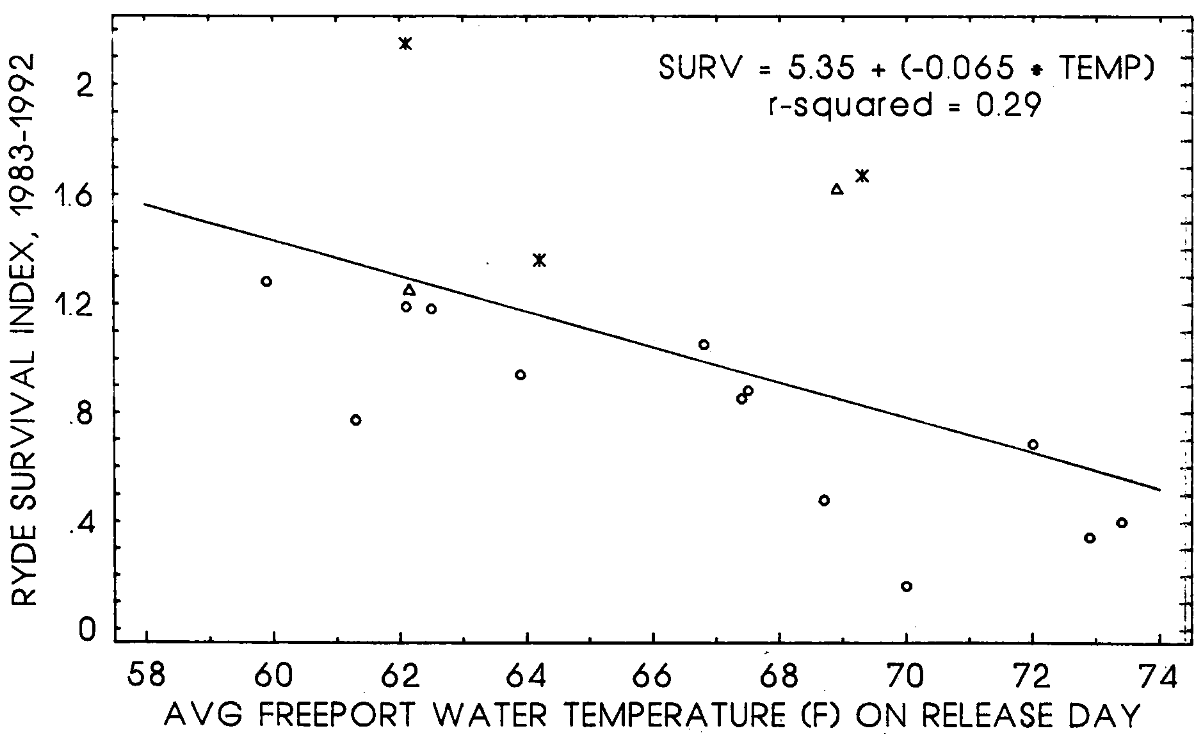
TABLE 2.

| RELSITE | RELDATEB | TRAWL SURVIVAL | FRACTION DIVERTED | OBSERVED RYDESURV | INTERIOR SURVIVAL | JUL DAY | TEMPFREE | WEST1_6 | WEST4_6 | EXPORTS 1-6 DAYS | LNEXP1_6 | EXPORTS 4-6 DAYS | LNEXP4_6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| courtland | 05/16/83 | 1.06 | 0.227 | 1.18 | 0.651 | 136 | 60.1 | 38162. | 36623. | 2647. | 7.881182 | 2678. | 7.892826 |
| courtland | 06/11/84 | 0.61 | 0.616 | 1.05 | 0.336 | 163 | 65.5 | 1181. | 1074. | 5608. | 8.631949 | 5325. | 8.580168 |
| courtland | 05/10/85 | 0.34 | 0.643 | 0.77 | 0.101 | 130 | 61.3 | 1161. | 476. | 6138. | 8.722254 | 6768. | 8.819961 |
| courtland | 05/28/86 | 0.35 | 0.637 | 0.68 | 0.162 | 148 | 71.6 | 8398. | 7534. | 4739. | 8.463581 | 5663. | 8.641709 |
| courtland | 04/28/87 | 0.67 | 0.412 | 0.85 | 0.413 | 118 | 67.3 | -218. | 1371. | 5733. | 8.653995 | 5462. | 8.60557 |
| courtland | 05/01/87 | 0.4 | 0.548 | 0.88 | 0.004 | 121 | 67.5 | 1110. | 850. | 5545. | 8.620652 | 5627. | 8.635332 |
| courtland | 05/03/88 | 0.7 | 0.387 | 0.94 | 0.32 | 124 | 63.5 | -1306. | -118. | 6162. | 8.726156 | 7039. | 8.859221 |
| courtland | 05/06/88 | 0.76 | 0.547 | 1.28 | 0.329 | 127 | 62.1 | -6. | 107. | 7651. | 8.942592 | 8263. | 9.019543 |
| courtland | 06/21/88 | 0.17 | 0.412 | 0.4 | -0.158 | 173 | 72. | -3220. | -2165. | 6464. | 8.774004 | 6868. | 8.834628 |
| courtland | 06/24/88 | 0.02 | 0.535 | 0.34 | -0.258 | 176 | 74.3 | -1902. | -1638. | 6269. | 8.743372 | 5669. | 8.642768 |
| courtland | 05/02/89 | 0.84 | 0.684 | 1.19 | 0.6784 | 122 | 60.8 | 4260. | 4182. | 2000. | 7.600903 | 1684. | 7.428927 |
| courtland | 06/02/89 | 0.35 | 0.664 | 0.48 | 0.2846 | 153 | 68.7 | 905. | -75. | 4243. | 8.353025 | 4687. | 8.452548 |
| courtland | 06/15/89 | 0.21 | 0.657 | 0.16 | 0.236 | 166 | 70.9 | -18. | -1163. | 3951. | 8.281724 | 4259. | 8.35679 |
| georgiana | 04/06/92 | * | * | 1.36 | 0.41 | 97 | 64.2 | -913. | 11. | 4221. | 8.347827 | 3062. | 8.026824 |
| georgiana | 04/14/92 | * | * | 2.15 | 0.71 | 105 | 62.1 | 1494. | 1391. | 945. | 6.851185 | 951. | 6.857514 |
| georgiana | 04/27/92 | * | * | 1.67 | 0.2 | 118 | 69.3 | 729. | 725. | 1358. | 7.213768 | 1499. | 7.312553 |

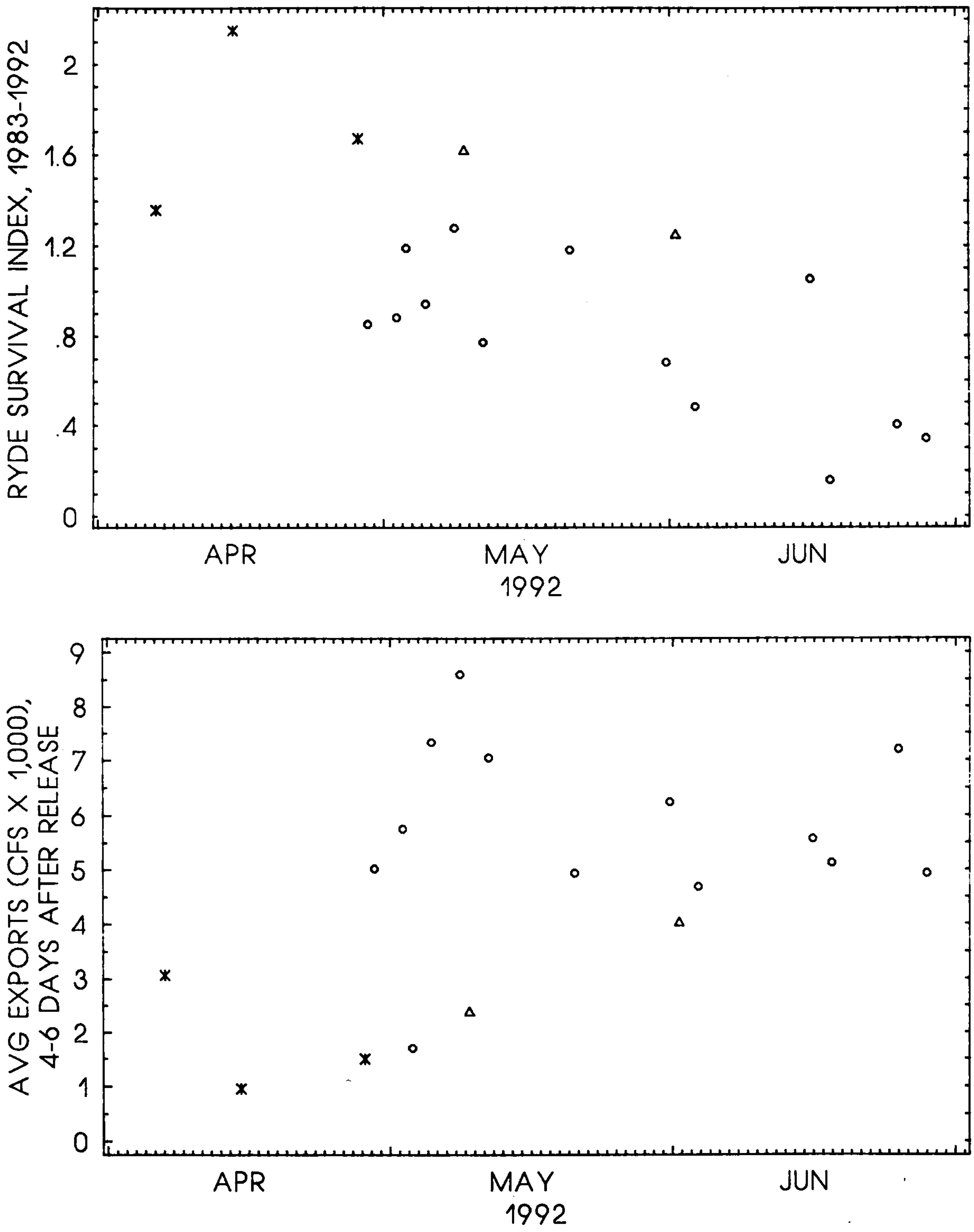
TABLE 3.

| RELSITE | RELDATEB | SURV_T | INTERIO TEMP | INTERIOR lnEXPORT | RYDE TEMP | RYDE lnEXPORT | FRACTION DIVERTED | PREDICT INTSURV | PREDICT RYDESURV | FACTORED SACSURV | JUL DAY | LENGTHmm | TEMP1 | TEMP1_3 | TEMP4_6 | SAC4_6 | WEST4_6 | EXP4_6 | lnEXP4_6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| discovery | 06/05/78 | 0. | 71.7 | 8.842027 | 73. | 8.969584 | 0.642 | -0.03079 | 0.304408 | 0. | 156 | 91. | 69.8 | 71.5 | 72.8 | 12767. | 7162. | 6216. | 8.734882 |
| discovery | 06/04/79 | 0.42 | 68.7 | 8.688646 | 68.8 | 8.661319 | 0.665 | 0.113608 | 0.70147 | 1.352475 | 155 | 75. | 68.8 | 69. | 68.3 | 11500. | 953. | 6598. | 8.794522 |
| discovery | 06/02/80 | 0.32 | 66.6 | 8.590955 | 66.2 | 8.552175 | 0.28 | 0.212869 | 0.902756 | 0.450966 | 154 | 96. | 66.9 | 66.7 | 66.2 | 14067. | 5397. | 4993. | 8.515792 |
| discovery | 06/04/80 | 0.35 | 66.1 | 8.434409 | 66.3 | 8.43961 | 0.536 | 0.261554 | 0.958643 | 0.598287 | 156 | 96. | 66.2 | 66.1 | 66.9 | 15367. | 5482. | 5462. | 8.60557 |
| discovery | 06/02/81 | 0.016 | 73.1 | 7.880237 | 74.3 | 7.853508 | 0.702 | 0.096041 | 0.841698 | 0.050275 | 153 | 90. | 72.4 | 72.8 | 75.1 | 9317. | 685. | 3400. | 8.131531 |
| discovery | 06/04/81 | 0. | 75.3 | 7.909948 | 75.1 | 8.183956 | 0.709 | 0.005704 | 0.61799 | 0. | 155 | 90. | 74.3 | 74.8 | 72.6 | 10933. | 2361. | 2237. | 7.712891 |
| discovery | 05/11/82 | 1.48 | 59.3 | 8.422003 | 59.5 | 8.412425 | 0.235 | 0.525849 | 1.344342 | 1.284727 | 131 | 76. | 59.5 | 59.4 | 60.5 | 36033. | 24930. | 5110. | 8.538955 |
| discovery | 05/12/82 | 1.54 | 59.5 | 8.412425 | 59.9 | 8.477343 | 0.236 | 0.519944 | 1.287149 | 1.392294 | 132 | 78. | 59.3 | 59.6 | 61.1 | 34333. | 24399. | 4546. | 8.422003 |
| discovery | 06/04/82 | 0.64 | 62.8 | 8.065789 | 63.4 | 8.011024 | 0.243 | 0.457964 | 1.350368 | 0.564616 | 155 | 76. | 62.7 | 63. | 64.1 | 27833. | 10268. | 3836. | 8.252186 |
| miller | 05/05/88 | 0.65 | 62.1 | 9.019584 | 59.9 | 9.059013 | 0.661 | 0.305667 | 0.970174 | 1.224256 | 126 | 77.5 | 63.5 | 61.8 | 60.5 | 13967. | 579. | 7706. | 8.949755 |
| miller | 06/23/88 | 0.09 | 74.3 | 8.642827 | 72.9 | 8.500928 | 0.644 | -0.09352 | 0.565252 | 0.638271 | 175 | 88.6 | 74.3 | 73.8 | 73.4 | 11237. | -2202. | 6639. | 8.800716 |
| miller | 06/01/89 | 0.16 | 68.7 | 8.45262 | 69.3 | 8.5689 | 0.664 | 0.157969 | 0.724562 | 0.459316 | 152 | 91. | 67.5 | 68.5 | 68.8 | 14267. | 698. | 3998. | 8.29355 |
| miller | 06/14/89 | 0.21 | 70.9 | 8.356711 | 70. | 8.541626 | 0.65 | 0.091241 | 0.701245 | 0.689106 | 165 | 87. | 70. | 70.3 | 69.4 | 13567. | 369. | 3868. | 8.260493 |
| miller | 05/07/90 | 0.8551 | 70.3 | 7.653969 | 68.9 | 7.76966 | 0.766 | 0.246435 | 1.181916 | 1.837583 | 127 | 73.9 | 70.3 | 69.8 | 66.8 | 8907. | 2316. | 2013. | 7.607381 |
| miller | 04/25/91 | 0.775 | 61.7 | 8.035603 | 60.3 | 7.8842 | 0.799 | 0.506014 | 1.588559 | 1.071025 | 115 | 81.5 | 62.2 | 61.4 | 62.2 | 5600. | 238. | 4155. | 8.332067 |
| miller | 04/29/91 | 0.485 | 63.5 | 7.913887 | 63. | 8.032685 | 0.85 | 0.459547 | 1.36038 | 0.815575 | 119 | 80. | 61.3 | 62.6 | 62.9 | 6183. | 993. | 2790. | 7.933797 |

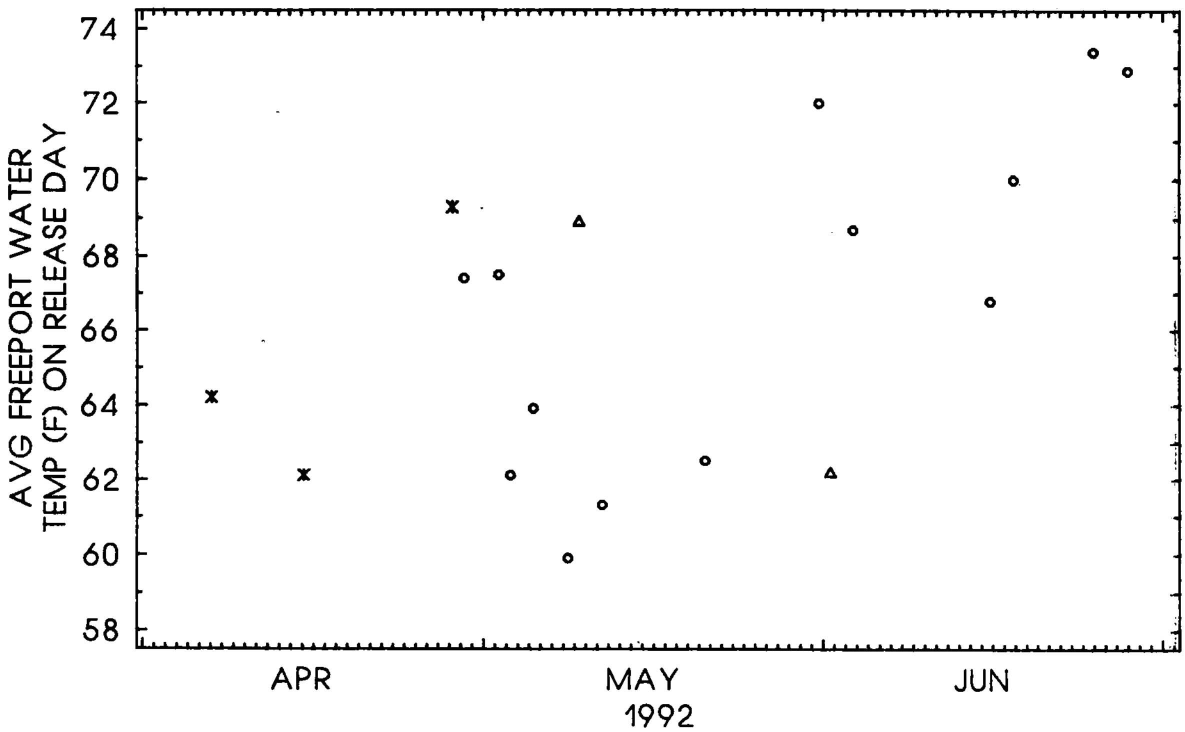


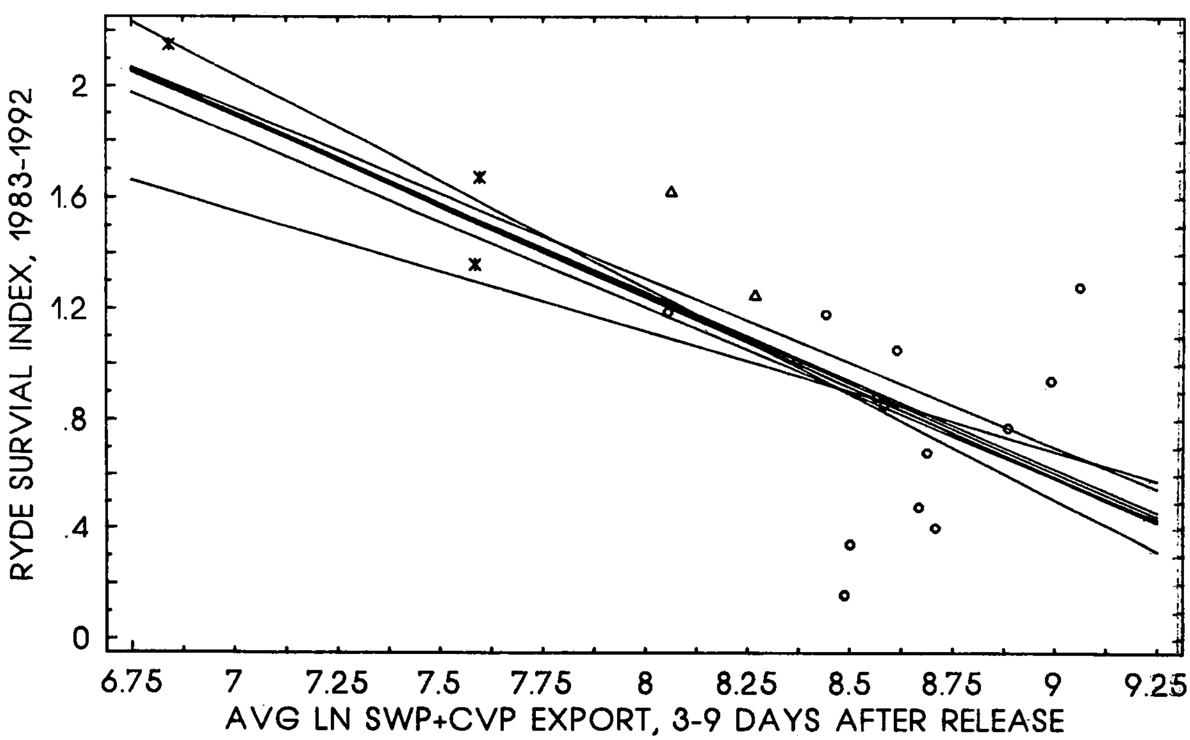




APPENDIX 5
FIGURES 1 AND 2
USFWS RYDE SURVIVAL INDEXES REGRESSION AGAINST NATURAL LOG OF SWP PLUS CVP EXPORTS, AND FREEPORT WATER TEMPERATURE




APPENDIX 5
FIGURES 3 AND 4
USFWS RYDE SURVIVAL INDEXES AND EXPORTS VERSUS JULIAN DAY




APPENDIX 5
FIGURE 5 AND 6
WATER TEMPERATURE AT FREEPORT VERSUS VERSUS JULIAN DAY, AND REGRESSION LINES OF RYDE SURVIVAL VERSUS EXPORTS REMOVING EACH YEAR ONE AT A TIME

OCT. 1 9 1992

TABLE 4.

DATA REMOVED FROM THE SET INDIVIDUALLY

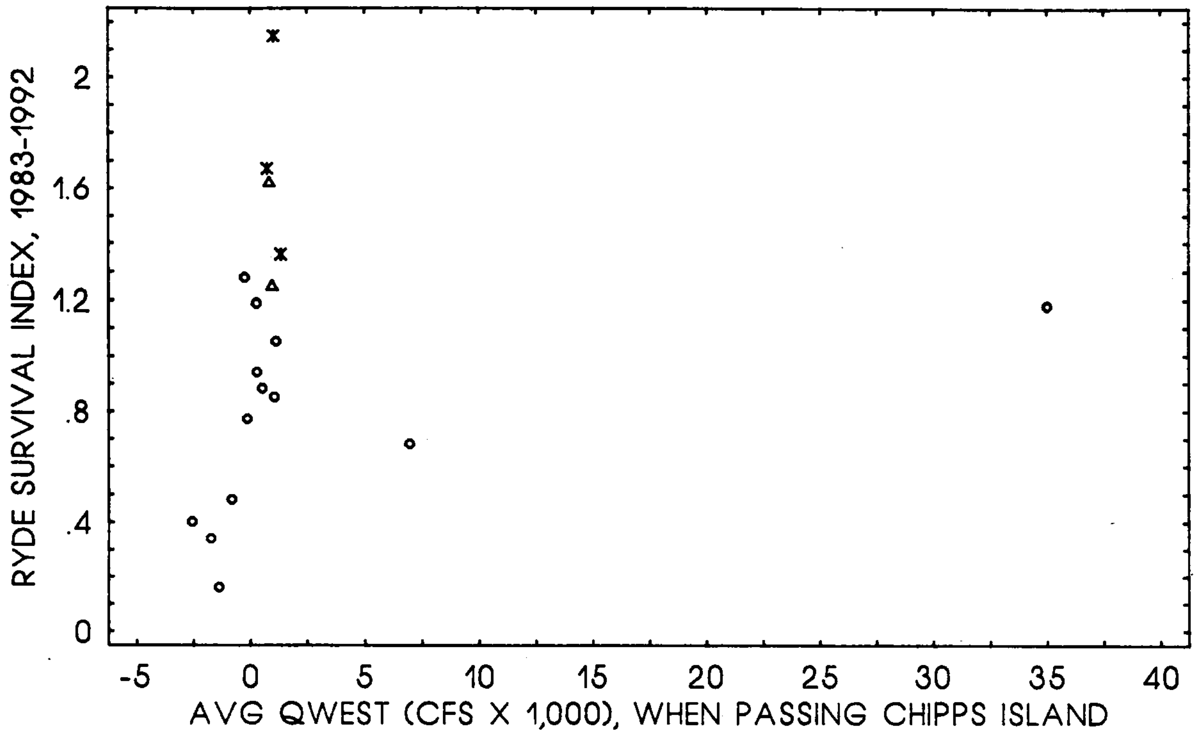
| RELEASE DATE | TRAWL SURV | SWP+CVP 3-9 DAYS | ln SWP+CVP 3-9 DAYS | REGRESSION EQUATIONS | R2 | ABS VALUE MEAN SLOPE - SLOPE |
|---|---|---|---|---|---|---|
| 05/20/83 | 1.18 | 4634. | 8.441175 | 6.44+(-.650*lnEXP39); | .51 | 0.00439 |
| 06/13/84 | 1.05 | 5508. | 8.613956 | 6.50+(-.657*lnEXP39); | .51 | 0.01139 |
| 05/11/85 | 0.77 | 7221. | 8.884748 | 6.50+(-.657*lnEXP39); | .50 | 0.01139 |
| 05/30/86 | 0.68 | 5931. | 8.687948 | 6.37+(-.639*lnEXP39); | .49 | 0.00661 |
| 04/29/87 | 0.85 | 5335. | 8.582045 | 6.42+(-.646*lnEXP39); | .50 | 0.00039 |
| 05/02/87 | 0.88 | 5244. | 8.56484 | 6.42+(-.647*lnEXP39); | .50 | 0.00139 |
| 05/04/88 | 0.94 | 8024. | 8.990192 | 6.77+(-.691*lnEXP39); | .53 | 0.04539 |
| 05/07/88 | 1.28 | 8607. | 9.060331 | 7.29+(-.755*lnEXP39); | .63 | 0.10939 |
| 06/22/88 | 0.40 | 6052. | 8.708144 | 6.22+(-.620*lnEXP39); | .50 | 0.02561 |
| 06/25/88 | 0.34 | 4919. | 8.50086 | 6.33+(-.631*lnEXP39); | .54 | 0.01461 |
| 05/03/89 | 1.19 | 3149. | 8.05484 | 6.44+(-.649*lnEXP39); | .50 | 0.00339 |
| 06/02/89 | 0.48 | 5812. | 8.66768 | 6.28+(-.626*lnEXP39); | .50 | 0.01961 |
| 06/16/89 | 0.16 | 4853. | 8.487352 | 6.32+(-.628*lnEXP39); | .57 | 0.01761 |
| 05/09/90 | 1.618294 | 3174. | 8.062748 | 6.19+(-.622*lnEXP39); | .50 | 0.02361 |
| 05/31/90 | 1.2461 | 3897. | 8.267962 | 6.39+(-.644*lnEXP39); | .50 | 0.00161 |
| 04/06/92 | 1.36 | 1969. | 7.585281 | 6.67+(-.675*lnEXP39); | .50 | 0.02939 |
| 04/14/92 | 2.15 | 936. | 6.841616 | 5.71+(-.564*lnEXP39); | .30 | 0.08161 |
| 04/27/92 | 1.67 | 1991. | 7.596392 | 6.19+(-.620*lnEXP39); | .45 | 0.02561 |

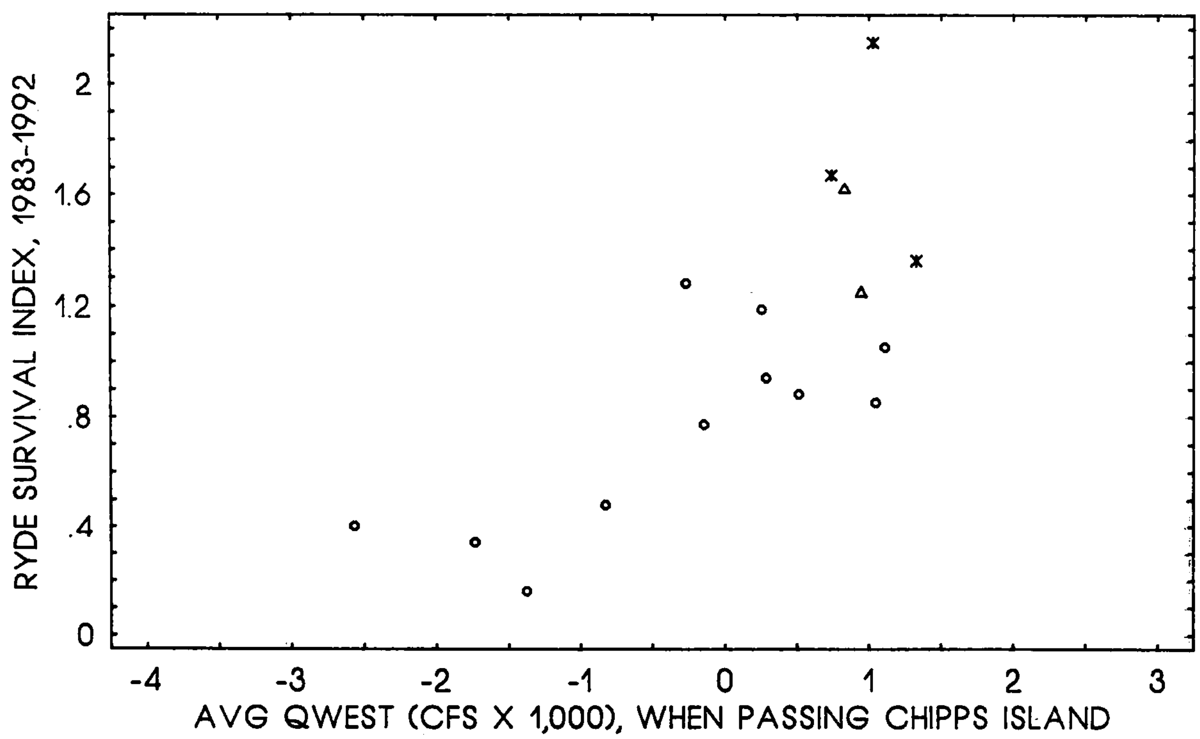
MEAN = -.64561

DATA REMOVED FROM THE SET ANNUALLY

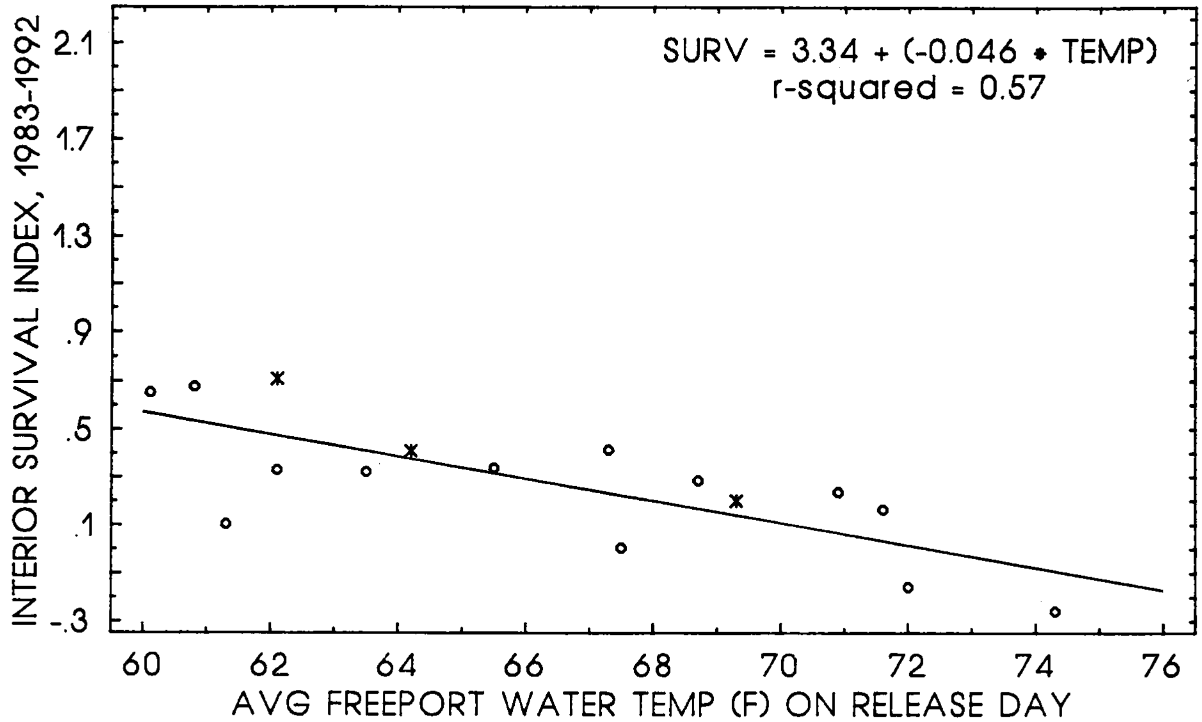
| RELEASE DATE | TRAWL SURV | SWP+CVP 3-9 DAYS | ln SWP+CVP 3-9 DAYS | REGRESSION EQUATIONS | R2 | ABS VALUE MEAN SLOPE - SLOPE |
|---|---|---|---|---|---|---|
| 05/20/83 | 1.18 | 4634. | 8.441175 | 6.44+(-.650*lnEXP39); | .51 | 0.01933 |
| 06/13/84 | 1.05 | 5508. | 8.613956 | 6.50+(-.657*lnEXP39); | .51 | 0.02633 |
| 05/11/85 | 0.77 | 7221. | 8.884748 | 6.50+(-.657*lnEXP39); | .50 | 0.02633 |
| 05/30/86 | 0.68 | 5931. | 8.687948 | 6.37+(-.639*lnEXP39); | .49 | 0.00833 |
| 04/29/87 | 0.85 | 5335. | 8.582045 | 6.42+(-.646*lnEXP39); | .50 | 0.01533 |
| 05/02/87 | 0.88 | 5244. | 8.56484 | | | |
| 05/04/88 | 0.94 | 8024. | 8.990192 | 7.41+(-.767*lnEXP39); | .70 | 0.13633 |
| 05/07/88 | 1.28 | 8607. | 9.060331 | | | |
| 06/22/88 | 0.40 | 6052. | 8.708144 | | | |
| 06/25/88 | 0.34 | 4919. | 8.50086 | | | |
| 05/03/89 | 1.19 | 3149. | 8.05484 | 6.18+(-.609*lnEXP39); | .58 | 0.02167 |
| 06/02/89 | 0.48 | 5812. | 8.66768 | | | |
| 06/16/89 | 0.16 | 4853. | 8.487352 | | | |
| 05/09/90 | 1.618294 | 3174. | 8.062748 | 6.14+(-.617*lnEXP39); | .50 | 0.01367 |
| 05/31/90 | 1.2461 | 3897. | 8.267962 | | | |
| 04/06/92 | 1.36 | 1969. | 7.585281 | 4.59+(-.434*lnEXP39); | .098 | 0.19667 |
| 04/14/92 | 2.15 | 936. | 6.841616 | | | |
| 04/27/92 | 1.67 | 1991. | 7.596392 | | | |

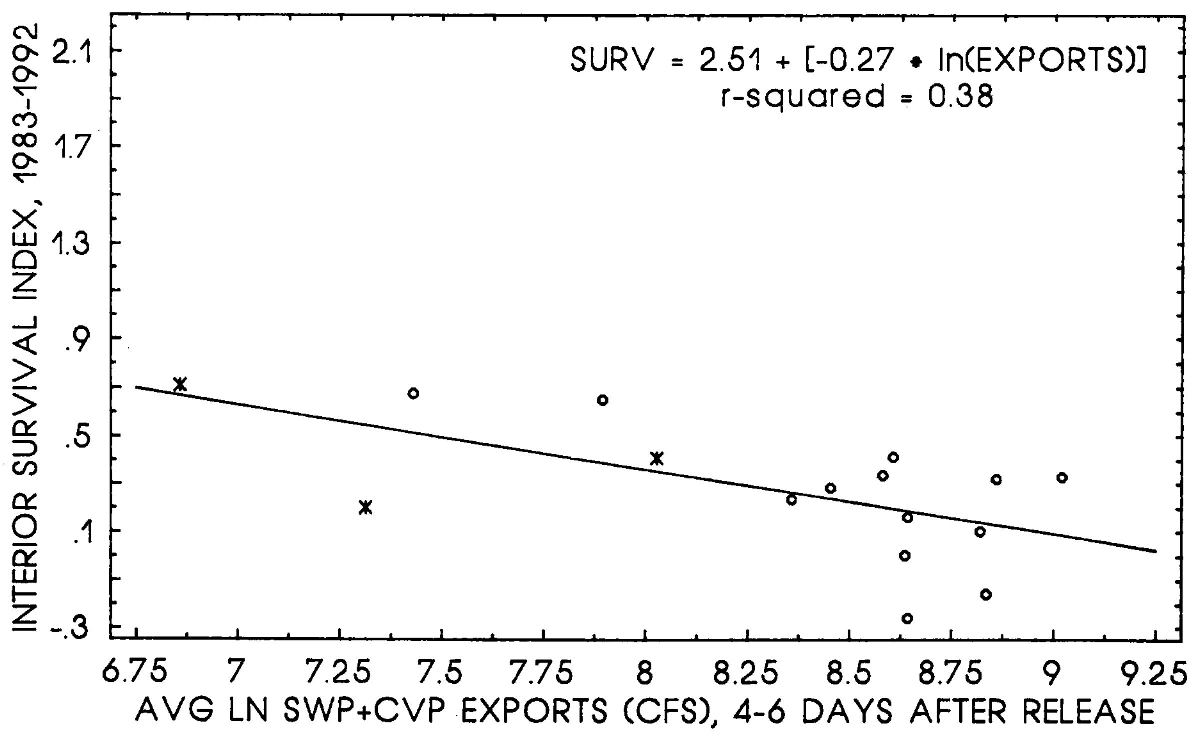
MEAN = -.63067



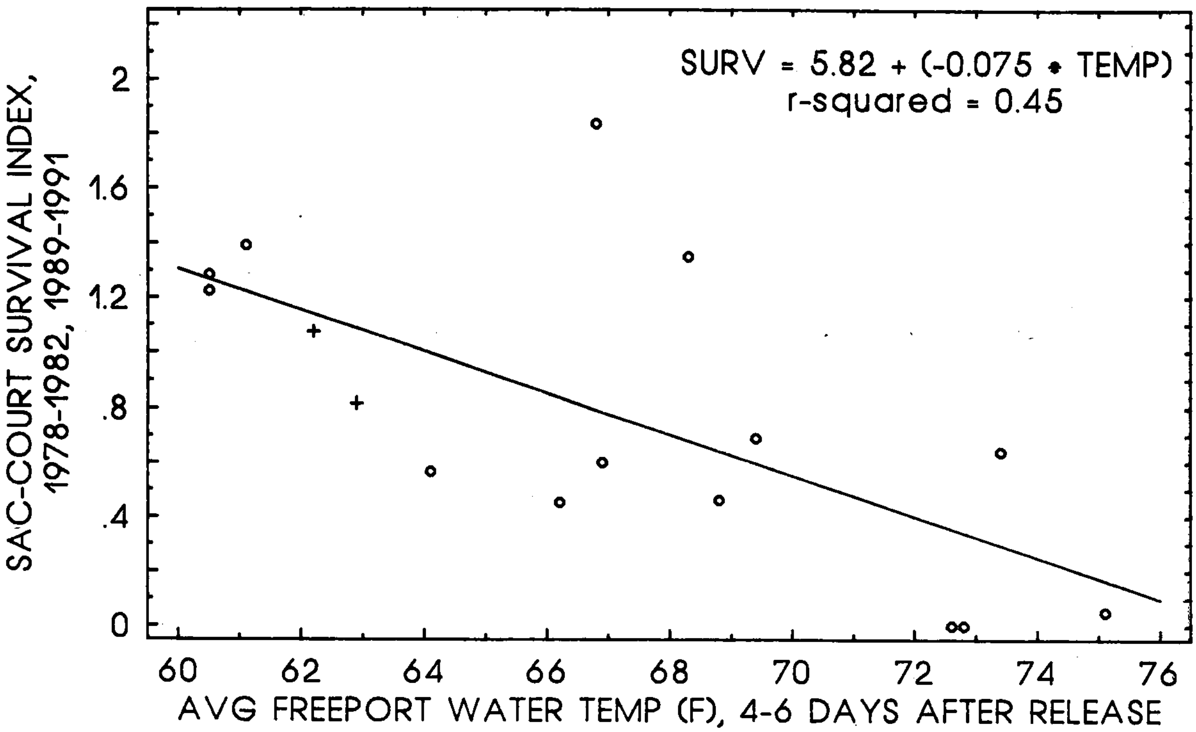



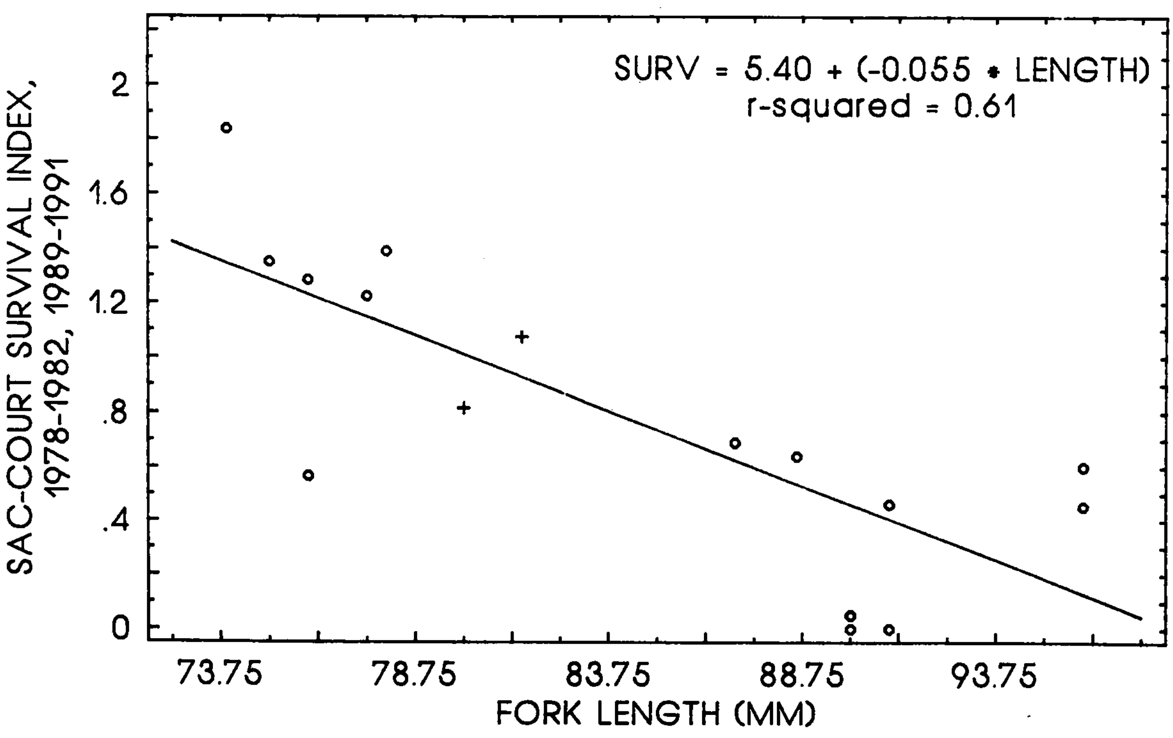

APPENDIX 5
FIGURES 7 AND 8
USFWS RYDE SURVIVAL INDEXES VERSUS
WESTERN DELTA FLOW ON TWO SCALES




APPENDIX 5
FIGURES 9 AND 10
USFWS SURVIVAL INDEXES REGRESSIONS AGAINST WATER TEMPERATURE AND NATURAL LOG OF SWP + CVP EXPORTS




APPENDIX 5
FIGURES 11 AND 12 USFWS
SURVIVAL INDEX DATA REGRESSION AGAINST WATER
TEMPERATURE AND SMOLT FORK LENGTH

CVP - OCAP RUNS PRE, TEM, and B

| | | | | EXPORTS | | | WATER TMEP | | | FRACTION DIVERTED | | | FEBRUARY SURVIVAL | | | | MARCH SURVIVAL | | | | APRIL SURVIVAL | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Y | ST | DEL | RUN | EXPFEB | EXPMAR | EXPAPR | TEMPFEB | TEMPMAR | TEMPAPR | DIVFEB | DIVMAR | DIVAPR | SACSFEB | INTSFEB | RYDESFEB | TOTAL | SACSMAR | INTSMAR | RYDESMAR | TOTAL | SACSAPR | INTSAPR | RYDESAPR | TOTAL |
| W | HI | 100 | PRE | 11289. | 9043. | 9713. | 50.7 | 54.5 | 59.9 | 0.225 | 0.231 | 0.239 | 2. | 0.69 | 1.32 | 2.36 | 1.72 | 0.58 | 1.24 | 1.87 | 1.31 | 0.36 | 0.9 | 1.01 |
| W | HM | 100 | PRE | 11289. | 11303. | 9898. | 50.7 | 54.5 | 59.9 | 0.226 | 0.231 | 0.239 | 2. | 0.69 | 1.32 | 2.36 | 1.72 | 0.54 | 1.12 | 1.7 | 1.31 | 0.36 | 0.89 | 1. |
| W | LM | 75 | PRE | 9237. | 10734. | 10873. | 50.7 | 54.5 | 59.9 | 0.226 | 0.231 | 0.24 | 2. | 0.72 | 1.43 | 2.54 | 1.72 | 0.55 | 1.14 | 1.73 | 1.31 | 0.34 | 0.84 | 0.94 |
| W | LO | 50 | PRE | 9363. | 10734. | 10873. | 50.7 | 54.5 | 59.9 | 0.228 | 0.231 | 0.24 | 2. | 0.72 | 1.43 | 2.54 | 1.72 | 0.55 | 1.14 | 1.73 | 1.31 | 0.34 | 0.84 | 0.94 |
| A | HI | 100 | PRE | 11289. | 10929. | 10873. | 50.7 | 54.5 | 59.9 | 0.236 | 0.235 | 0.253 | 2. | 0.69 | 1.32 | 2.34 | 1.72 | 0.55 | 1.13 | 1.71 | 1.31 | 0.34 | 0.84 | 0.93 |
| A | HM | 100 | PRE | 11289. | 10669. | 10873. | 50.7 | 54.5 | 59.9 | 0.246 | 0.236 | 0.253 | 2. | 0.69 | 1.32 | 2.33 | 1.72 | 0.55 | 1.15 | 1.73 | 1.31 | 0.34 | 0.84 | 0.93 |
| A | LM | 75 | PRE | 9237. | 10360. | 10873. | 50.7 | 54.5 | 59.9 | 0.248 | 0.242 | 0.595 | 2. | 0.72 | 1.43 | 2.51 | 1.72 | 0.56 | 1.16 | 1.75 | 1.31 | 0.34 | 0.84 | 0.71 |
| A | LO | 50 | PRE | 11289. | 10750. | 10872. | 50.7 | 54.5 | 59.9 | 0.248 | 0.242 | 0.597 | 2. | 0.69 | 1.32 | 2.33 | 1.72 | 0.55 | 1.14 | 1.72 | 1.31 | 0.34 | 0.85 | 0.71 |
| D | HI | 100 | PRE | 11253. | 10799. | 10872. | 50.7 | 54.5 | 59.9 | 0.257 | 0.592 | 0.602 | 2. | 0.69 | 1.33 | 2.33 | 1.72 | 0.55 | 1.14 | 1.36 | 1.31 | 0.34 | 0.85 | 0.71 |
| D | HM | 100 | PRE | 11253. | 10799. | 10873. | 50.7 | 54.5 | 59.9 | 0.259 | 0.615 | 0.6 | 2. | 0.69 | 1.33 | 2.33 | 1.72 | 0.55 | 1.14 | 1.34 | 1.31 | 0.34 | 0.84 | 0.71 |
| D | LM | 75 | PRE | 11253. | 10717. | 5731. | 50.7 | 54.5 | 59.9 | 0.259 | 0.615 | 0.646 | 2. | 0.69 | 1.33 | 2.33 | 1.72 | 0.55 | 1.14 | 1.34 | 1.31 | 0.46 | 1.19 | 0.94 |
| D | LO | 50 | PRE | 9849. | 9059. | 4790. | 50.7 | 54.5 | 59.9 | 0.259 | 0.617 | 0.659 | 2. | 0.71 | 1.4 | 2.44 | 1.72 | 0.58 | 1.24 | 1.43 | 1.31 | 0.49 | 1.29 | 1. |
| C | HI | 100 | PRE | 11001. | 10620. | 6755. | 50.7 | 54.5 | 59.9 | 0.649 | 0.637 | 0.675 | 2. | 0.69 | 1.34 | 1.84 | 1.72 | 0.55 | 1.15 | 1.32 | 1.31 | 0.43 | 1.1 | 0.85 |
| C | HM | 100 | PRE | 11001. | 10783. | 5563. | 50.7 | 54.5 | 59.9 | 0.649 | 0.637 | 0.697 | 2. | 0.69 | 1.34 | 1.84 | 1.72 | 0.55 | 1.14 | 1.31 | 1.31 | 0.46 | 1.21 | 0.9 |
| C | LM | 75 | PRE | 10065. | 10392. | 3429. | 50.7 | 54.5 | 59.9 | 0.661 | 0.643 | 0.751 | 2. | 0.71 | 1.39 | 1.88 | 1.72 | 0.56 | 1.16 | 1.33 | 1.31 | 0.56 | 1.47 | 1.03 |
| C | LO | 50 | PRE | 9651. | 9173. | 2454. | 50.7 | 54.5 | 59.9 | 0.668 | 0.64 | 0.784 | 2. | 0.72 | 1.41 | 1.9 | 1.72 | 0.58 | 1.23 | 1.4 | 1.31 | 0.62 | 1.65 | 1.1 |
| E | HI | 100 | PRE | 5600. | 2634. | 2353. | 50.7 | 54.5 | 59.9 | 0.731 | 0.813 | 0.769 | 2. | 0.82 | 1.71 | 2.12 | 1.72 | 0.81 | 1.91 | 1.75 | 1.31 | 0.63 | 1.68 | 1.14 |
| E | HM | 100 | PRE | 3493. | 2618. | 1479. | 50.7 | 54.5 | 59.9 | 0.8 | 0.814 | 0.802 | 2. | 0.91 | 1.96 | 2.24 | 1.72 | 0.81 | 1.91 | 1.75 | 1.31 | 0.71 | 1.93 | 1.25 |
| D | LO | 50 | TEM | 9849. | 8685. | 3411. | 50.7 | 54.5 | 59.9 | 0.259 | 0.617 | 0.68 | 2. | 0.71 | 1.4 | 2.44 | 1.72 | 0.59 | 1.26 | 1.46 | 1.31 | 0.56 | 1.47 | 1.12 |
| C | HM | 100 | TEM | 11001. | 10783. | 4083. | 50.7 | 54.5 | 59.9 | 0.641 | 0.637 | 0.732 | 2. | 0.69 | 1.34 | 1.85 | 1.72 | 0.55 | 1.14 | 1.31 | 1.31 | 0.52 | 1.38 | 0.98 |
| C | LM | 75 | TEM | 10065. | 10783. | 2437. | 50.7 | 54.5 | 59.9 | 0.661 | 0.636 | 0.784 | 2. | 0.71 | 1.39 | 1.88 | 1.72 | 0.55 | 1.14 | 1.32 | 1.31 | 0.62 | 1.66 | 1.11 |
| C | LO | 50 | TEM | 9291. | 9270. | 907. | 50.7 | 54.5 | 59.9 | 0.661 | 0.64 | 0.856 | 2. | 0.72 | 1.43 | 1.92 | 1.72 | 0.58 | 1.22 | 1.39 | 1.31 | 0.81 | 2.2 | 1.32 |
| E | HI | 100 | TEM | 5096. | 1870. | 1680. | 50.7 | 54.5 | 59.9 | 0.744 | 0.851 | 0.794 | 2. | 0.84 | 1.76 | 2.15 | 1.72 | 0.88 | 2.1 | 1.83 | 1.31 | 0.69 | 1.86 | 1.22 |
| W | HI | 100 | B | 11289. | 10994. | 9512. | 50.7 | 54.5 | 59.9 | 0.225 | 0.231 | 0.239 | 2. | 0.69 | 1.32 | 2.36 | 1.72 | 0.54 | 1.13 | 1.71 | 1.31 | 0.36 | 0.91 | 1.02 |
| W | HM | 100 | B | 11289. | 10994. | 10453. | 50.7 | 54.5 | 59.9 | 0.226 | 0.231 | 0.239 | 2. | 0.69 | 1.32 | 2.36 | 1.72 | 0.54 | 1.13 | 1.71 | 1.31 | 0.35 | 0.86 | 0.97 |
| W | LM | 75 | B | 9237. | 10425. | 10419. | 50.7 | 54.5 | 59.9 | 0.226 | 0.231 | 0.24 | 2. | 0.72 | 1.43 | 2.54 | 1.72 | 0.55 | 1.16 | 1.75 | 1.31 | 0.35 | 0.87 | 0.98 |
| W | LO | 50 | B | 8768. | 10425. | 10420. | 50.7 | 54.5 | 59.9 | 0.229 | 0.231 | 0.24 | 2. | 0.73 | 1.46 | 2.59 | 1.72 | 0.55 | 1.16 | 1.75 | 1.31 | 0.35 | 0.87 | 0.98 |
| A | HI | 100 | B | 9129. | 8815. | 7058. | 50.7 | 54.5 | 59.9 | 0.236 | 0.235 | 0.252 | 2. | 0.73 | 1.44 | 2.54 | 1.72 | 0.59 | 1.25 | 1.88 | 1.31 | 0.42 | 1.08 | 1.2 |
| A | HM | 100 | B | 7418. | 8522. | 7128. | 50.7 | 54.5 | 59.9 | 0.246 | 0.236 | 0.251 | 2. | 0.77 | 1.55 | 2.72 | 1.72 | 0.59 | 1.27 | 1.91 | 1.31 | 0.42 | 1.07 | 1.19 |
| A | LM | 75 | B | 7202. | 7546. | 6420. | 50.7 | 54.5 | 59.9 | 0.248 | 0.241 | 0.261 | 2. | 0.77 | 1.57 | 2.74 | 1.72 | 0.62 | 1.34 | 2.01 | 1.31 | 0.44 | 1.13 | 1.24 |
| A | LO | 50 | B | 7256. | 7563. | 6486. | 50.7 | 54.5 | 59.9 | 0.248 | 0.241 | 0.26 | 2. | 0.77 | 1.56 | 2.73 | 1.72 | 0.62 | 1.33 | 1.99 | 1.31 | 0.44 | 1.12 | 1.24 |
| D | HI | 100 | B | 5834. | 4846. | 4436. | 50.7 | 54.5 | 59.9 | 0.257 | 0.264 | 0.287 | 2. | 0.81 | 1.68 | 2.91 | 1.72 | 0.7 | 1.58 | 2.32 | 1.31 | 0.51 | 1.33 | 1.43 |
| D | HM | 100 | B | 5726. | 4684. | 4437. | 50.7 | 54.5 | 59.9 | 0.259 | 0.267 | 0.287 | 2. | 0.81 | 1.69 | 2.92 | 1.72 | 0.71 | 1.6 | 2.34 | 1.31 | 0.51 | 1.33 | 1.43 |
| D | LM | 75 | B | 5618. | 4554. | 4436. | 50.7 | 54.5 | 59.9 | 0.26 | 0.27 | 0.287 | 2. | 0.82 | 1.7 | 2.94 | 1.72 | 0.71 | 1.61 | 2.35 | 1.31 | 0.51 | 1.33 | 1.43 |
| D | LO | 50 | B | 5654. | 4603. | 4470. | 50.7 | 54.5 | 59.9 | 0.26 | 0.27 | 0.287 | 2. | 0.82 | 1.7 | 2.94 | 1.72 | 0.71 | 1.61 | 2.35 | 1.31 | 0.51 | 1.33 | 1.43 |
| C | HI | 100 | B | 3818. | 4196. | 3983. | 50.7 | 54.5 | 59.9 | 0.293 | 0.278 | 0.314 | 2. | 0.89 | 1.91 | 3.22 | 1.72 | 0.73 | 1.66 | 2.41 | 1.31 | 0.53 | 1.39 | 1.47 |
| C | HM | 100 | B | 3818. | 4228. | 4033. | 50.7 | 54.5 | 59.9 | 0.293 | 0.278 | 0.314 | 2. | 0.89 | 1.91 | 3.22 | 1.72 | 0.72 | 1.65 | 2.39 | 1.31 | 0.53 | 1.38 | 1.46 |
| C | LM | 75 | B | 3818. | 4228. | 4016. | 50.7 | 54.5 | 59.9 | 0.293 | 0.277 | 0.314 | 2. | 0.89 | 1.91 | 3.22 | 1.72 | 0.72 | 1.65 | 2.39 | 1.31 | 0.53 | 1.38 | 1.46 |
| C | LO | 50 | B | 3818. | 4228. | 2067. | 50.7 | 54.5 | 59.9 | 0.293 | 0.277 | 0.339 | 2. | 0.89 | 1.91 | 3.22 | 1.72 | 0.72 | 1.65 | 2.39 | 1.31 | 0.65 | 1.75 | 1.8 |
| E | HI | 100 | B | 2340. | 2569. | 992. | 50.7 | 54.5 | 59.9 | 0.339 | 0.345 | 0.348 | 2. | 0.98 | 2.18 | 3.55 | 1.72 | 0.82 | 1.92 | 2.65 | 1.31 | 0.79 | 2.15 | 2.2 |
| E | HM | 100 | B | 2340. | 2569. | 605. | 50.7 | 54.5 | 59.9 | 0.339 | 0.345 | 0.356 | 2. | 0.98 | 2.18 | 3.55 | 1.72 | 0.82 | 1.92 | 2.65 | 1.31 | 0.88 | 2.42 | 2.45 |