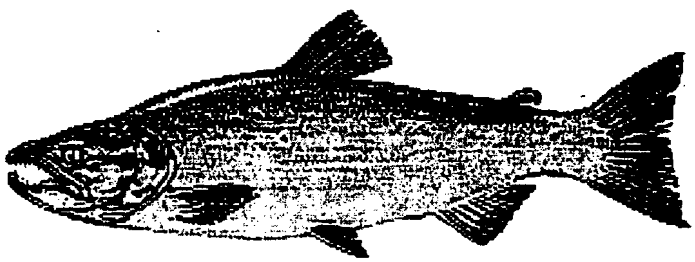
# ABUNDANCE AND SURVIVAL

# OF

# JUVENILE CHINOOK SALMON

# IN THE

# SACRAMENTO-SAN JOAQUIN ESTUARY



1994 ANNUAL PROGRESS REPORT
FY 94 WORK GUIDANCE
APRIL 1997

SACRAMENTO-SAN JOAQUIN ESTUARY
FISHERY RESOURCE OFFICE
U.S. FISH AND WILDLIFE SERVICE
STOCKTON, CALIFORNIA

U.S. FISH & WILDLIFE SERVICE
DEPARTMENT OF THE INTERIOR

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## Introduction

Work in 1994 by the Sacramento-San Joaquin Estuary Fishery Resource Office was conducted to update and refine our knowledge of factors influencing young salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. Sampling was conducted during the 1994 season between August 5, 1993, and July 27, 1994, with various sampling gears to increase our knowledge of all races of juvenile chinook salmon rearing and migrating through the lower Sacramento River and Delta.

Objectives of the 1994 Interagency Salmon Study were to:

- Monitor the relative abundance, distribution, and timing of juvenile chinook salmon rearing and migrating through the lower Sacramento River and Delta.
- Evaluate the significance of fry rearing in the Delta to overall production of the four races of chinook salmon.
- Determine relative survival (using marked hatchery-reared fall and late-fall) of juvenile salmon released in the upper river and Delta, and identify potential factors influencing survival.
- Identify management measures that could reduce the impacts of water project operations on salmon migrating through and rearing in the Delta.

At varying times during the 1994 field season, the following methods were employed in the Delta and lower Sacramento River to capture juvenile salmonids: midwater trawling, beach seining, fyke netting, pushnetting and rotary screw trapping (for locations and site names see Figures 1-4 ). Presumably, different-sized juveniles of the various races have different spatial and temporal distributions within the lower river and Delta. Although the larger juveniles (greater than 150 mm) are probably not effectively sampled using these gears, the salvage facilities in the South Delta catch larger-sized juveniles and that data is being used concurrently to evaluate the abundance, distribution and survival of juvenile salmon in the Delta.

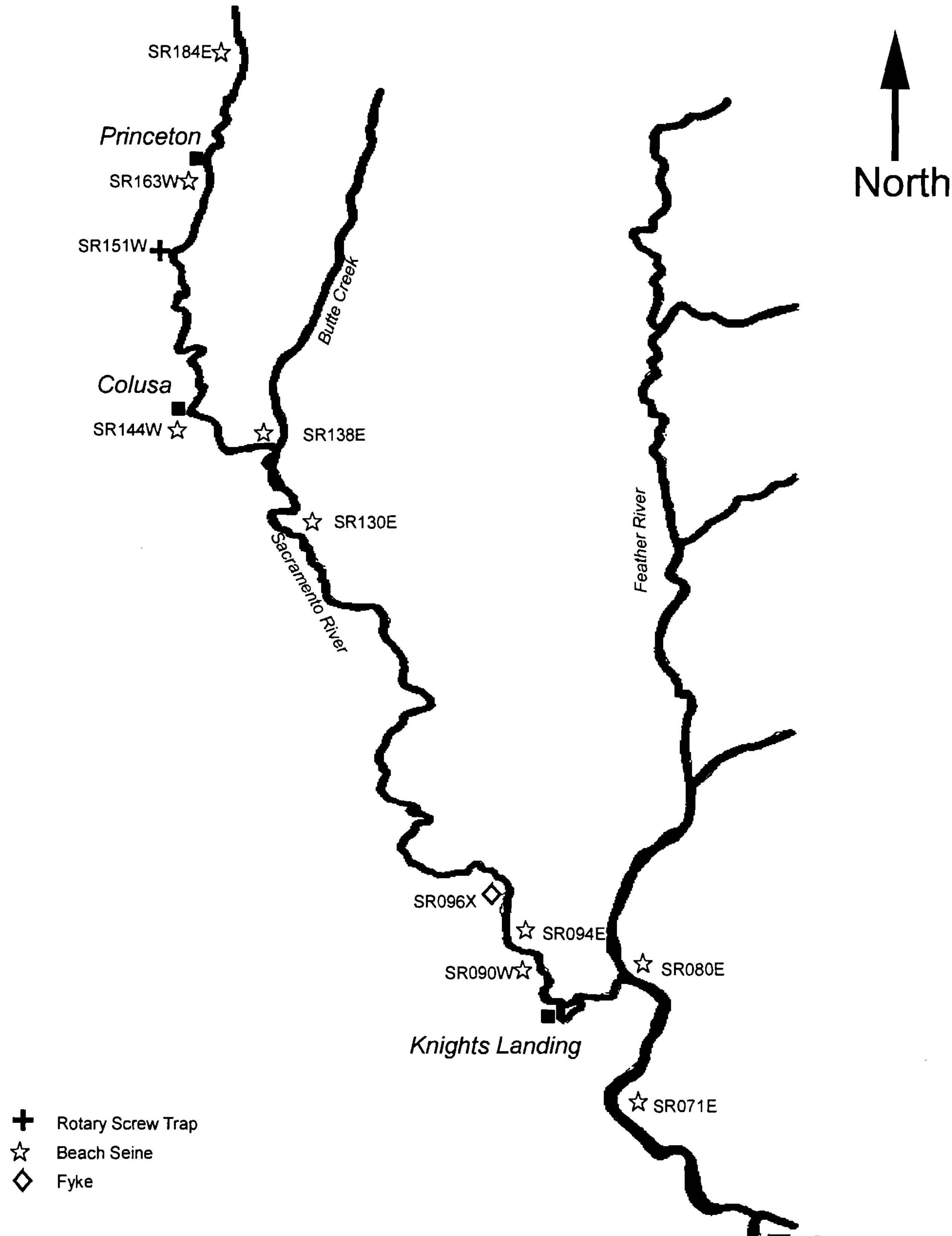



Figure 1. Lower Sacramento River seine, fyke, and rotary screw trap sites used in the 1993-1994 sampling year by SSJEFRO.

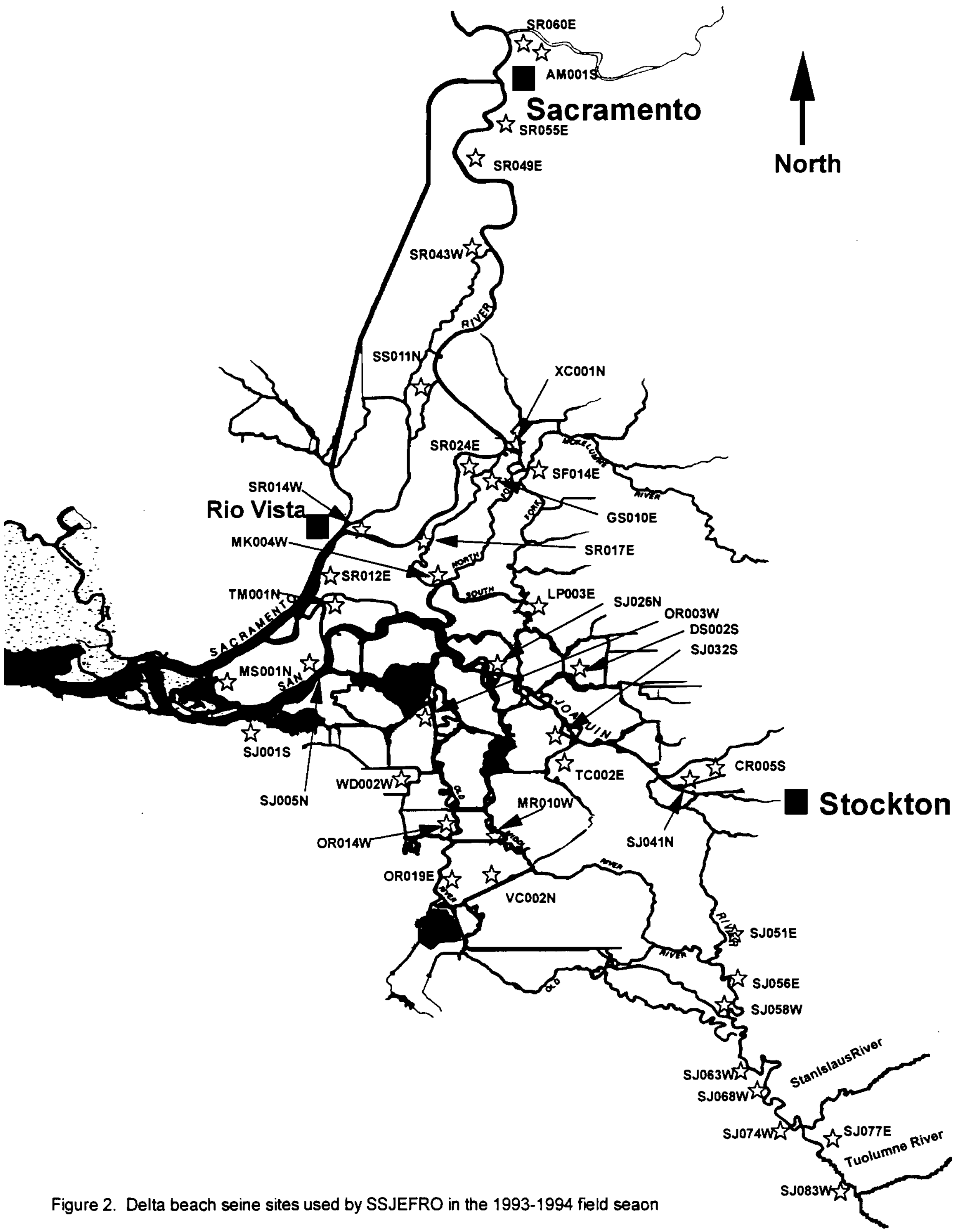



Figure 2. Delta beach seine sites used by SSJEFRO in the 1993-1994 field seaon

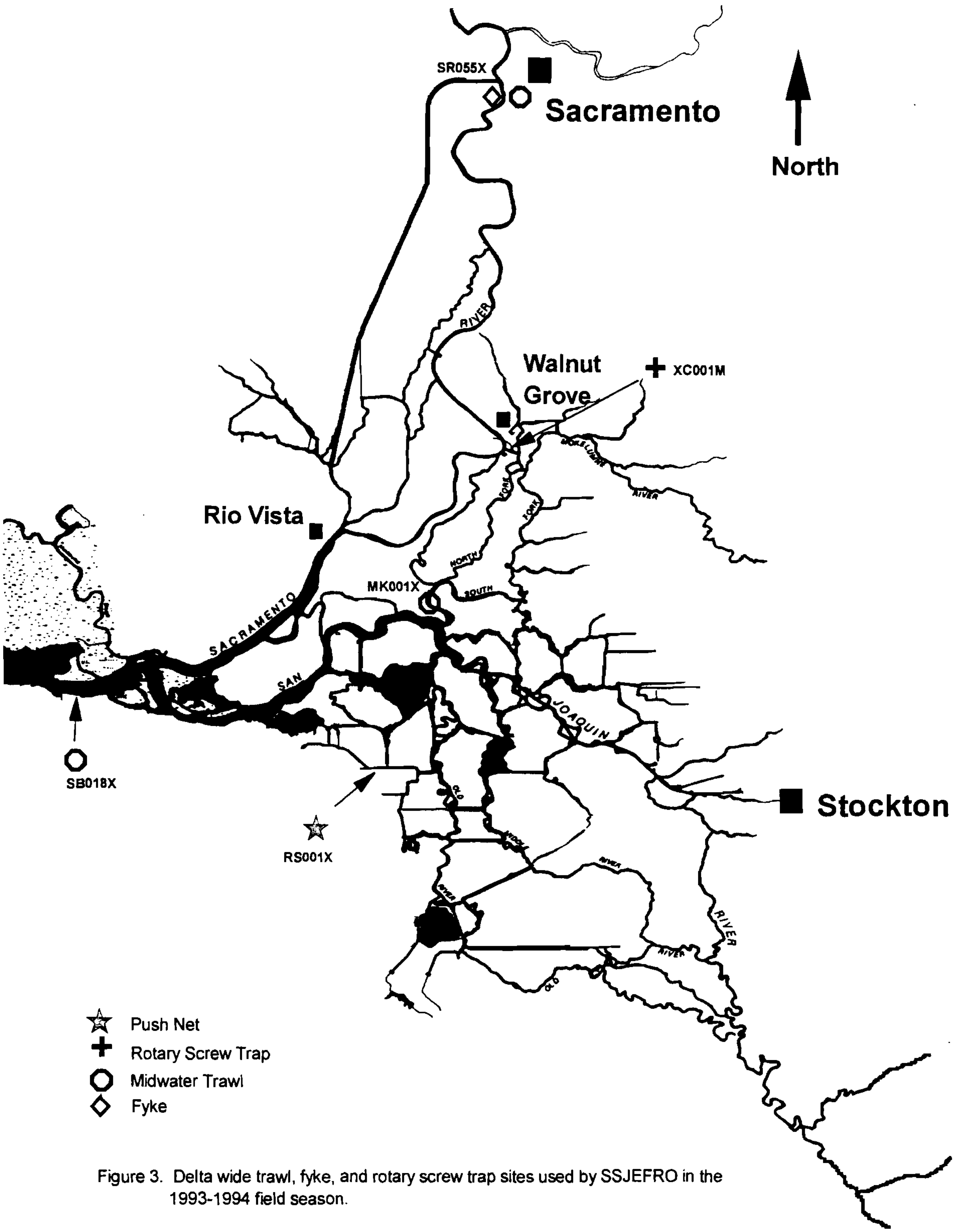



Figure 3. Delta wide trawl, fyke, and rotary screw trap sites used by SSJEFRO in the 1993-1994 field season.

Figure 4. Station codes and names for all gears used by SSJEFRO in 1994. Seine codes are organized by biological area.

**Beach Seine**

<u>Lower Sacramento River</u>

| | |
|---|---|
| SR184E | Ord Bend |
| SR163W | Princeton |
| SR144W | Colusa State Park |
| SR138E | Ward's Landing |
| SR130E | South Meridian |
| SR094E | Reels Beach |
| SR090W | Knights Landing |
| SR080E | Verona |
| SR071E | Elkhorn |

<u>Central Delta</u>

| | |
|---|---|
| XC001N | Delta Cross Channel |
| GS010E | Georgiana Slough |
| SF014E | Wimpy's |
| MK004W | B&W Marina |
| DS002S | King's Island |
| SJ005N | Eddo's |
| TM001N | Brannon Island |
| SJ001S | Antioch Dunes |
| LP003E | Terminous |

<u>San Joaquin</u>

| | |
|---|---|
| SJ051E | Dos Reis |
| SJ056E | Mossdale |
| SJ058W | Weatherby |
| SJ063W | Big Beach |
| SJ068W | Durham |
| SJ074W | Sturgeon Bend |
| SJ077E | Route 132 |
| SJ083W | North of Tuolumne River |

<u>North Delta</u> American River AM001S

| | |
|---|---|
| SR060E | Discovery Park |
| SR049E | Garcia Bend |
| SR043W | Clarksburg |
| SS011N | Steamboat Slough |
| SR024E | Koket |
| SR017E | Isleton |
| SR014W | Rio Vista |
| SR012E | Stump Beach |
| MS001N | Sherman Island |

<u>South Delta</u>

| | |
|---|---|
| SJ032S | Lost Isle |
| SJ026N | Venice Island |
| WD002W | Veale Tract |
| OR019E | Old River |
| MR010W | Woodward Island |
| ~~LP003E~~ | ~~Terminous~~ |
| SJ041N | Dad's Point |
| VC002N | Victoria Canal |

**Trawl**

| | |
|---|---|
| SB018X | Chipps Island |
| SR055M | Sherwood Harbor |
| MK001X | Mokelumne River |

**Fyke**

| | |
|---|---|
| SR096X | Knights Landing |
| SR055X | Sherwood Harbor |

**Rotary Screw Trap**

| | |
|---|---|
| SR151W | Colusa |
| XC001M | Delta Cross Channel |

**Pushnet**

| | |
|---|---|
| RS001M | Rock Slough |

Elements of the study in 1994 were:

Lower Sacramento River

- Rotary screw trapping: near Colusa at river mile (RM) 151 five days and four nights per week from September 9, 1993, to June 15, 1994, to gain additional information on rearing and migration of juvenile chinook in the lower Sacramento River.
- Beach seining: weekly between Ord Bend (RM 184) and Elkhorn (RM 71) on the lower Sacramento River from August 1993 to July 1994, to estimate the relative inter and intra-annual abundance as well as the distribution of all races of salmonid fry.
- Fyke netting: at Knights Landing on the Sacramento River (RM 96) five days and four nights per week from October 27, 1993, to March 31, 1994, to document the movement of chinook fry just upstream of the Delta.

Delta

- Beach seining: weekly from Discovery Park (RM 60) on the Sacramento River to Antioch and in various locations in the central and southern Delta as well as the lower San Joaquin River to estimate the relative inter and intra-annual abundance and the distribution of all races of salmonid fry (September 1993 through July 1994).
- Midwater trawling and fyke netting: at Sacramento from three to five days per week beginning September 27, 1993, and ending June 17, 1994, to estimate the relative abundance and timing of juvenile salmon entering the Delta. Knowing when and at what life stage the various races enter the Delta is helpful in managing water project protective criteria, such as the operation of the Delta Cross Channel Gates.
- Midwater trawling: at Chipps Island, from three to seven days per week between November 1, 1993, and June 30, 1994. The Chipps Island trawl is used to estimate the number of unmarked fish emigrating from the Delta and to recover marked smolts released in mark and recapture experiments. Trawling was initiated earlier in the 1994 season to further our understanding of winter and late-fall run outmigration.
- Midwater trawling: on the Mokelumne River twice weekly from January 7 to February 16, 1994, to gain additional information on rearing and migration of juvenile chinook in the central Delta and identify juvenile salmon that may be at most risk from the CVP/SWP pumping operations.

- Rotary screw trapping: in the Delta Cross Channel five days per week between September 28, 1993, and January 6, 1994, to document relative numbers of chinook entering the central Delta.
- Pushnetting: weekly from January 20, to June 3, 1994, to assist the Department of Fish and Game in evaluating juvenile salmon entrainment in Contra Costa Canal in Rock Slough.
- Coded wire tagging (CWT): mark and recapture studies to determine Delta survival of fall and late-fall run smolts under varied environmental conditions.

Specific questions addressed by tag studies in 1994 were:

a. Sacramento/Delta:

1. What is the survival of salmon smolts migrating through the Delta (released near Sacramento) under various environmental conditions?

2. Does installation of a barrier at the head of Old River (south Delta) have an effect on Sacramento basin smolt survival?

b. San Joaquin Delta

1. What is the survival of salmon smolts migrating down the San Joaquin River without a barrier at the head of Upper Old River?

2. What is the survival of salmon smolts diverted into the south Delta (released at lower Old River), and can the effect of a barrier at the head of Old River on survival and indirect mortality be estimated?

CWT recovery data generated by the ocean fishery is available to confirm past conclusions based on trawl recovery information.

In addition, we will determine if our results in 1994 are consistent with past conclusions and whether our present smolt survival models predict values of survival similar to those observed.

A Critical Water Year

The 1994 water year (October 1993 - September 1994) was classified as a critical water year type with very little precipitation in the Sacramento basin during the fall and winter of 1993-1994. Average monthly flow at Verona in past water years (1993, and between 1987 and 1992) is compared to that observed in 1994 in Figure 5. The 1994 water year had very low flow at Verona throughout the year and was similar to average levels observed during previous drought years (USGS, 1993 and USGS, 1994).

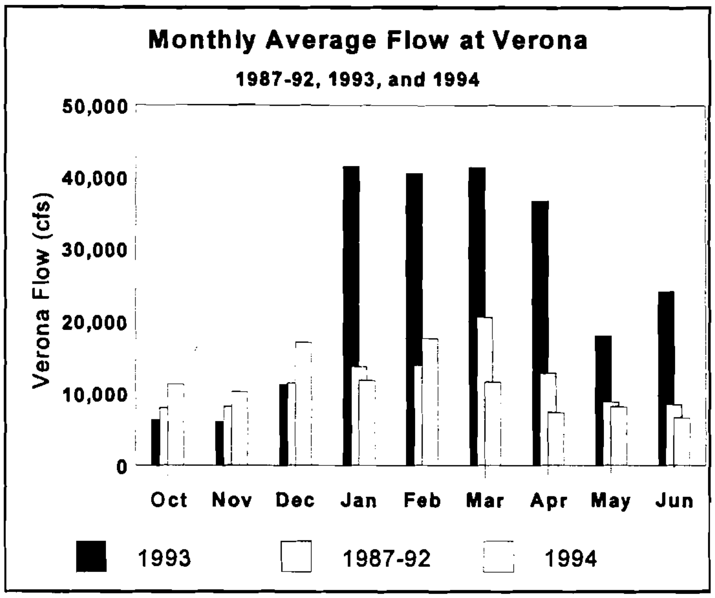


Figure 5. Average monthly flow at Verona (cfs) from 1987-1992, 1993, and 1994.

Race Designation

The SSJEFRO is one of several salmon monitoring groups in the Central Valley that are using length to determine juvenile chinook salmon race in the lower Sacramento River and Delta. The daily size criterion which is based on data collected from growth rates of chinook from the Tehema Colusa fish channels was developed by Frank Fisher, of California Department of Fish and Game (1992), and further modified by Sheila Greene of California Department of Water Resources.

Although its use is necessary for field identification of the various races, several problems exist regarding the validity of the size criterion. For instance, there is likely an overlap in size between fall run juveniles and mainstem spawning spring run juveniles as they may be hybridizing. Historically, they had been spatially separated, as the spring run spawned at higher elevations which are now blocked by dams. In addition, there is likely overlap in migration timing of late-fall and “true” tributary spring run that are hypothesized to migrate through the lower River and Delta as yearlings. Some concern has also been voiced in differentiating between late-fall and winter run accurately. Although we are aware of these potential limitations involving the use of length to differentiate between races it appears to be the most effective means of identification at this time. All four races are designated in the field using the size criteria (based on fork length), however, for this report fall and mainstem spring run juveniles are combined into a group identified as fall spawning fish and are designated as fall/spring run.

## Lower Sacramento River Fry and Smolt Abundance

## Colusa Rotary Screw Trap

A rotary screw trap, (Figure 6) was fished along the Sacramento River (RM 151) several miles North of Colusa from September 9, 1993, to June 15, 1994, five days and four nights per week, to detect juvenile salmon movement downstream. The duration of the sampling effort (September - June) provided an opportunity for juveniles of all races to be sampled.

A rotary screw trap is a large cone suspended between two floating pontoons (see Figure 6). As the current flows through the cone it revolves due to its internal design. Fish are transported through the cone and kept in the live box (large box at end of trap which holds fish for processing) until measured and released. The effectiveness of the rotary screw trap can be estimated by the number of revolutions per minute (RPM) the cone spins, or total revolutions the cone has rotated during a particular fishing period. Generally, less than three RPM is considered insufficient for juvenile chinook sampling. A minimum flow of approximately 2ft/sec is required to spin the cone at three RPM. Debris is removed and all fish are processed daily at a minimum to prevent fish mortality. Table 1 lists monthly chinook catch totals and calculated monthly catches by hour. Daily catches per hour are averaged to estimate the mean weekly catch. The monthly catch value is the average of the weekly values within the month.

The majority of juvenile salmon captured were fall/spring run in the months of January and February. Most late-fall were caught in October and the majority of winter run were caught in January, but catches of both races were low. Graphs of daily chinook catches by race versus Colusa flow is shown in Figure 7.

A total of 50 late-fall were captured in the Colusa rotary screw trap between September 9, 1993, and May 10, 1994. The highest catches generally appeared to respond to increases in flow. These fish ranged in size between 61 and 163 mm, indicating the rotary screw trap is at least partially effective at catching larger sized juveniles at this site. The one fish observed in May was 34 mm, indicating movement of late-fall fry in to the lower Sacramento river.

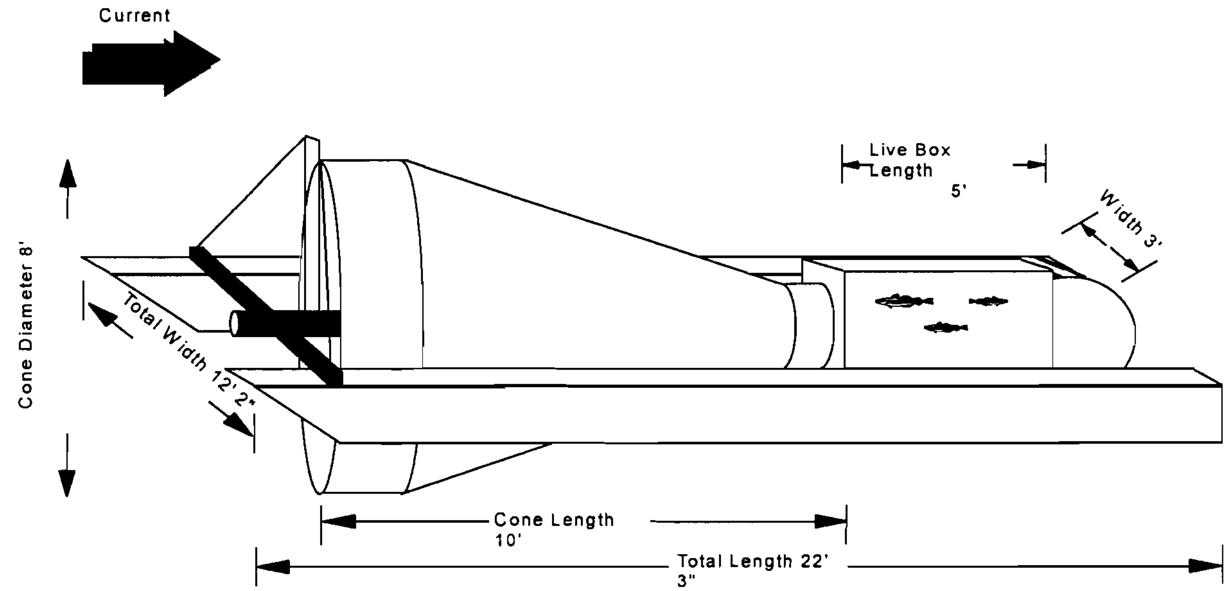



Figure 6. Schematic diagram of rotary screw trap used by SSJEFRO.

Table 1. Monthly chinook catch of the various races in the Colusa rotary screw trap between September 9, 1993, and June 15, 1994. Daily catches per hour are averaged by week and by month to obtain the monthly catch per hour.

| Month | Late-fall | Winter | Fall/Spring | Total Catch per hour |
|---|---|---|---|---|
| September | 8 | 0 | 0 | 0.060 |
| October | 21 | 1 | 2 | 0.064 |
| November | 2 | 0 | 0 | 0.004 |
| December | 14 | 6 | 238 | 1.165 |
| January | 3 | 23 | 3,413 | 11.455 |
| February | 1 | 5 | 1,969 | 6.537 |
| March | 0 | 2 | 372 | 0.968 |
| April | 0 | 0 | 1,319 | 3.582 |
| May | 1 | 0 | 413 | 1.154 |
| June | 0 | 0 | 17 | 0.083 |
| Total | 50 | 37 | 7,743 | Average = 2.507 |

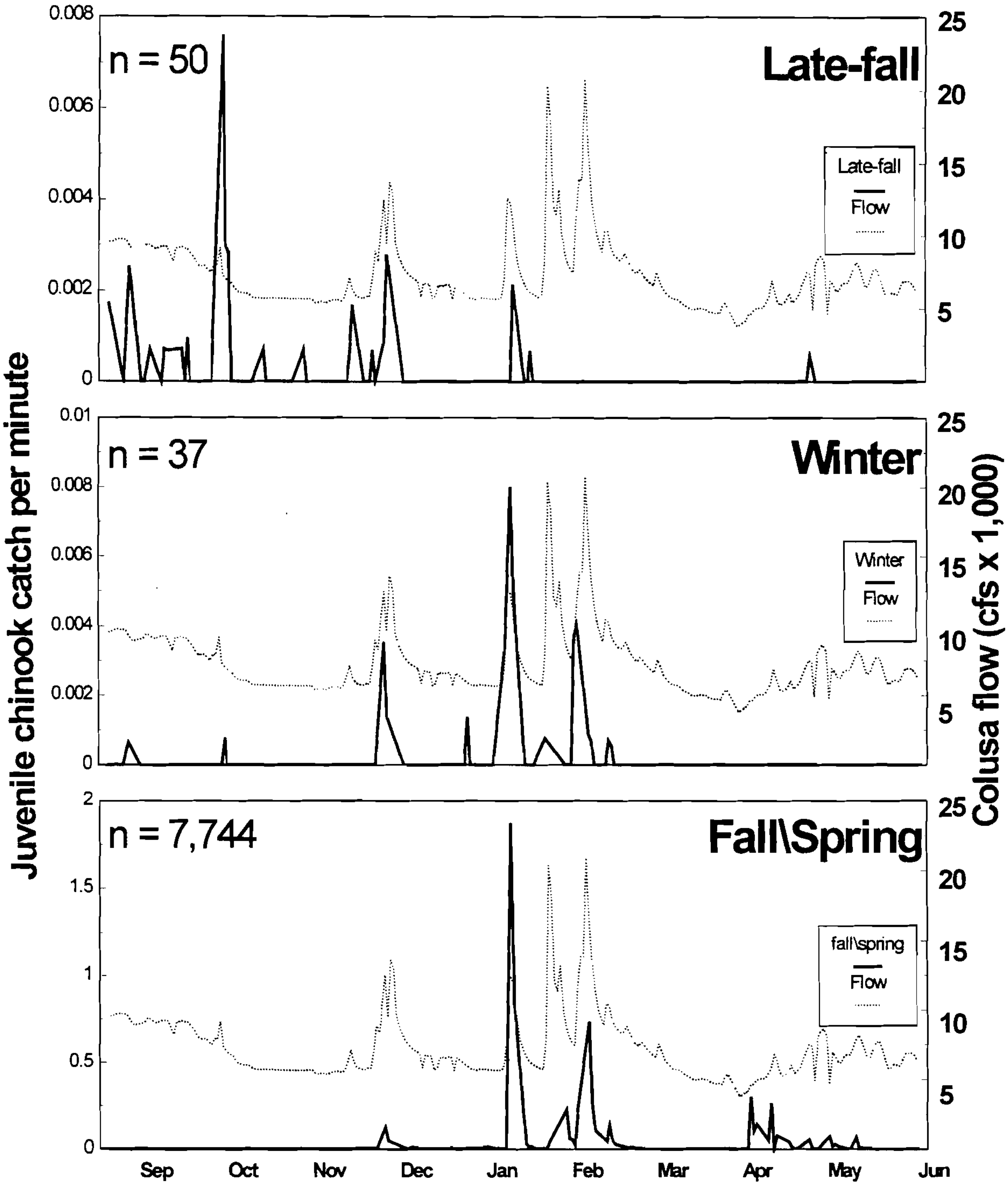



Figure 7. Catch per minute of chinook salmon in the Colusa rotary screw trap and Colusa flow (cfs) between September 9, 1993 and June 15, 1994.

Winter run were captured between September 16, 1993, and March 2, 1994, with a total catch of 37 for the season. Size ranged between 42 and 130 mm. The largest peak appeared to be in late January at the onset of an increased flow event (Figure 7). Another peak was observed in late February at the beginning of the last major flow increase of the season. Like the late-fall, catch of winter run also seemed to respond to increases in flow, especially during flow events in December and late January.

In comparison, the rotary screw trap recovered over 150 winter run during the previous (1992-1993) season, however, approximately 80 percent of those captured were during a two-day storm event. Movement appears to occur at the onset of most of the major flow events. It is unclear if this is because the fish are actually moving at that time, or because the gear becomes more effective during high flow periods due to increased turbidity, etc. Further evaluation of this question is needed.

The first initial pulse of fall/spring run was observed on December 13 (238 fish), with a small increase in flow. The next and largest peak (2,104) did not occur until January 26, 1994, which coincided with an increase in flow similar to that observed in December. Another group of fall/spring run moved downstream after a minor flow increase in mid-April. A total of 7,744 fall/spring run were captured between October 5, 1993, and June 15, 1994. Size ranged between 28 and 135 mm.

It appears that in 1994 the vast majority of juvenile salmon passed the rotary screw trap near Colusa prior to the month of March (Figure 7). Winter and late-fall run were detected in low abundances after increases in flow. Fall/spring run comprised the majority of the catch. The rotary screw trap proved effective at sampling all races of chinook over a broad size range.

## Lower Sacramento River Beach Seine

Beach seining was conducted along the lower Sacramento River to estimate the relative abundance and distribution of juvenile salmonids in the lower river. Beach seining is most effective for chinook fry as they rear in shallow areas, closer to shore, where seining is conducted. Although some larger sized juveniles are caught, the gear is not considered effective for smolt or yearling sized fish that migrate in the deeper parts of the main channel.

In most cases, sampling was done weekly, however, some sites were not accessible due to reasons beyond our control such as flooding, low water, etc.

A total of nine sites along the lower Sacramento River were seined weekly between August 5, 1993, and July 27, 1994. The sites range from Ord Bend (RM 184) approximately 40 miles north of Colusa to Elkhorn boat ramp (RM 71) which is approximately ten miles north of Sacramento (Figure 1).

Before valid comparisons in abundance and timing within and between years are made, catches are corrected by effort by standardizing to catch per cubic meter. Catch per cubic meter for each seine haul was calculated by the following equation: M3 = 1/2D*W*L (see Figure 8 for diagram) where M3 = total meters cubed within the seine haul, D = average depth of seine haul in meters, W= width of seine haul in meters (distance parallel from the shore), and L= length of seine haul in meters (distance from shore). Daily catch per cubic meter by race was calculated by averaging catch per cubic meter at each station for the day. Historically, seine catches had been standardized to number caught per seine haul. Standardizing to catch per cubic meter allows

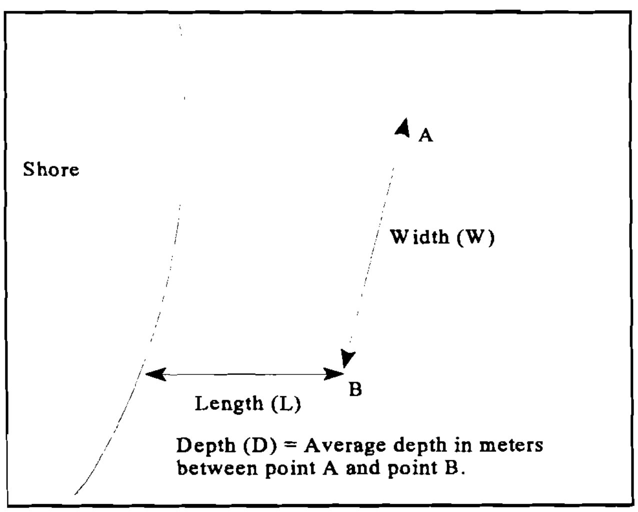



Figure 8. Beach seine dimensions used for catch per cubic meter calculation.

estimates to be somewhat more refined and quantitative.

Catches per month of each race in the lower Sacramento River are indicated in Table 2. A total of 53 late-fall were captured between 76 and 148 mm from August 31, 1993, to February 9, 1994, along the lower Sacramento River which is three times more than that caught in 1993 (18). Table 3 shows average monthly catch per meter cubed of all races caught in the lower Sacramento River seine for 1993 and 1994 field seasons. Timing and relative abundance comparisons using such few catches increases the possibility of error.

Table 2. 1993-1994 beach seine catches of unmarked chinook salmon by month and race in the lower Sacramento River between river mile 71 and 184.

| Month | Late-fall | Winter | Fall/spring | Hauls |
|---|---|---|---|---|
| August | 1 | 0 | 2 | 28 |
| September | 2 | 0 | 0 | 44 |
| October | 29 | 2 | 1 | 43 |
| November | 10 | 0 | 0 | 47 |
| December | 9 | 5 | 146 | 49 |
| January | 1 | 7 | 571 | 44 |
| February | 1 | 12 | 888 | 42 |
| March | 0 | 0 | 594 | 48 |
| April | 0 | 0 | 258 | 41 |
| May | 0 | 0 | 97 | 42 |
| June | 0 | 0 | 0 | 55 |
| July | 0 | 0 | 0 | 41 |
| Total | 53 | 26 | 2,557 | 524 |

Table 3. Monthly catch per meter cubed in the lower Sacramento River seine for 1992-1993 and 1993-1994 seasons.

| | Late-fall | | Winter | | Fall/spring | |
|---|---|---|---|---|---|---|
| | 92-93 | 93-94 | 92-93 | 93-94 | 92-93 | 93-94 |
| Sep | 0 | 0 | .001 | 0 | 0 | 0 |
| Oct | 0 | .004 | 0 | 0 | 0 | 0 |
| Nov | .001 | .001 | .019 | 0 | 0 | 0 |
| Dec | .001 | .001 | .007 | .001 | .028 | .064 |
| Jan | 0 | 0 | .023 | .004 | .157 | .121 |
| Feb | 0 | .001 | .023 | .008 | .228 | .639 |
| Mar | 0 | 0 | 0 | 0 | .413 | .485 |
| Apr | .003 | 0 | 0 | 0 | .331 | .066 |
| May | .004 | 0 | 0 | 0 | .055 | .017 |
| Jun | 0 | 0 | 0 | 0 | .006 | 0 |

* Catches <.001 are indicated as 0 on the table, thus differences may be reflected from Table 2.

A total of 26 winter run, between October 26, 1993, and February 25, 1994, were captured in the lower Sacramento River in the beach seines during the 1994 sampling year. Size ranged between 42 and 141 mm with peak catches in February. In the 1993 season, 117 winter run were captured between September 9, 1992, and February 26, 1993. Catch per cubic meter of winter run was much lower in 1994 than in the 1993 season. Figure 9 illustrates catch per cubic meter by day at lower Sacramento River beach seine sites to document the relative abundance of each of the races over time. Flow at Colusa is also included in the figure to show how it relates to catch. As in past years, catches can increase after elevations in flow in the lower Sacramento River, however, there are times when catches increase (January 2, 1994) when no increase in flow has been observed.

The vast majority of species captured in the lower Sacramento River beach seine were fall/spring run, with a total of 2,557 caught. Most fry were captured in December and January, with a mean size of 44 mm. This likely reflects the large numbers of fall run compared to other races in the Central Valley. Only 1,614 fall/spring juveniles were caught in the lower Sacramento River beach seine in 1993, however effort was

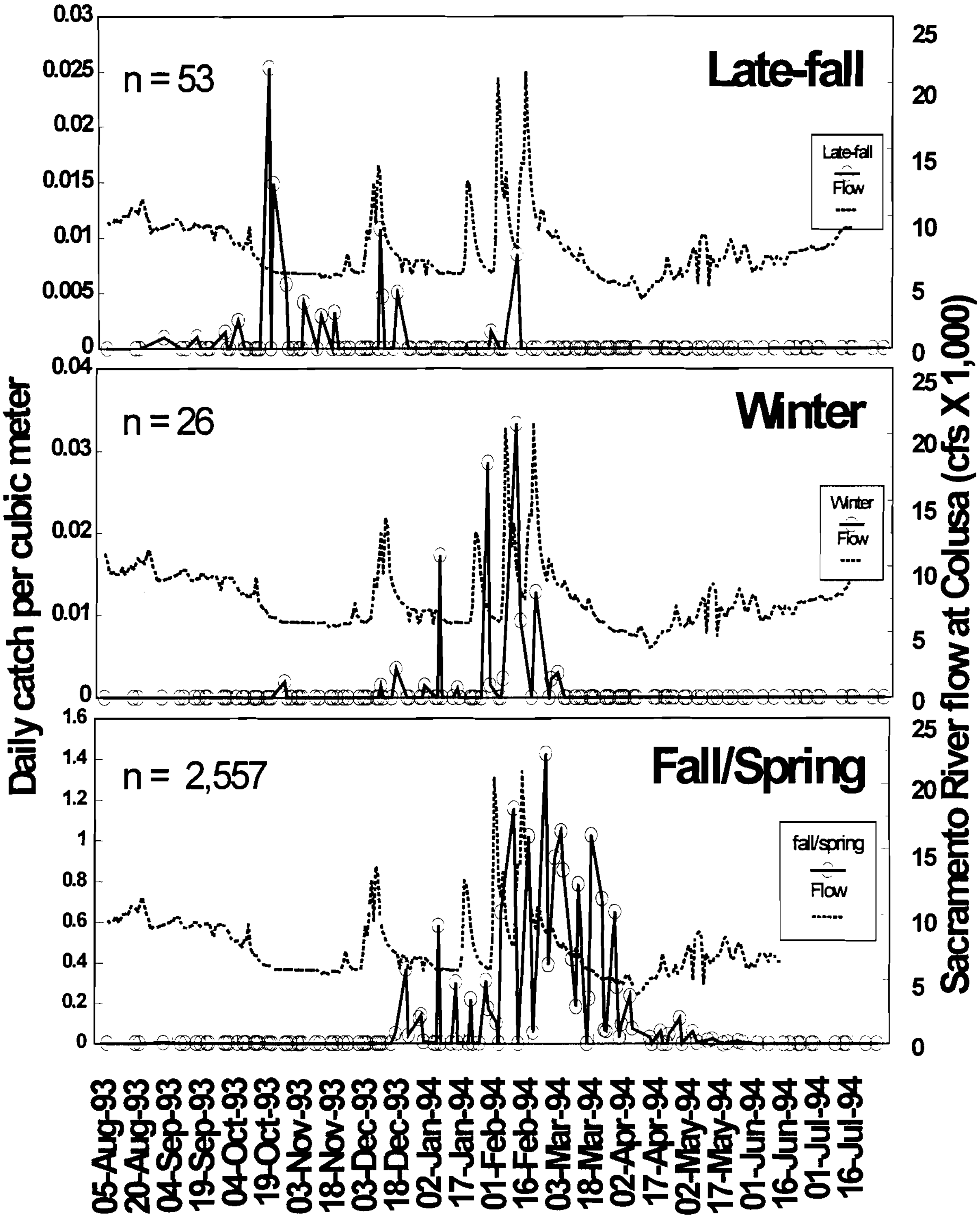



Figure 9. Daily catch per cubic meter seined of chinook salmon by race in the lower Sacramento River. Mean daily flow is measured at Colusa.

lower. In 1994, Fall/spring run were observed between August and May with the greatest number observed in February. Sizes ranged between 28 mm (March) and 135 mm (October) fork length.

Overall, catches were lower in 1994 than 1993, possibly due to less favorable conditions caused by the drier water year type.

It was interesting to note the presence of late-fall fry (mean size = 39 mm) from the 1993 year class in April and May and the high number of yearlings from the same year class the following October, November, December and February. No fry were observed in April and May of 1994 from the following years, year class. This difference may be due to the flow differences between years, with high flows in 1993 moving at least some of late-fall population downstream as fry. In dry years it is possible that all the late-fall rear upstream and migrate through the lower Sacramento River area as yearlings during the fall months.

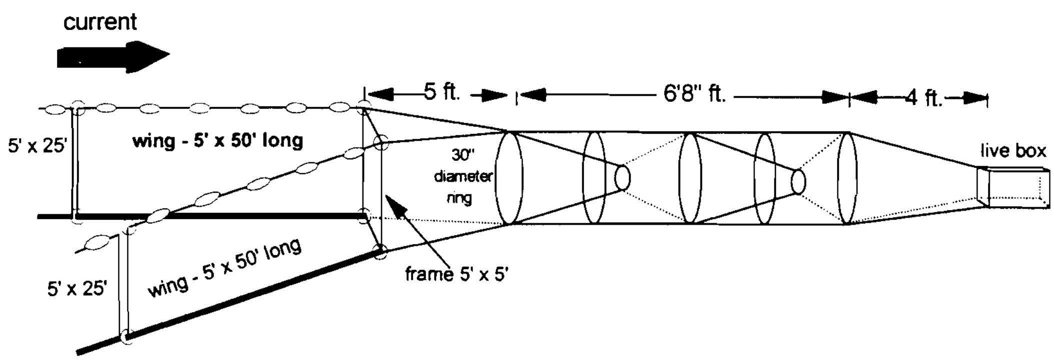



Figure 10. Schematic diagram of fyke net used by SSJEFRO

## Knights Landing Fyke

To increase our knowledge of fry rearing in the lower Sacramento River, two fyke nets were fished near Knights Landing (RM 96) along the Sacramento River five days and four nights per week between October 27, 1993, and March 31, 1994.

A fyke net is a passive trapping device with a series of internal fykes used to fish in the current (see Figure 10). The fyke is placed on the bank in shallow water, enabling the nets to catch small fish rearing near shore. Because the fyke nets fish at the surface as well as sit on the bottom of the river, fluctuations in water level (stage) must be carefully observed to assure they maintain proper position when fishing.

No winter or late-fall run chinook were captured in the Knights Landing fyke during the 1994 season. It appears not many winter run fry were rearing in the lower river in the fall of 1993. Catches were very low (or none) for both the fyke at Knight's Landing as well as the lower river beach seine. Late-fall during the fall months are larger such that the fykes would not effectively sample for them likely due to gear avoidance. Late-fall fry in the spring months were not observed in the fykes in lower Sacramento River beach seine in 1994.

A total of 725 fall/spring run were caught between December and March. Table 4 indicates monthly totals of fall/spring run catch and catch per hour fished. The peak captures were in February and are somewhat later than the peak observed in the Colusa screw trap (January), but the same as that observed in the lower Sacramento River beach seine. The absolute numbers captured were much less with the fyke than the other gears. The mean size captured in February was similar using the fyke net (39 mm) and with the beach seine (44 mm).

Table 4. Fall/spring run chinook catch per hour fished by month in the fyke nets at Knights Landing in 1994. No winter or late-fall run were captured.

| Month | Catch | Catch/hour |
|---|---|---|
| October * | 0 | 0 |
| November | 0 | 0 |
| December | 4 | 0.02 |
| January | 54 | 0.29 |
| February | 470 | 1.59 |
| March | 197 | 0.26 |

* Sampling began October 27, 1993

## Delta Fry and Smolt Sampling

### Delta Beach Seine

(North, Central and South Delta)

A total of 10 sites were seined weekly in the northern Delta on or in close proximity to the Sacramento River from Sacramento (RM 60) to South of Rio Vista (RM 12) between September 9, 1993, and July 28, 1994. A total of nine sites were seined weekly in the central Delta between September 9, 1993, and July 28, 1994 and thirteen sites were seined weekly in the South Delta between November 12, 1993, and June 30, 1994. One site was added to the central Delta area (Calaveras River) to investigate the possibility of juvenile chinook presence in the Calaveras River (see Figure 2).

A total of six late-fall juveniles were recovered in the various beach seining areas of the Delta in December and January of the 1993 -1994 season. Sizes range between 117 and 172 mm. Late-fall captures in the Delta were much lower than in the lower Sacramento River (54), and may be related to the fish being larger in the Delta that in the lower river (ranged between 76 and 148 mm). The seine is not as effective for larger salmon, because they generally inhabit offshore areas.

Only two juvenile winter run chinook salmon were captured in the Delta in the 1993-1994 season, with one captured at Garcia Bend in the North Delta and one captured at Wimpy's Marina (South Fork of the Mokelumne) in the central Delta on February 28. Sizes were 102 and 111 mm. In contrast, twenty six winter run were caught in the North Delta in the 1993 season from November 9, 1992, to March 10, 1993.

Fall/spring run: Juvenile fall/spring run catches in the North Delta using the beach seine are commonly high. A total of 2,304 fall/spring run were captured in the North Delta, 481 in the central Delta and 259 in the South Delta. Catches occurred between November and June. Peaks for the combined areas were in February (Table 5 and Figure 11). Average size of capture of fall/spring run in the North, central, and South Delta was 46 millimeters and the range was 25-150 mm, indicating that most of the beach seine catch in the Delta was fry, although a few large smolts were captured.

Figure 12 is a graph of the lower Sacramento River, northern Delta, and central Delta average salmonid catches per haul between January and March from 1978 to 1994.

The catch per haul for all three areas in 1994 is lower than in most past years.

Past information has shown that in general, catch per seine haul in the northern Delta is correlated to flow at Freeport (Figure 13). Flow as well as catches were low in 1994. The 1994 data fits the historical relationship well, keeping the $R^2$ unchanged at 0.78.

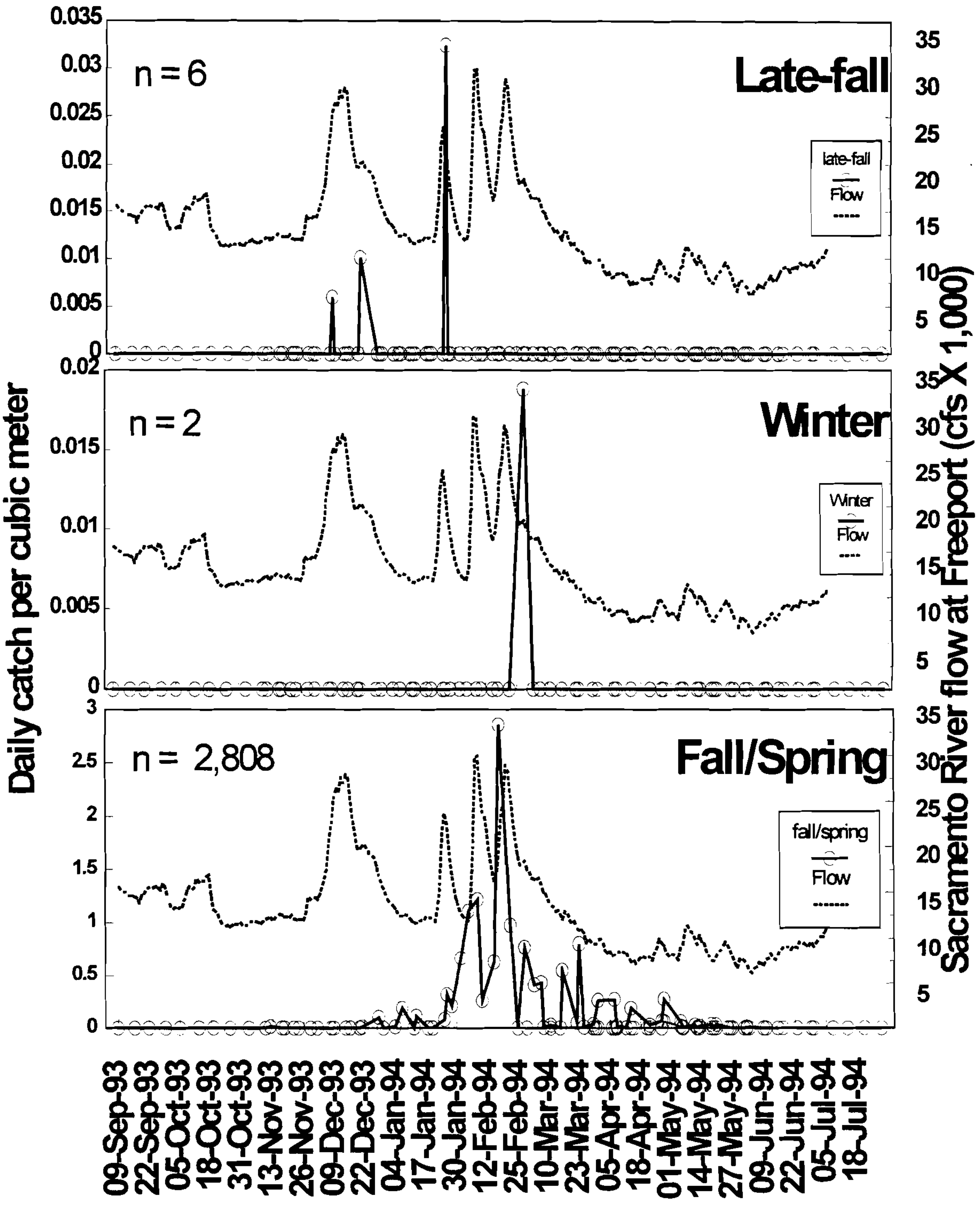



Figure 11. Catch per meter$^3$ of chinook salmon by race in the North, South, and central Delta seine.
Mean daily flow is measured at Freeport.

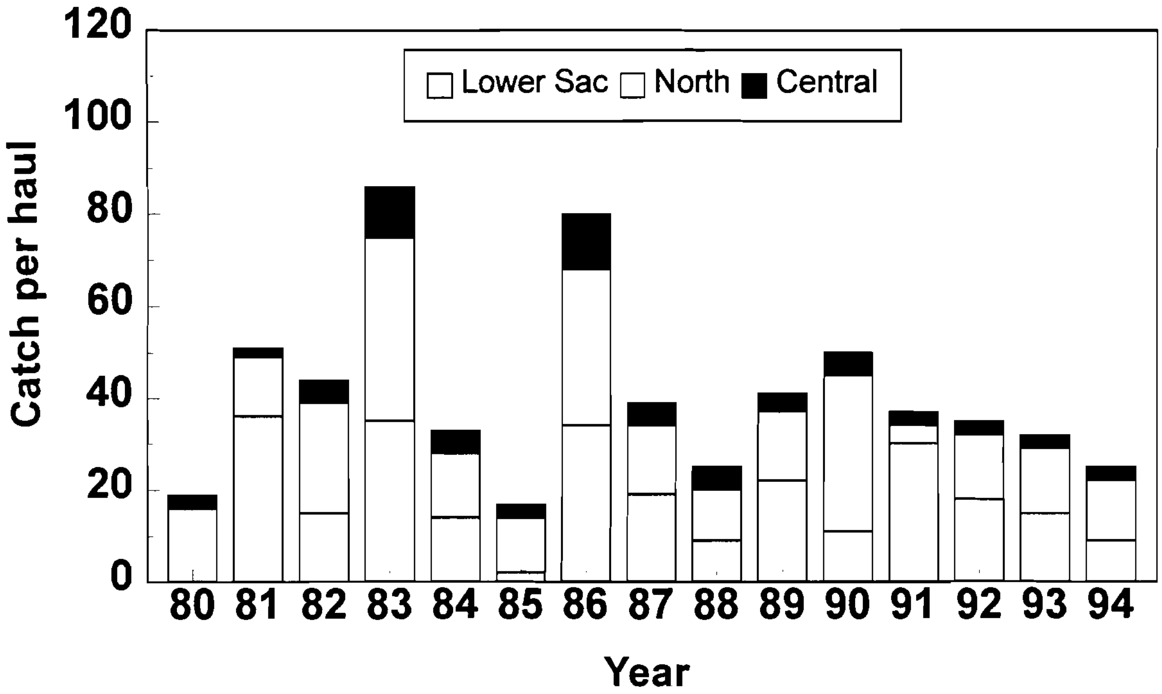



Figure 12. January through March average catch per seine haul from 1978 to 1994 of chinook salmon juveniles in the lower Sacramento River, northern Delta, and central Delta. No sampling was done in the lower Sacramento River in 1980.

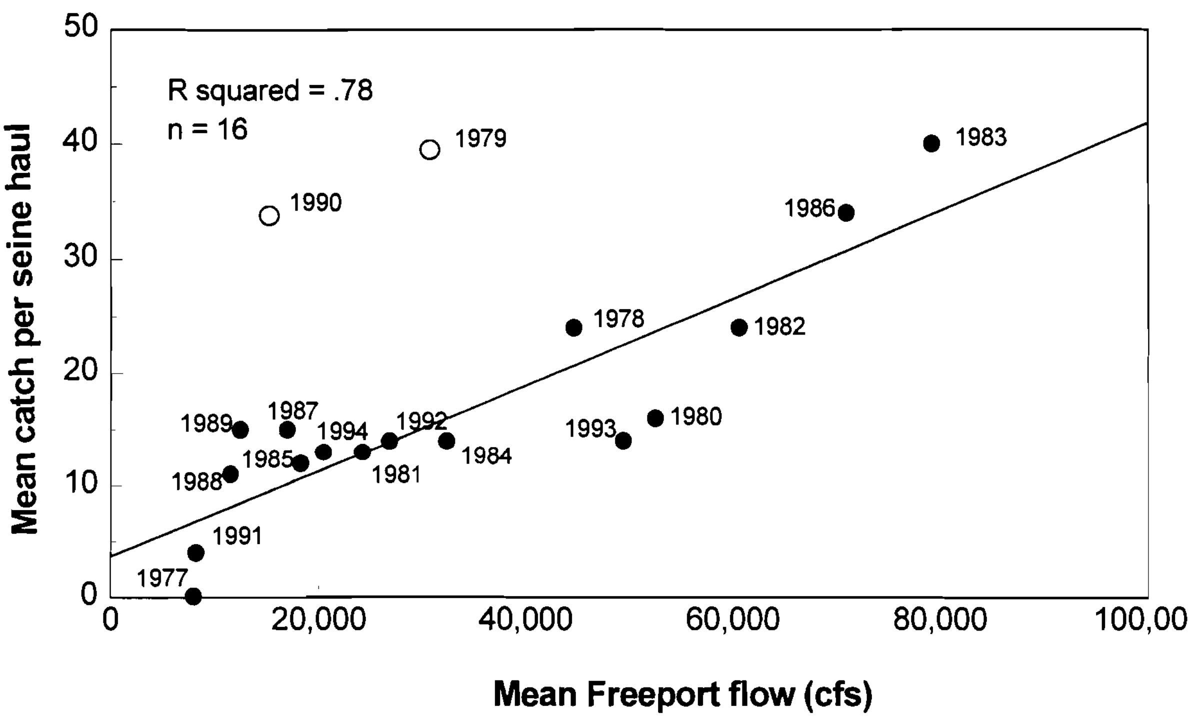



Figure 13. Mean catch per seine haul of chinook in the Northern Delta (January-March) versus February mean flow of the Sacramento River at Freeport. Open circles are points not used in the calculation.

Table 5. 1993-1994 unmarked beach seine catches of fall/spring juvenile chinook salmon by month in the North, central, and South Delta areas. Note: South Delta sampling did not begin until November and stopped in June.

| Month | Catch Fall/spring | Catch per cubic meter |
|---|---|---|
| September | 0 | 0 |
| October | 0 | 0 |
| November | 2 | .0006 |
| December | 12 | .0029 |
| January | 119 | .0361 |
| February | 1,943 | .4934 |
| March | 582 | .1165 |
| April | 115 | .0484 |
| May | 24 | .0083 |
| June | 3 | .0001 |
| July | 0 | 0 |
| Total | 2,800 | .7063 |

## Lower San Joaquin River Seine

A new San Joaquin River beach seine survey was initiated in 1994 which incorporates eight additional sites (Dos Reis, Mossdale, Weatherby, Big Beach, Durham, Sturgeon Bend, Route 132, and North of Toulumne River) along the San Joaquin River to begin documenting abundance and distribution trends of San Joaquin fall run chinook.

A total of seven sites were seined weekly in the lower San Joaquin River between March 30, 1994, and June 3, 1994. A total of 53 fall/spring juveniles captured were recovered in April with size ranging between 47 and 89mm. To document the fall/spring run migration season better, seining in the future will start earlier in the season.

## Sacramento Fyke

Fyke nets (see Figure 10) were used in the Sacramento River near the city of Sacramento (RM 55) to document the presence of fry entering the Delta. Two fykes were set adjacent to the midwater trawl site in West Sacramento, one on the East, and one on the West bank of the Sacramento River and fished four days and nights per week from October 4, 1993, to May 26, 1994. Calculating fyke effort using catch per cubic meter has shown to be unattainable because tide influences the stage and velocity of the water entering the fyke, which can fluctuate drastically within a day. Until the catches using the fyke nets can be directly compared to the trawl data, indices of absolute abundance for all juveniles entering the Delta can not be adequately made.

Winter and late-fall run were not captured in the fykes at Sacramento (as was the case with the Knights Landing fykes) most likely because these races tend to be larger when they migrate through the Delta and are not as susceptible to capture by the fyke. Figure 14 compares 1992-1993 and 1993-1994 chinook catches by hour in the fykes. It is unclear why February catches were so much higher in 1994 than in 1993.

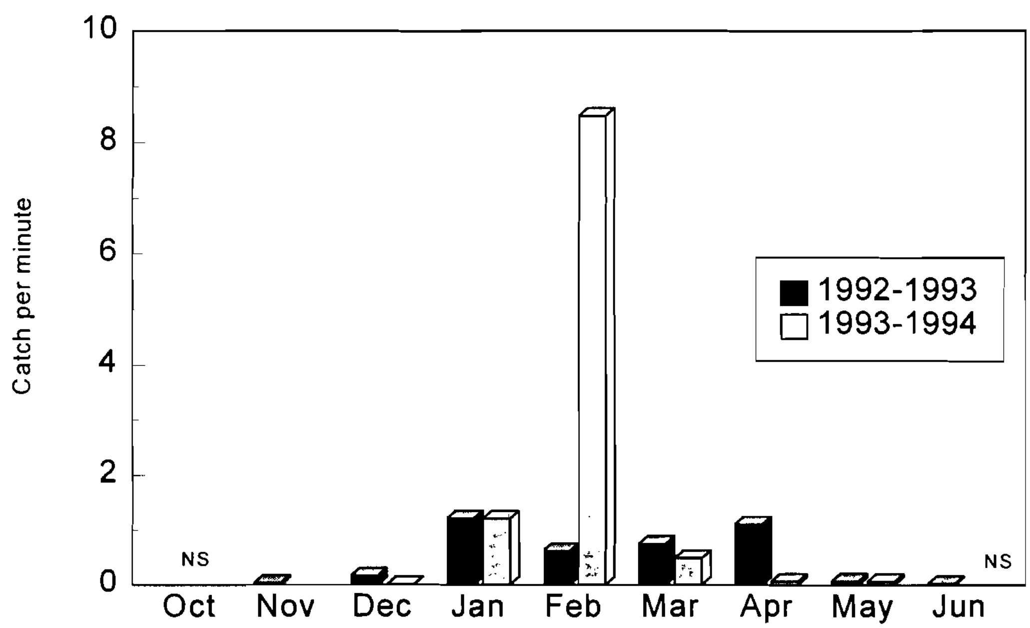



Figure 14. Chinook catch per minute in the Sacramento fykes by month in 1993 and 1994. The mean catch by day was averaged to generate a mean for each month.

## Midwater Trawl at Sacramento

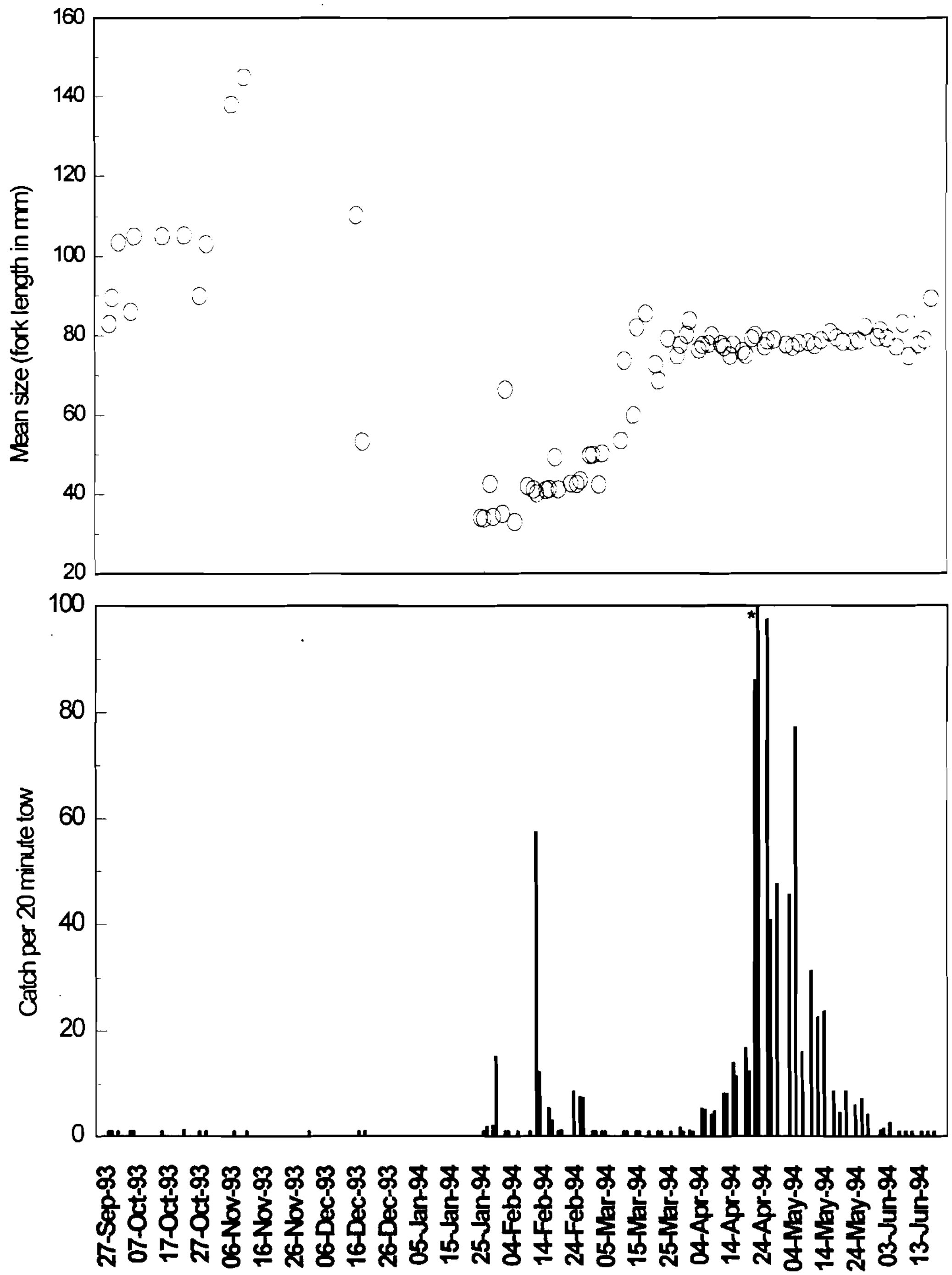
Midwater trawling was done approximately four miles downstream of Sacramento in order to estimate abundance and timing of juvenile salmon entering the Delta. The same site has been sampled since 1988 except in 1990, where sampling occurred near the town of Courtland approximately 21 miles downstream of the present site.

Ten 20-minute tows were conducted three to four times per week starting September 27, 1993, and ending June 17, 1994. The midwater trawl is primarily targeting larger, smolt sized juvenile chinook that migrate in the deeper, main part of the channel.

Figure 15 presents the mean daily fork length and catch per day of salmon caught in the midwater trawl at Sacramento during the sampling period. Larger salmon were captured in low abundance from late September to early December. Some fall/spring run fry were captured in late January and February, but the majority appeared to be smolts (~80mm) passing Sacramento in April and May.

Monthly catches of all races are indicated in Table 6. A total of 31 late-fall were captured in the Sacramento trawl, with the majority captured in October. As indicated in Figure 16 late-fall run catches increased in October, after a small increase in flow at Freeport. The next two pulses of water appeared to stimulate late-fall movement into the Delta. Table 7, which indicates catch of all races of chinook by cubic meter per month, shows the abundance of late-fall to be highest in October and then in September.

A total of fifteen winter run were captured in the Sacramento trawl between February and April of 1994. Similar effort in 1993 captured 269 winter run. Although the peak of winter run in 1994 was observed in February (Table 7), such low catches make it difficult to determine spatial distribution of winter run entering the Delta. The peak catches in 1992 and 1993 occurred in March.




* April 22, 1994 caught 460.0 fish per tow

Figure 15. Mean size and catch per 20 minute tow at Sacramento between September 27, 1993 and June 17 1994 Note: if catch per tow is less than 1.0 and greater than 0 values were changed to 1.0 to improve visibility.

Table 6. Total number of unmarked chinook salmon by race caught in the midwater trawl near Sacramento between September 27, 1993, and June 17, 1994.

| Month | Late-fall | Winter | Fall/spring |
|---|---|---|---|
| Sep | 4 | 0 | 1 |
| Oct | 19 | 0 | 0 |
| Nov | 1 | 0 | 1 |
| Dec | 4 | 0 | 4 |
| Jan | 1 | 0 | 192 |
| Feb | 2 | 8 | 1,036 |
| Mar | 0 | 2 | 69 |
| Apr | 0 | 5 | 6,588 |
| May | 0 | 0 | 2,425 |
| Jun | 0 | 0 | 73 |
| Total | 31 | 15 | 10,389 |

Table 7. 1993-1994 unmarked chinook captures in the Sacramento midwater trawl per 20 minute tow by month between September 27, 1993, and June 17, 1994.

| Month | Late-fall | Winter | Fall/spring |
|---|---|---|---|
| Sep | .142 | 0 | .033 |
| Oct | .182 | 0 | 0 |
| Nov | .005 | 0 | .007 |
| Dec | .033 | 0 | .053 |
| Jan | .006 | 0 | .986 |
| Feb | .010 | .045 | 5.689 |
| Mar | 0 | .012 | .445 |
| Apr | 0 | .025 | 44.087 |
| May | 0 | 0 | 17.273 |
| Jun | 0 | 0 | .888 |

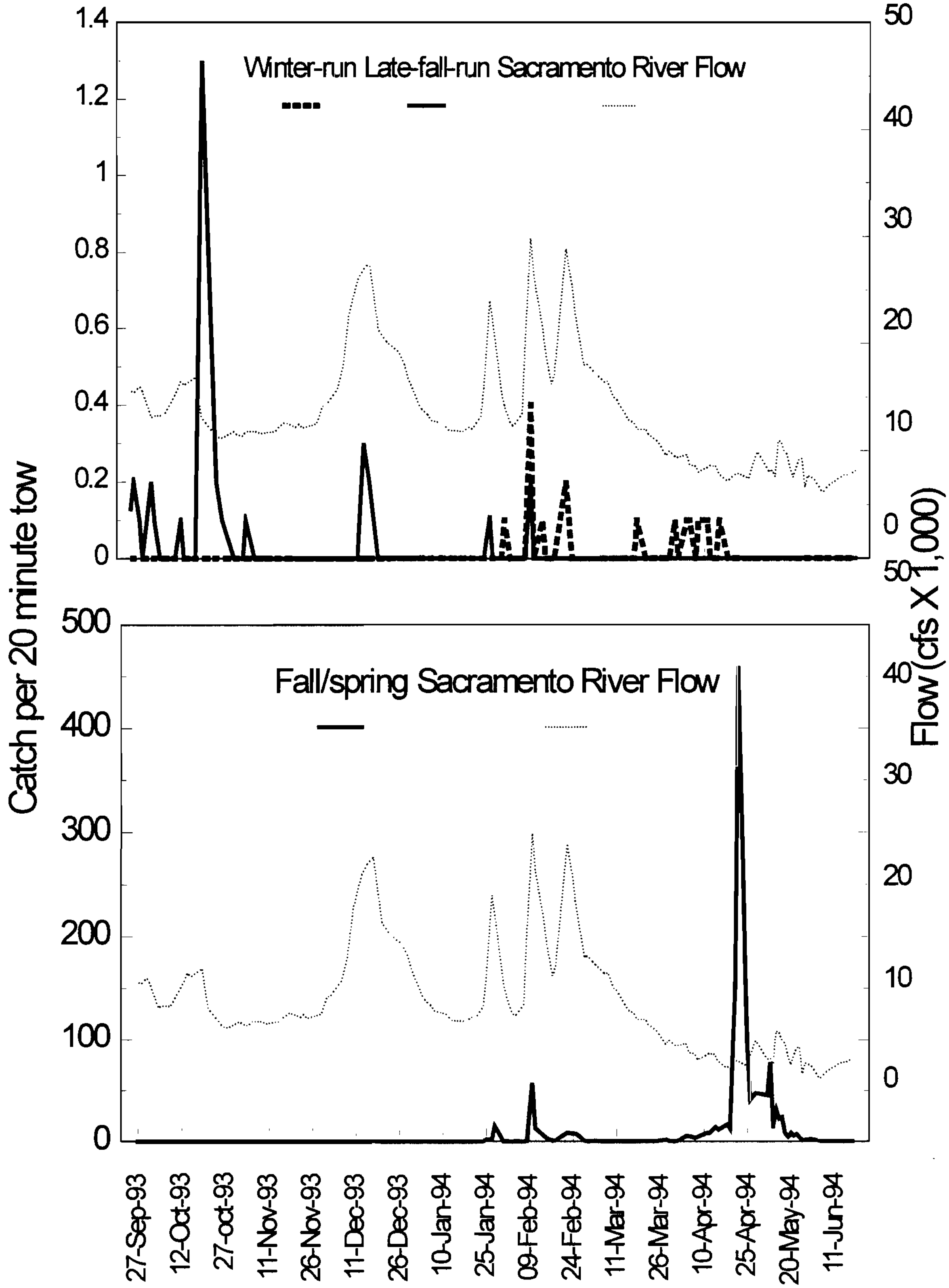



Figure 16. Catch per 20 minute tow by race at Sacramento and mean daily flow at Freeport between September 27, 1993 and June 17, 1994.

Fall/spring run catches in the Sacramento trawl were likely dominated by the large number of smolts (approximately 11 million) released from Coleman National Fish Hatchery on April 14, 1995 (see Figures 15 and 16). A significant fall/spring run fry movement was observed in late January and early February as flows increased which may have moved the fry into the midchannel of the Sacramento River at Sacramento, making them vulnerable to the trawl.

## Delta Cross Channel Rotary Screw Trap

To determine the relative number of fish entering the Delta Cross Channel, a rotary screw trap was fished at the gates of the Delta Cross Channel between September 28, 1993, and January 6, 1994 (ceased fishing in January due to gate closure). A total of one fall/spring run and five late-fall run were captured. Because sufficient flow is required to turn the drum of the rotary screw trap, it only fishes effectively during flood tides when the height of the Sacramento River causes higher flows through the Cross Channel. Currents are not sufficient enough to turn the cone during ebb or slack periods. Table 8 lists raw catch by race in the Delta Cross Channel rotary screw trap. Catches were extremely low, but this may have been partly due to the fact that the trap only fishes effectively during flood tides.

Table 8. Monthly chinook catch in the Delta Cross Channel rotary screw trap between September 29, 1993, and January 6, 1994.

| Month | Late-fall | Winter | Fall/spring |
|---|---|---|---|
| September | 0 | 0 | 0 |
| October | 0 | 0 | 0 |
| November | 0 | 0 | 0 |
| December | 5 | 0 | 1 |
| January | 0 | 0 | 0 |

## Mokelumne Trawl

To gain knowledge of juvenile chinook use of the central Delta, trawling was conducted three days per week from January 7, 1993, to February 16, 1994, in the lower Mokelumne River. A total of twenty fall/spring, one winter, and two late-fall were captured in the Mokelumne trawl. Catches per month are shown in Table 9. Though catches were low, they do indicate a presence of late-fall and winter run chinook in the central Delta.

Table 9. Chinook catch per month by race in the Mokelumne trawl.

| Month | Late-fall | Winter | Fall/spring |
|---|---|---|---|
| January | 2 | 0 | 2 |
| February | 0 | 1 | 18 |

## Midwater Trawling at Chipps Island

Trawling at Chipps Island for the 1994 season began in November rather than April as in previous years to gain more information about winter and late-fall run. Ten 20 minute tows were conducted between three and seven days a week depending on the need to recover coded wire tagged salmon for survival studies.

The majority of smolts in 1994 migrated through the Delta in April and May, reflecting the high numbers of fall/spring run relative to other races. In 1994, mean juvenile chinook abundance in the western Delta at Chipps Island for the months of April, May, and June was 7.83 salmon per 20 minute tow, which was lower than the mean between 1978 and 1993 (18.4 salmon per 20 minute tow, Figure 17). The mean catch for June was extremely low at 0.48 fish/tow. The low flows in 1994 may have decreased salmon survival and abundance at Chipps Island. Higher water temperatures in June are likely in years of low flow and could decrease the survival of late moving fish. Figure 18 represents average fork length and overall catch of chinook smolts at Chipps Island. Catches by race are standardized per 20 minute tow and provided on a daily basis in Figure 19. From November to April, average size at capture was generally higher than for those captured in April, May, and June representing larger late-fall, winter run, and fall/spring run yearlings. Table 10 identifies juvenile salmon catches at Chipps Island by race.

Most late-fall were recovered during the month of December. Sixty eight were recovered between November 3, 1993, and February 25, 1994, with size ranging between 103 and 230 mm. Catch per tow in December (Table 11) was more than three times that of any other month. As expected, the peak late-fall migration is later at Chipps Island than at Sacramento (October vs. December) however trawling at Chipps Island did not start until November making a direct comparison difficult.

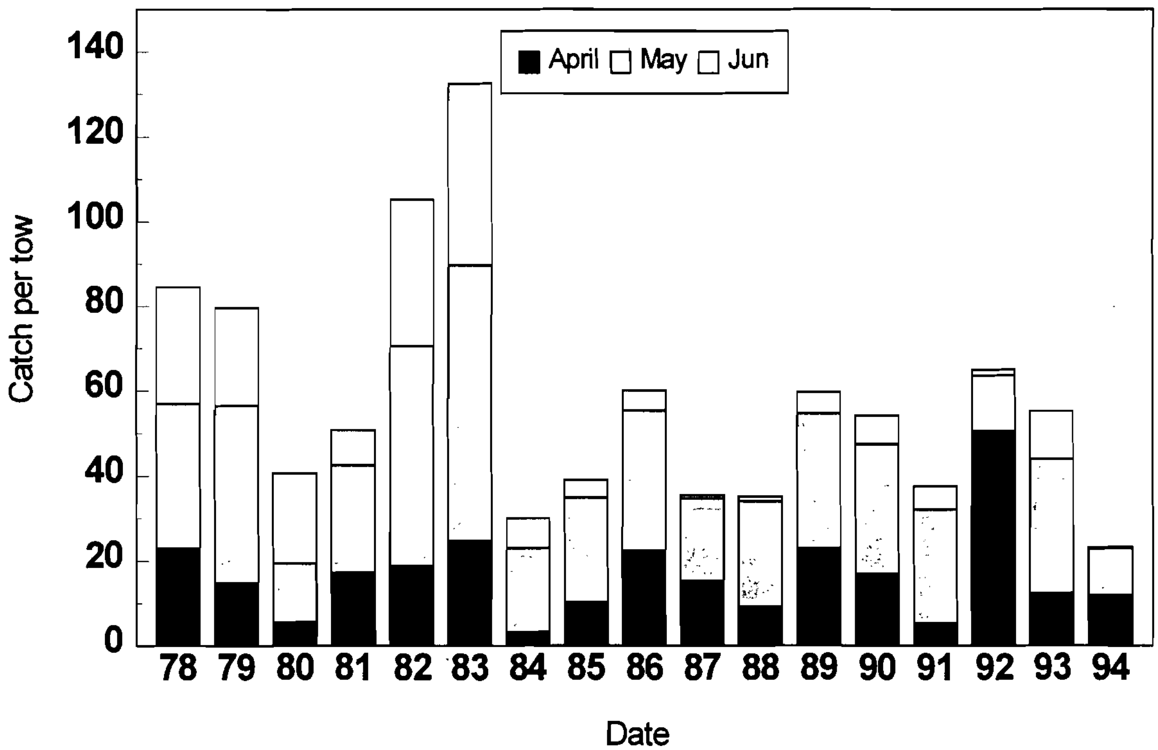



Figure 17. Mean catch of salmon smolts per 20 minute tow with Chipps Island midwater trawl in April, May, and June from 1978 to 1994.

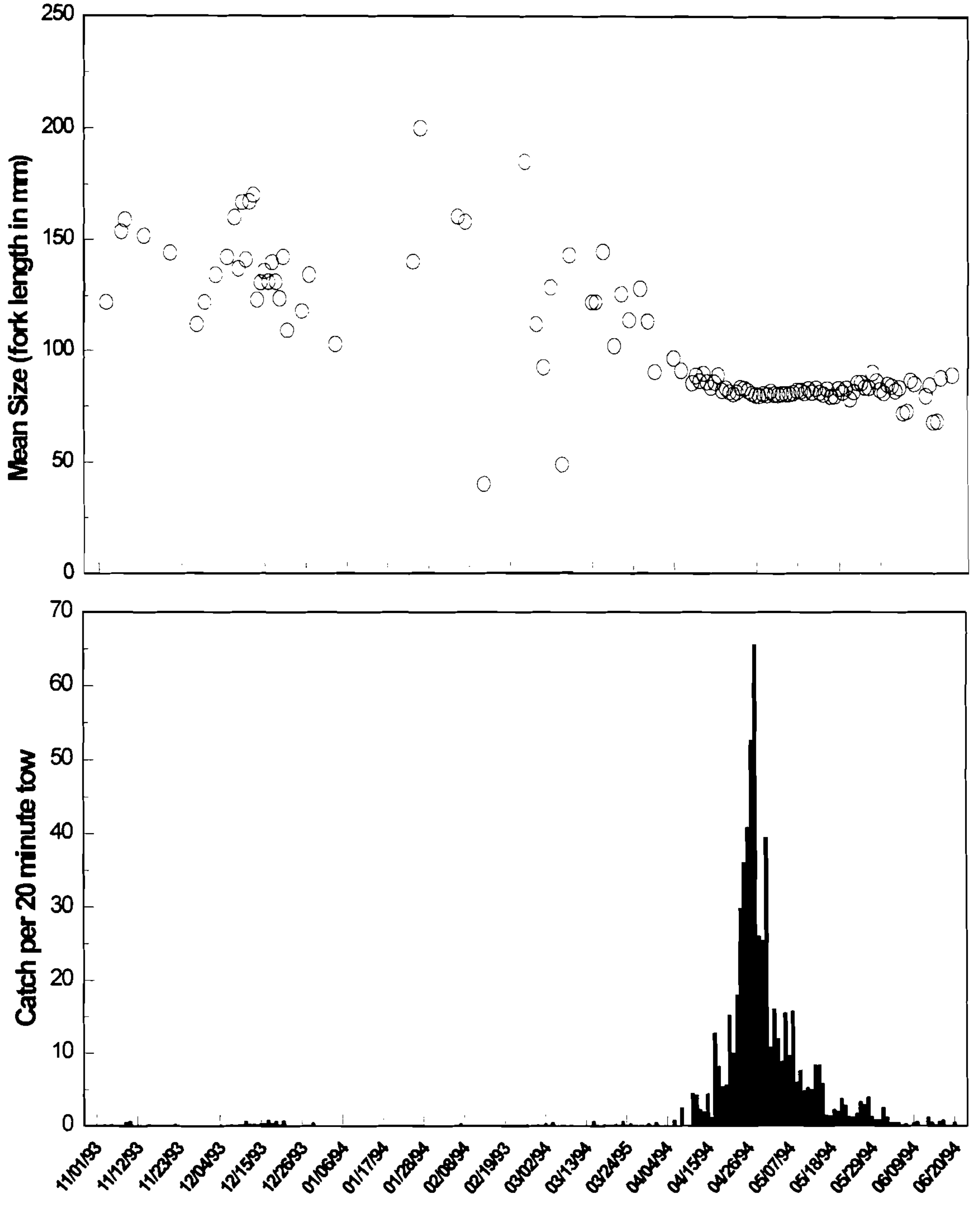



Figure 18. Mean size per day and average catch per tow at Chipps Island between November 1993 and June 1994.

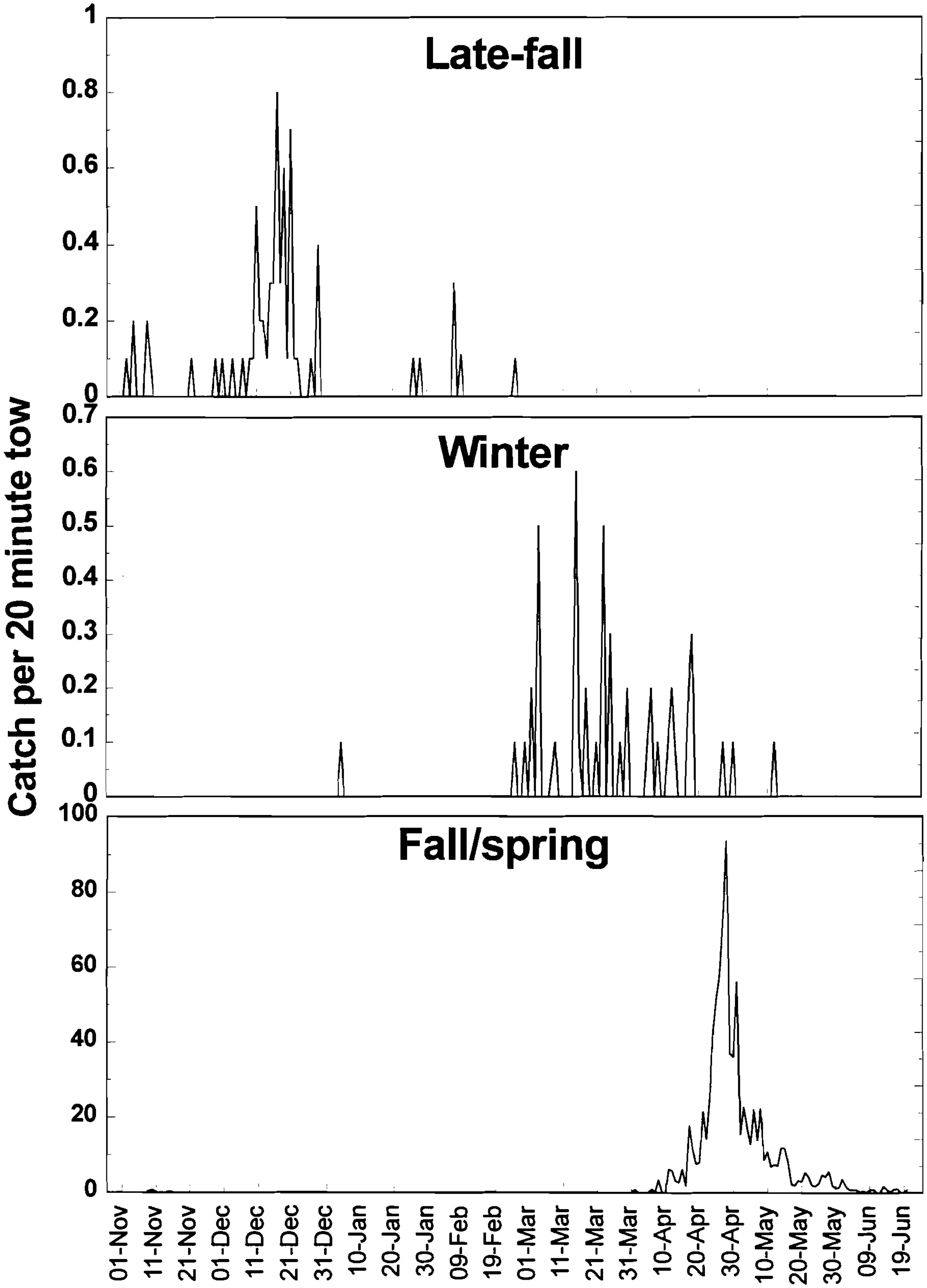


Figure 19. Chinook catch per twenty minute tow at Chipps Island between November 1, 1993 and June 20, 1994

Table 10. Total number of juvenile chinook by race caught in the midwater trawl at Chipps Island between Nov 1, 1993, and June 20, 1994.

| Month | Late-fall | Winter | Fall/spring |
|---|---|---|---|
| November | 8 | 0 | 11 |
| December | 53 | 0 | 0 |
| January | 2 | 1 | 0 |
| February | 5 | 2 | 1 |
| March | 0 | 29 | 5 |
| April | 0 | 14 | 3,713 |
| May | 0 | 1 | 2,094 |
| June | 0 | 0 | 102 |
| Total | 68 | 47 | 5,926 |

A total of 47 winter run from 103 to 162 mm were captured between January 5, 1994, and May 12, 1994. Peak catches of winter run were in March (.227) and in February at Sacramento (.045). Based on these dates, it appears that in 1994 the majority of winter run moved between Sacramento and Chipps Island fairly quickly.

Table 11. Average number of juvenile chinook captured per tow (20 min) by race in the midwater trawl at Chipps Island between November 1, 1993, and June 20, 1994.

| Month | Late-fall | Winter | Fall/spring |
|---|---|---|---|
| November | .070 | 0 | .077 |
| December | .193 | 0 | .003 |
| January | .013 | .007 | 0 |
| February | .034 | .020 | .007 |
| March | 0 | .227 | .040 |
| April | 0 | .052 | 12.004 |
| May | 0 | .002 | 10.725 |
| June | 0 | 0 | .510 |

Peak fall/spring run catches were in April rather than May as was the case in 1993. An average of 12 fall/spring run salmon were caught per twenty minute tow during the month of April with a size range of 57 to 115 mm. Yearling sized fish were captured in November and December and smolts were captured in April, May, and June. The majority of fish captured in April at Chipps Island were most likely Coleman fall run which were released on April 14. Prior to 1985, the smolts appeared to be more evenly distributed among all three months (see Figure 20). Historically, Coleman National Fish Hatchery smolt production was released in May during the late 70's and early 80's with a change to April in recent years. The minimal variability in size between April and June (Figure 18) shows the constant size of smoltification by fall/spring run and the influence of the large Coleman National Fish Hatchery release where size is generally uniform. Peak captures of fall/spring at Chipps Island appear similar to Sacramento midwater trawl peak catches in April and May, however, spikes in catches at Sacramento during February do not show at Chipps (see Figure 21). The large spikes in February at Sacramento were fry and most likely would not migrate out past Chipps Island until they were of smolt size. Beach seining at Antioch shows that very few fry were observed in the vicinity of Chipps Island in February.

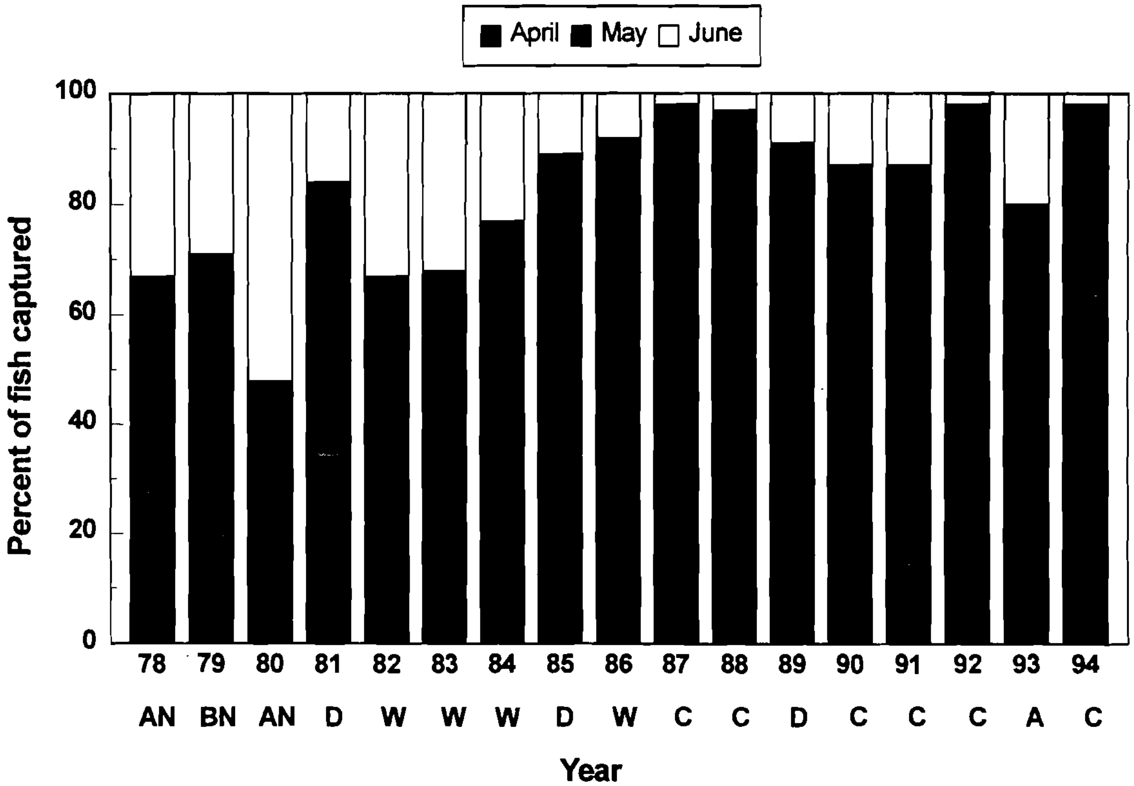



Figure 20. Percent of total midwater trawl chinook smolt catch in April, May, and June at Chipps Island from 1978 to 1994. Water year types are also indicated (AN = above normal, BN = below normal, D = Dry, W = Wet, C = critical).

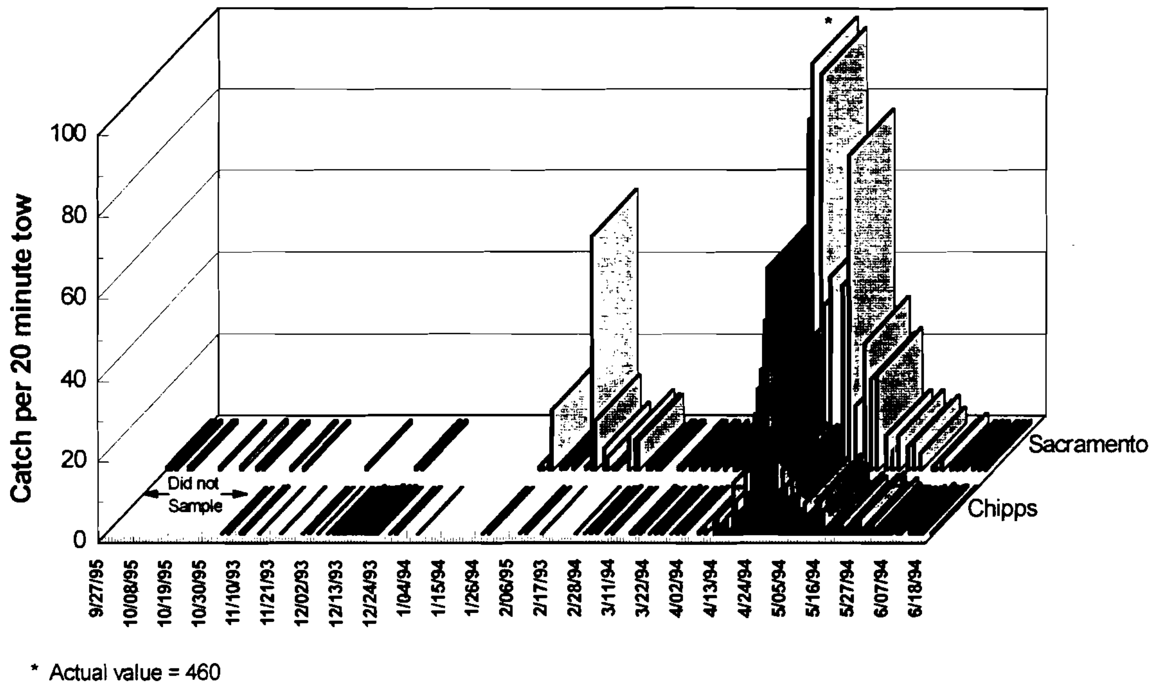



Figure 21. Average chinook catch per tow at Chipps Island and Sacramento between November 1993 and June 1994. Chipps Island was not sampled between September and November.

## Delta Gear Size Selectivity

Table 12 compares size of capture of all races of juvenile chinook in the Sacramento midwater trawl and fyke, Delta area beach seines, and Chipps Island midwater trawl. It appears the fyke nets at Sacramento consistently captured smaller fish than the beach seine or midwater trawl at Sacramento. We would expect Chipps Island to catch larger fish because they are emigrating to sea when they reach Chipps Island. While the beach seine and fyke nets target rearing juveniles along the banks of the river, they captured some smolt sized fish in April, May, and June as well. Fry were captured between January and March in the seine and fyke net. While fry were also recovered in the Sacramento trawl between January and February, by March the influence of the smolts is observed. Yearlings were observed between September and December in the Sacramento trawl and in November in the seine.

Chipps Island captured mostly yearling sized fish from November to March. April and May catches were generally similar between gears and show the uniformity of fall run smolts migrating through the Delta.

Table 12. Comparison between the mean size per month in the fyke, Sacramento trawl, Delta seine, and Chipps Island trawl between September, 1993, and June, 1994.

| Month | Fyke Net | Sacramento Trawl | Seine | Chipps Island |
|---|---|---|---|---|
| Sep | 0 | 93.80 | 0 | no sample |
| Oct | 0 | 102.47 | 0 | no sample |
| Nov | 0 | 141.50 | 148 | 146.89 |
| Dec | 35.75 | 74.75 | 57.33 | 138.17 |
| Jan | 34.87 | 35.05 | 43.22 | 147.67 |
| Feb | 38.90 | 41.94 | 41.10 | 149.86 |
| Mar | 48.33 | 71.49 | 49.48 | 118.29 |
| Apr | 67.04 | 78.38 | 67.63 | 82.13 |
| May | 67.67 | 78.09 | 78.38 | 81.29 |
| Jun | no sample | 80.07 | 79.33 | 81.81 |

Catches and size distribution in these months is also influenced by the massive hatchery releases from Coleman NFH.

## Absolute Abundance Estimates

Two methods were used as a comparison for calculating the absolute abundance of all races of juvenile chinook salmon at Chipps Island; method I, which uses a trawl efficiency rate from previous studies, and method II which incorporates percent of time and area sampled. Due to the lack of efficiency studies at Sacramento in 1994, no absolute abundance estimates were done using the Sacramento trawl. Efficiency studies will be done in the future to assess absolute abundance at each site.

Method I: Method I uses the following formula: $N_i = n_i/t_i\ (0.0055)$, where $N_i$ = annual number of absolute abundance, $n_i$ = number of salmon caught during specified time with the midwater trawl at Chipps Island, and $t_i$ = fraction of time sampled, and .0055 = the estimated average fraction of smolts collected by the midwater trawl at Chipps Island in years 1980 - 1984 (a measure of trawl efficiency) (USFWS, Exhibit 31, 1987).

Method II: The second method used to estimate abundance at Chipps Island expands raw catches to correct for the amount of time and area sampled in each month (the fraction of area sampled is 30'/3900' = 0.007692). Method II uses the following formula: $N_i = n_i/t_i(.007692)$; where $N_i$ = annual number of absolute abundance, and $n_i$ = number of salmon caught during specified time with the midwater trawl at Chipps Island, and $t_i$ = the fraction of time sampled. We assume in this expansion process that the salmon are equally distributed in time and space and that our net is 100% efficient.

Estimated abundance of late-fall at Chipps Island was between 102,000 and 136,000 in 1994. Since trawling did not start until April during the 1993 field season, late-fall efficiency could not be estimated for that year.

The 1993 estimate of 225,000 winter run passing Chipps Island was higher than the 1994 estimate of between 89,000 and 120,000. Winter run juvenile production estimates provided by the National Marine Fisheries Service (based on adult returns, percent grilse, total number of eggs, survival, etc.) estimate approximately 74,000 winter run entering the Delta in 1994 which is in close agreement with the Chipps Island estimate.

Absolute abundance of fall/spring run at Chipps Island was estimated to be between 6,000,000 and 10,000,000 smolts in 1994 which is lower compared to the 1993 estimate of almost 16,000,000. Water conditions during 1993 were much more favorable for salmon and could contribute to higher survival in 1993 and raise the estimate of abundance for that year.

Figure 22 is a graphic representation comparing the two abundance estimates used from April 1 to June 30, at Chipps Island between 1978 and 1994. Although the two methods used to calculate abundance at Chipps Island are in fairly good agreement, method II which corrects for the amount of time and area sampled is consistently lower than method I which uses trawl efficiency to estimate abundance. Estimates between both methods are in agreement as abundance estimates are not usually precise. Both methods identify abundance in 1994 as being very low compared to past years.

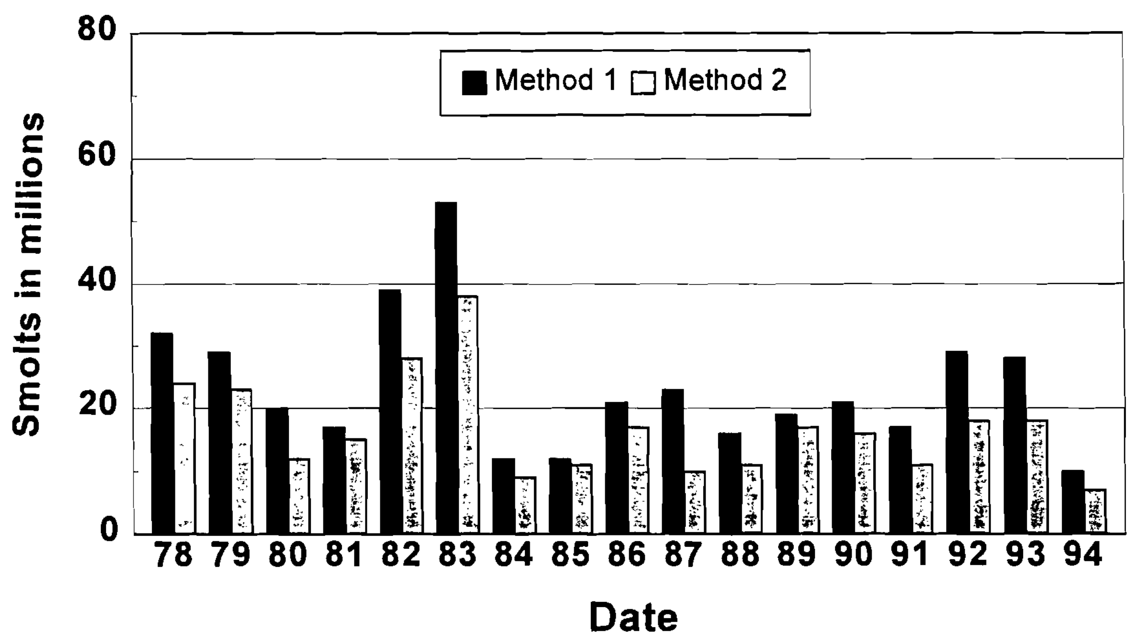



Figure 22. Comparison of absolute estimates of smolt abundance at Chipps Island between April 1 and June 30, from 1978 to 1994 using method 1 and method 2.

## Coded Wire Tag Experiments

During the winter of 1993 and the spring of 1994, coded wire tag experiments were conducted to refine our understanding of juvenile salmon survival through the Sacramento and San Joaquin Deltas. Specific questions we attempted to address with tagging studies in 1994 were:

a) in the Sacramento River/Delta:

1. What is the survival of salmon smolts migrating through the Delta under various environmental conditions?
2. Does installation of a barrier at the head of Old River (south Delta) have an effect on Sacramento basin smolt survival?

b) in the San Joaquin River/Delta:

1. What is the survival of salmon smolts migrating down the San Joaquin River with and without a barrier at the head of upper Old River?
2. What is the survival of salmon smolts diverted into the south Delta (released at lower Old River), and can the effect of a barrier at the head of Old River on survival and indirect mortality be estimated?

Survival is estimated by dividing the number of tags recovered from each particular tag group by the number released, corrected for the fraction of time and channel width sampled using a midwater trawl at Chipps Island (*USFWS, Exhibit 31 to SWRCB, July 1987*). Although sometimes referred to as survival, this is actually only an index of survival. Survival indices were very low throughout the Delta in 1994.

## Sacramento Delta Experiments

Knowledge of chinook salmon smolt survival in the Sacramento River and the Delta is primarily based on studies conducted with smolt sized fall run fish. Factors that have been found to affect survival include temperature, export rates and the status of the Delta Cross Channel gates (Kjelson et al., 1989). In general, smolts diverted into the central Delta exhibit lower survival than those that remain in the main river channel. Experiments are generally conducted in April and May, when hatchery reared Sacramento River fall run chinook generally reach smolt size (>75mm).

Recently, attention has become focused on Sacramento winter run salmon which have been federally listed as an endangered species since 1992. The 1994 Biological Opinion issued by the National Marine Fisheries Service included criteria for the protection of winter run juveniles, such as closure of the cross channel gates between February 1 and April 30, and Q-west flow criteria. Winter run are believed to be less vulnerable to predation and temperature related mortality than fall run fish due to their greater size and the relatively cool water temperatures that occur in the Delta during most of their outmigration.

Late-fall run releases:

The study conducted in December 1993 was designed to gain information on mortality of winter run juveniles within the Delta using late-fall run yearlings. They would likely be more representative of winter run than fall run smolts because of their similar size, and because overlap in their migration periods exposes them to similar, cool water temperatures.

Late-fall run chinook salmon (BY92) from Coleman National Fish Hatchery were released in the Sacramento River at Ryde and in Georgiana Slough on December 2, 1993. Recoveries were made at Chipps Island and at the salvage facilities in the south Delta. The vast majority of the fish were recovered in December at the various recovery locations but a few recoveries were made as late as March and April. Recoveries at the fish facilities were much higher for the group released into Georgiana Slough (Table 13). Survival indices were much higher for the marked fish released at Ryde (1.90) than for those released into Georgiana Slough (0.28). The ratio between the two indices is 6.8. These indices include a single March recovery from each release group while the rest of the recoveries were made in December. If the March outliers are discarded from the calculations, the resulting indices are 1.15 for Ryde and 0.11 for Georgiana Slough. The Ryde:Georgiana Slough ratio of survival is then over 10:1.

The ratio of survival indices between release sites is similar to past experiments using fall run fish. It should be noted that direct comparisons should not be made between survival indices of fall and late fall run as there may be differences in gear efficiency at Chipps Island for different sized fish. Relative comparisons using a ratio provide a valid way to compare the groups. They are shown in Table 13.

Table 13. Release dates, mean fork length of release groups (FL), survival index ($\hat{S}$), survival ratios and expanded numbers of fish counted at state (SWP) and federal (CVP) salvage facilities from studies conducted with coded wire tagged fall run (F) and late-fall run (LF) chinook salmon smolts, April 1992 through December 1993.

| Date | Race | Sacramento River (Ryde) Releases | | | Georgiana Slough Releases | | | Ryde: Georgiana Survival Ratio |
|---|---|---|---|---|---|---|---|---|
| | | FL(mm) | $\hat{S}$ | CVP/SWP | FL(mm) | $\hat{S}$ | CVP/SWP | |
| 04/06/92 | F | 77 | 1.36 | 0 / 34 | 74 | 0.41 | 10 / 4 | 3.3 |
| 04/14/92 | F | 82 | 2.15 | 0 / 0 | 81 | 0.71 | 12 / 8 | 3.0 |
| 04/27/92 | F | 81 | 1.67 | 0 / 0 | 83 | 0.20 | 1 / 4 | 8.3 |
| 04/14/93 | F | 61 | 0.41 | 0 / 0 | 63 | 0.13 | 0 / 24 | 3.2 |
| 05/10/93 | F | 75 | 0.86 | 0 / 0 | 75 | 0.29 | 15 / 36 | 3.0 |
| **12/02/93** | **LF** | **129** | **1.90** | **0 / 10** | **119** | **0.28** | **168 / 79** | **6.8** |

Although water temperatures at time of release were low (51 ° F ), combined CVP and SWP exports were high (over 10,000 cfs). Qwest values were slightly positive (Table 14). The Delta Cross Channel gates were open until January 8, 1994, and then closed for the remainder of the recovery period.

Table 14. Water temperature at time of release, mean export (cfs) and QWEST (cfs) from release to peak recovery date at Chipps Island, for coded wire tagged fall and late-fall run chinook salmon smolts, April 6, 1992 through December 19, 1993.

| Sacramento River at Ryde | | | | Georgiana Slough | | | |
|---|---|---|---|---|---|---|---|
| Dates: Release Recovery | T(°F) | Exports | Qwest | Dates: Release Recovery | T(°F) | Exports | Qwest |
| 04/06/92 04/15/92 | 64 | 3073 | 53 | 04/06/92 04/20/92 | 64 | 2425 | 499 |
| 04/14/92 04/21/92 | 63 | 1097 | 1410 | 04/14/92 04/20/92 | 64 | 1093 | 1449 |
| 04/27/92 05/02/92 | 67 | 1578 | 729 | 04/27/92 05/04/92 | 67 | 1883 | 749 |
| 04/14/93 05/06/93 | 58 | 3696 | 3214 | 04/14/93 05/12/93 | 58 | 3246 | 3493 |
| 05/10/93 05/14/93 | 59 | 1497 | 4161 | 05/10/93 05/22/93 | 65 | 1883 | 749 |
| **12/02/93 12/12/93** | **51** | **10316** | **72** | **12/02/93 12/19/93** | **51** | **10646** | **509** |

Low survival of fall run chinook salmon smolts in the central Delta relative to that in the mainstem Sacramento is well documented (Table 13) and has been attributed in part to predation and the adverse effects of high water temperature. Results of this study suggest that despite cooler water temperatures and the presumed reduced vulnerability to predation, survival for juvenile late-fall (and likely winter run juveniles) diverted into the central Delta via Georgiana Slough is less than for those migrating down the mainstem Sacramento River. The relatively low numbers recovered at the fish facilities suggest that in-channel mortality in the central/south Delta continues to account for the high mortality of fish diverted off the mainstem Sacramento River. This in-channel mortality does not appear to be temperature related but caused by some other factor. This other factor may be the complex central Delta hydrology which alters smolt migratory behavior.

While the gate status of the Delta Cross Channel was not a direct factor affecting mortality in this study because of the downstream location of our release sites, the Cross Channel and Georgiana Slough together have the capacity to divert about 70% of the flow of the mainstem Sacramento River. Based on expected mortality rates of diverted smolts, closure of the Cross Channel gates and measures to prevent smolts from entering Georgiana Slough should continue to be considered important components of the effort to increase survival through the Delta for juvenile winter run chinook salmon.

It should be noted, however, that closure of the Delta Cross Channel can result in increased negative (upstream) flow in the central and western Delta when export rates are high. The results in Table 13 and 14 show that entrainment, at the south Delta fish facilities of smolts released into the Sacramento River downstream of both the Delta Cross Channel and Georgiana Slough (at Ryde), does occur even when the Cross Channel gates are open and QWEST flow is slightly positive. It should be noted, however, that none were recovered at the fish facilities from the Ryde groups at the higher levels of QWEST flows. Further experimentation is necessary to improve our understanding of how migrating smolts respond to Delta flow patterns and cross channel gate closures.

Fall run releases:

Coded wire tag experiments conducted in the Sacramento Delta in 1994 involved releasing two separate groups of approximately 50,000 Feather River Hatchery fall run smolts at Miller Park near Sacramento (RM 57); one on May 3 and another on May 24, to estimate survival through the Delta under different environmental conditions. Survival indices were extremely low at 0.07 and 0.00 respectively, the latter resulting from no recoveries at Chipps Island. River temperatures were generally high (67 degrees for both releases) and flows at Freeport (from release date to last day of capture) and exports were relatively low. Flow at Freeport averaged 9510 cfs and combined CVP/SWP exports averaged 1700 cfs after the first release. Following the second release Freeport flows dropped to 7955 cfs and average exports increased to 2325 cfs (Table 15). Survival for the second group was lower even though the average fish size was greater.

Although the Delta Cross Channel gates were closed until May 27, both groups could have been diverted into the interior Delta via Georgiana Slough and this may be at least partially responsible for the low survival indices obtained. Furthermore, no recoveries were made at the south Delta fish facilities of either release indicating that indirect mortality accounts for the losses.

The 1994 indices were much lower than those calculated for four Miller Park releases made in the spring of 1993 (a wet year), which ranged from 0.35 to 0.75. Survival was also much lower than for similar releases made in past critical water year types. In 1990, an index of 0.85 was obtained, and two indices generated in 1991 were 0.49 and 0.78. No Miller Park releases were made in 1992.

The measured survival indices are much lower than those predicted by the Sacramento Delta Smolt Survival Model (Kjelson et al., 1989, 1991). The model predicts an index of 0.28 for the release on May 3, and an index of 0.26 for the release on May 24. It is unclear why survival indices were lower than expected from releases made at Sacramento in 1994. As will be documented in later sections of this report, survival was low also for all releases made in the Delta in 1994.

Table 15. Release temperatures (Fahrenheit), average fish size at release (fork length in millimeters), barrier status, average flow at Sacramento and Vernalis, average Delta exports, and survival indices for Delta CWT releases in 1994.

| release date & location | temp. @ release (F) | ave. size @ release (mm) | delta X-channel status | HOR barrier status | ave. flow @ Sac. (cfs) | ave. flow @ Vernalis (cfs) | ave. CVP & SWP exports (cfs) | survival index |
|---|---|---|---|---|---|---|---|---|
| May 3 Miller Park | 67 | 83 | closed | NA | 9510 | NA | 1700 | 0.07 |
| May 24 Miller Park | 67 | 91 | open 5-27 | NA | 7955 | NA | 2325 | 0 |
| Apr 12 Ryde | 62.5 | 76 | closed | no | 8140 | 1990 | 1570 | 0.20 |
| Apr 12 Georgiana Sl. | 62 | 77 | closed | no | 7540 | 1485 | 1350 | 0.06 |
| Apr 11 Lower Old R. | 62 | 74 | closed | no | NA | 1430 | 1465 | 0 |
| Apr 13 Jersey Point | 64 | 72 | closed | no | NA | 2005 | 1445 | 0.19 |
| Apr 25 Ryde | 62 | 76 | closed | yes | 9000 | 2550 | 1530 | 0.18 |
| Apr 25 Georgiana Sl. | 62 | 73 | closed | yes | 9050 | 2315 | 1480 | 0.11 |
| Apr 26 Lower Old R. | 62 | 76 | closed | yes | NA | 2525 | 1950 | 0 |
| Apr 27 Jersey Point | 63 | 78 | closed | yes | NA | 2305 | 1950 | 0.28 |
| Apr 11 Mossdale | 63 | 74 | closed | no | NA | 1430 | 1465 | 0 |
| Apr 26 Mossdale | 60 | 77 | closed | yes | NA | 2500 | 1860 | 0.04 |
| May 2 Mossdale | 66 | 82 | closed | yes | NA | 2155 | 1705 | 0 |
| May 9 Mossdale | 68 | 89 | closed | yes | NA | 2175 | 1710 | 0.02 |

NA = not applicable

Notes: Average flows at Sacramento and Vernalis and average export values are from dayflow.
Average flows at Sacramento and Vernalis are from date of release to last day of recovery, or for 14 days after release if no recoveries were made at Chipps Island (survival = zero).
Average exports are for 14 days after release.

**<u>Ryde/Georgiana Slough/Jersey Point/Lower Old River releases</u>**:

One of the primary elements being evaluated through CWT studies in 1994 was the effect of a barrier at the head of Old River (HOR) on juvenile salmon survival for smolts originating from the Sacramento basin (including winter run). To test the hypothesis that at a given set of flow and export conditions a HOR barrier would increase movement of juvenile salmon from the central Delta toward the pumping plants, releases were made at Ryde, Georgiana Slough, Lower Old River and Jersey Point with and without the HOR barrier in place. If the hypothesis were correct, it would be expected that the survival of smolts released in Georgiana Slough, relative to the lower Old River and Jersey Point releases, would decrease with the barrier in place. The "without barrier" paired releases were made on April 11-13, and the "with barrier" releases made on April 25-27. The barrier was installed on April 23. Water temperatures were similar between the two sets of releases as were exports which were low throughout the experiment (Table 15).

The resulting survival indices are shown in Table 15. Like the Miller Park releases, survival was also low for the other delta releases made in 1994. Smolts released in lower Old River had the lowest survival indices estimated, as no recoveries from either group were made at Chipps Island. Georgiana Slough groups also had very poor survival (0.06 and 0.11) but were somewhat better than for those released in lower Old River. As expected, relative survival was greatest for smolts released at Ryde and Jersey Point. Although absolute survival indices are important and show the relatively poor survival of all groups, it is the relative differences between release groups that will allow us to estimate the impact of the HOR barrier on the survival of smolts diverted into Georgiana Slough from the Sacramento River.

Differential survival between groups was assessed by estimating the percentage of smolts released in Georgiana Slough that migrated to Jersey Point (the western Delta) and determining if that percentage lessened for the second group with the HOR barrier in place. To estimate these percentages a simple algebraic equation was used:

$y_i = a_i (x) + b_i(1-x)$ where

y = survival index generated for the Georgiana Slough group
a = survival index generated for the Jersey Point group
x = the percentage of Georgiana Slough smolts making it to Jersey Point
b = survival index generated for the Lower Old River group
I = the first group or the second group of releases.

We have assumed in this analysis that the smolts from Georgiana Slough can only move towards Jersey Point or lower Old River and that the percentage of smolts arriving from Georgiana Slough at each site survive at a similar rate as those released in lower Old River and at Jersey Point. The specific numeric equations for each of the two releases are listed below. The estimate of the percent arriving at Jersey Point serves as a basis for comparison between the two groups.

| | | | |
|---|---|---|---|
| April 11 - 13 releases: | .06 = .19 (x) + 0.0 (1-x) | x= 0.32 | No HOR barrier in place |
| April 25 - 27 releases: | .11 = .28 (x) + 0.0 (1-x) | x=0.39 | HOR barrier in place |

This analysis shows that the percentage of Georgiana Slough smolts arriving at Jersey Point was similar between the two sets of releases (32% versus 39%) with and without the barrier in place, although the estimate was somewhat greater for the with barrier releases. Absolute survival indices for all interior Delta releases (except lower Old River which was 0), were also greater with the barrier than without the barrier in place. The two Ryde release groups survived at a similar rate, although slightly greater without the barrier in place. This limited data appears to show that the barrier at the head of Old River (at least under conditions similar to the spring of 1994) does not increase the mortality of smolts entering the central Delta via Georgiana Slough. The low survival indices overall do place additional uncertainty in our conclusion. Recoveries of these release groups as adults in the ocean fishery in addition a release made at Benicia may confirm or reject our inital conclusions. In addition, future experiments should incorporate sufficient release sizes to assure a larger number of recoveries of all groups at Chipps Island.

Marked groups also were released at Ryde and in Georgiana Slough in 1992 and 1993. When comparing the 1994 Ryde and Georgiana Slough survival indices to these similar releases, we again see that survival for both groups in 1994 was much lower than in the past two years (Table 16). In general temperatures and export levels were favorable, and flows were similar to those in 1992 but much lower than in 1993.

When Ryde and Georgiana Slough survival indices are compared as ratios, we see that without a barrier the ratios between years is very similar (Table 16). However, when the barrier is in place there is extreme variability in the ratio. It is likely that the environmental and export conditions during the time the barrier is in place drive this ratio.

Ocean recoveries also serve as an independent confirmation of these ratios in 1992. Ratios between the two groups generated from recoveries of the marked fish in the ocean fishery as adults also show that the

Ryde groups survived 2 to 7 times better than Georgiana Slough groups in 1992 and 1993 (Table 17).

Table 16. Coded wire tag survival indices for groups of smolts released at Georgiana Slough and Ryde, status of the Upper Old River barrier, river temperatures at time of release, and the ratio of survival between the paired groups.

| Release date | Survival Index Ryde | Temp. (°F) | Survival Index Georgiana Slough | Temp. (°F) | Ryde/Georgiana Slough Ratio |
|---|---|---|---|---|---|
| 4/6/92 (no barrier) | 1.36 | 64° | 0.41 | 64° | 3.3 |
| 4/14/92 (no barrier) | 2.15 | 63° | 0.71 | 64° | 3.0 |
| 4/27/92 (barrier) | 1.67 | 67° | 0.20 | 67° | 8.4 |
| 4/14/93 (no barrier) | 0.41 | 58° | 0.13 | 58° | 3.2 |
| 5/10/93 (no barrier) | 0.86 | 59° | 0.29 | 65° | 3.0 |
| 4/12/94 (no barrier) | 0.20 | 62.5 | 0.06 | 62 | 3.6 |
| 4/25/94 (barrier) | 0.18 | 62 | 0.11 | 62 | 1.6 |

Table 17. Ocean recovery rates of the Ryde and Georgiana Slough release groups of 1992, and the ratios (Ryde:Georgiana Slough) of these ocean recovery rates.

| Release date | Ocean Recovery Rates Ryde | Ocean Recovery Rates Georgiana Slough | Ocean Recovery Rate Ratio Ryde:Georgiana Slough |
|---|---|---|---|
| 4/6/92 | 0.0066 | 0.0028 | 2.4 |
| 4/14/92 | 0.0116 | 0.0045 | 2.6 |
| 4/27/92 | 0.0040 | 0.0006 | 6.7 |
| 4/14/93 | 0.0092 | 0.0033 | 2.8 |
| 5/10/93 | 0.0204 | 0.0056 | 3.6 |

Recoveries at the Salvage Facilities:

Recoveries at the state and federal facilities for the lower Old River groups were similar with and without the HOR barrier in place (Appendix 1). The CVP is located directly on Old River and may explain why greater numbers were recovered at that facility. Based on similar survival indices to Chipps Island (zero) and the similar but low recovery numbers at the facilities, it appears that in 1994, indirect mortality was very high in the south Delta, with or without a HOR barrier in place.

A few recoveries also were made at the fish salvage facilities from the first group released at Jersey Point (Appendix 1). Although Qwest was positive for both releases, it appears that even smolts at Jersey Point can be affected by south Delta exports, albeit to a lesser degree than upper San Joaquin or south Delta releases.

No Ryde or Georgiana Slough released fish were recovered at the fish salvage facilities.

Additional recoveries::

Recoveries were made from the first Georgiana Slough release (2), and the first and second Jersey Point releases (2 and 1, respectively) in fyke nets deployed by the Department of Fish and Game at the entrance of Contra Costa Canal. In addition, one fish was recovered from the April 11 lower Old River release, in a push net conducted in Rock Slough, which leads into the Contra Costa Canal.

One fish from the April 12th Ryde release and one from the April 25th Ryde release were captured in the midwater trawl in Montezuma Slough. Two recoveries from the second Jersey Point release also were made with this trawl. Although this does demonstrate that fish from both the Sacramento and San Joaquin Rivers are diverted into Montezuma Slough, no quantitative information can be extrapolated because the sampling in Montezuma Slough was only conducted over a fraction of the total period in which the tagged fish were moving out of the system.

Recoveries of these releases also were made in the beach seine survey at sites near or downstream of the release locations. One recovery of interest was a fish from the first Georgiana Slough release which was captured on the San Joaquin River at the east end of Venice Island (SJ026N, see Figure 2, page 3), over five miles upstream of the mouth of the Mokelumne River. This shows that with low outflow (San Joaquin River flows were about 1500 cfs during this period in 1994), fish migrating down the Mokelumne River can move upstream in the San Joaquin River where they then may be more susceptible to diversion into the south Delta. The presence of the HOR barrier may tend to increase outflow along this stretch of the San Joaquin River and minimize this upstream movement of Mokelumne/Sacramento basin smolts.

## San Joaquin Delta Experiments

Mossdale releases:

Four releases of approximately 50,000 smolts each at Mossdale (above the head of Old River) were made to evaluate survival of San Joaquin fall run with and without the presence of a HOR barrier.

The first Mossdale release was made on April 11, before the barrier was installed. Water temperature at release was 63 degrees, mean Vernalis flow was approximately 1500 cfs and exports were relatively low (average 1465 cfs) for the 15 days following the release (Table 15). Survival to Chipps Island of this release was zero as none of these fish were collected there. The barrier was installed on April 23, and the first barrier-present Mossdale release was made on April 26. Survival of this group increased to 0.04. Average flow at Vernalis was higher (2500 cfs) and temperatures were cooler for this release. Average exports were low for both releases but increased slightly following the second release.

A second barrier-present release was made at Mossdale on May 2. Water temperatures increased to 66 degrees, and average Vernalis flow and average exports dropped slightly from the previous release. None of these fish were recovered at Chipps Island and survival of this group was zero. A final Mossdale release was made on May 9, with water temperatures of 68 degrees and average Vernalis flows and exports similar to conditions during the May 2 release. Survival of this group was again very low (0.02). These low survival indices may indicate that even with a barrier present at the head of Old River, flow on the San Joaquin needs to be increased over the levels present in 1994 in order to provide conditions necessary for the successful outmigration of chinook smolts.

Perhaps the most distinct difference between the barrier-absent and barrier-present release groups is in the numbers recovered at the salvage facilities. Many more recoveries were made at the fish facilities from the Mossdale groups without the HOR barrier in place (Appendix 1). This seems to provide evidence that the barrier is successful in reducing direct mortality of smolts at the pumps. But, as observed above, it does not necessarily decrease overall mortality or increase survival to Chipps Island. Indirect losses apparently account for a larger percentage of the mortality when the barrier is in place, at least under the conditions present during the spring of 1994.

It should be noted that confidence in the true differences in survival between releases decreases when overall survival indices are very low as they were in 1994, as these estimates are based on just a few individual fish recovered at Chipps Island. Sampling variation can thus have a more dramatic effect on individual indices and their ratios.

When comparing the observed survival indices to those predicted by the San Joaquin Delta Salmon Smolt Survival Model (Brandes, 1994), we see that the model predicted survival without the HOR barrier in place very well, while it was somewhat less accurate with the barrier present (Table 18). The data used to develop the model did not include data obtained with the barrier in place, which may account for the reduced agreement under this condition.

Table 18. Head of Old River barrier status, observed mortality, mortality predicted by the San Joaquin Delta Salmon Smolt Survival model, and the difference between observed and predicted mortality of CWT releases at Mossdale in 1994.

| release date and location | HOR barrier | observed mortality | predicted mortality | observed - predicted |
|---|---|---|---|---|
| Apr 11 Mossdale | no | 1 | 0.94 | 0.06 |
| Apr 26 Mossdale | yes | 0.98 | 0.72 | 0.26 |
| May 2 Mossdale | yes | 1 | 0.78 | 0.22 |
| May 9 Mossdale | yes | 0.99 | 0.80 | 0.19 |

## Survival of Other Releases

Releases also were made at Benicia, downstream of the Delta, on May 10 and May 31 as controls, from which independent estimates of survival will be obtained from the recoveries of adults in the ocean fishery. These independent estimates will be used to later confirm the survival estimates obtained with the Chipps Island trawl.

Overall conditions for survival in the Sacramento and San Joaquin Deltas were not favorable in the spring of 1994. This is supported by low survival of other CWT groups released in other regions of the Sacramento and San Joaquin Rivers and Delta (Appendix 1).

Survival calculated for paired releases made in the tributaries of the San Joaquin River was low as well, with indices of 0.033 for the upper Tuolumne, 0.037 for the lower Tuolumne, 0.06 for the upper Merced, and 0.02 for the lower Merced. Again, it is difficult to discern true differences between groups when absolute survival estimates are so low, but the similarity in indices between the upper and lower groups within each tributary indicates that survival within each tributary was relatively high. Most mortality appeared to occur downstream in the Delta.

Releases at New Hope Landing on the Mokelumne River on May 10 and May 23, 1994, again yielded low survival indices of 0.11 and 0.18 respectively. This is much lower than measured in 1991 (1.63 and 0.45); and comparable to other poor survival years such as 1992 (0.14 and 0.06), and 1993 (0.27 and 0.11). Release temperatures of up to 68°F may have contributed to the poor 1994 indices.

On the Sacramento River side, survival of fish released at the Feather River Hatchery was generally very poor, including 0.00 for a release on May 2.

Releases made in Battle Creek on April 14 had a survival index of 0.13. This does not compare favorably with indices calculated for two similar releases in 1993 (both at 0.69) which was an above normal water year, but is similar to survival in 1990 (0.17), 1991 (0.21), and 1992 (0.12), all critical water years.

## Special Studies

Weekly sampling was conducted in Rock Slough, January to June to assist the Department of Fish and Game in evaluating juvenile salmon entrainment in the Contra Costa Canal. Pushnetting was chosen because the shallow, narrow channel was not suited for other types of trawls, and there were no good shores for beach seining. Although two salmon were captured, the slow speed of the pushnet did not appear to make it very efficient for catching fast moving salmonids in the middle of the channel.

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Appendix 1. 1994 coded wire tag release and recovery information, survival to Chipps Island, and salvage numbers at the CVP and SWP fish salvage facilities.

| RELEASE INFORMATION | | | | | | | RECOVERED AT CHIPPS | | | | | | SALVAGED AT FACILITIES ** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LOCATION | TAG CODE | DATE | RACE | # OF FISH | MEAN FL (mm) | TEMP | 1ST CATCH | LAST CATCH | # OF FISH | SAMPLE MIN | % TIME SAMP | SURVIVAL | SWP raw | SWP expanded | CVP raw | CVP expanded | SWP Predator | CVP Predator |
| **Delta Releases:** | | | | | | | | | | | | | | | | | | |
| Georgiana Slough* | 06-45-21 | 02-Dec-93 | late fall | 33668 | 119 | 51 | 12-Dec-93 | 04-Mar-94 | 5 | 8357 | 0.07 | 0.276 | 17 | 79 | 14 | 168 | 14 | 3 |
| Ryde* | 06-45-22 | 02-Dec-93 | late fall | 34929 | 129 | 50.5 | 06-Dec-93 | 16-Mar-94 | 37 | 10553 | 0.07 | 1.898 | 2 | 10 | 0 | 0 | 5 | 0 |
| Miller Park | 06-31-42 | 03-May-94 | fall | 53232 | 83 | 67 | 07-May-94 | 15-May-94 | 4 | 1800 | 0.14 | 0.070 | 0 | 0 | 0 | 0 | 0 | 0 |
| Miller Park | 06-31-45 | 24-May-94 | fall | 50156 | 91 | 67 | | | 0 | | | 0.000 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ryde | 06-01-14-04- | 12-Apr-94 | fall | 51819 | 76 | 62.5 | 19-Apr-94 | 01-May-94 | 11 | 2600 | 0.14 | 0.199 | 0 | 0 | 0 | 0 | 0 | 0 |
| Georgiana Slough | 6-01-14-04-0 | 12-Apr-94 | fall | 51485 | 77 | 62 | 20-Apr-94 | 25-Apr-94 | 3 | 1200 | 0.14 | 0.055 | 0 | 0 | 0 | 0 | 0 | 0 |
| Jersey Point | 6-01-14-04-0 | 13-Apr-94 | fall | 50689 | 72 | 64 | 23-Apr-94 | 03-May-94 | 10 | 2200 | 0.14 | 0.185 | 3 | 4 | 1 | 12 | 0 | 0 |
| Lower Old R. | 6-01-14-03-1 | 11-Apr-94 | fall | 50032 | 74 | 62 | | | 0 | | | 0.000 | 6 | 10 | 7 | 84 | 0 | 0 |
| Ryde | 6-01-14-04-0 | 25-Apr-94 | fall | 56139 | 76 | 62 | 27-Apr-94 | 11-May-94 | 11 | 3000 | 0.14 | 0.183 | 0 | 0 | 0 | 0 | 0 | 0 |
| Georgiana Slough | 6-01-14-04-0 | 25-Apr-94 | fall | 50235 | 73 | 62 | 03-May-94 | 20-May-94 | 6 | 3600 | 0.14 | 0.112 | 0 | 0 | 0 | 0 | 0 | 0 |
| Jersey Point | 6-01-14-04-0 | 27-Apr-94 | fall | 53810 | 78 | 63 | 02-May-94 | 22-May-94 | 16 | 4200 | 0.14 | 0.278 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lower Old R. | 6-01-14-04-0 | 26-Apr-94 | fall | 50259 | 76 | 62 | | | 0 | | | 0.000 | 9 | 11 | 6 | 72 | 1 | 0 |
| Mossdale (w/o bar.) | 6-01-14-03-1 | 11-Apr-94 | fall | 51084 | 74 | 63 | | | 0 | | | 0.000 | 43 | 100 | 48 | 648 | 8 | 1 |
| Mossdale (w/ bar.) | 6-01-14-04-0 | 26-Apr-94 | fall | 50726 | 77 | 60 | 11-May-94 | 14-May-94 | 2 | 800 | 0.14 | 0.037 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mossdale (w/ bar.) | 06-31-41 | 02-May-94 | fall | 51632 | 82 | 66 | | | 0 | | | 0.000 | 3 | 42 | 1 | 12 | 0 | 0 |
| Mossdale (w/ bar.) | 06-31-43 | 09-May-94 | fall | 53880 | 89 | 68 | 22-May-94 | 22-May-94 | 1 | 200 | 0.14 | 0.017 | 3 | 13 | 0 | 0 | 0 | 0 |
| **Feather River:** | | | | | | | | | | | | | | | | | | |
| Feather River | 6-01-06-01-0 | 02-May-94 | fall | 100377 | 81 | N/A | | | 0 | | | 0.000 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Molelumne River:** | | | | | | | | | | | | | | | | | | |
| New Hope Landing | 06-48-03 | 10-May-94 | fall | 53606 | 87 | 68 | 15-May-94 | 26-May-94 | 5 | 2360 | 0.14 | 0.089 | 2 | 13 | 1 | 1 | 0 | 0 |
| New Hope Landing | 06-48-04 | 10-May-94 | fall | 49864 | 92 | 68 | 15-May-94 | 31-May-94 | 6 | 3160 | 0.13 | 0.121 | 1 | 18 | 1 | 12 | 1 | 0 |
| total | | | | 103470 | | | 15-May-94 | 31-May-94 | 11 | 3160 | 0.13 | 0.107 | 4 | 31 | 1 | 12 | 1 | 0 |
| New Hope Landing | 06-48-01 | 23-May-94 | fall | 51314 | 96.5 | 67 | 27-May-94 | 31-May-94 | 9 | 1000 | 0.14 | 0.164 | 0 | 0 | 0 | 0 | 0 | 0 |
| New Hope Landing | 06-48-02 | 23-May-94 | fall | 51418 | 95.5 | 67 | 27-May-94 | 06-Jun-94 | 10 | 2200 | 0.14 | 0.182 | 2 | 2 | 0 | 0 | 0 | 0 |
| total | | | | 102732 | | | 27-May-94 | 06-Jun-94 | 19 | 2200 | 0.14 | 0.173 | 2 | 2 | 0 | 0 | 0 | 0 |
| **Upper Sacramento River:** | | | | | | | | | | | | | | | | | | |
| ***Below Red Bluff | 5-01-01-09-0 | 10-Mar-94 | fall fry | 54191 | 40-60 | N/A | 25-Apr-94 | 29-Apr-94 | 2 | 1000 | 0.14 | 0.035 | 0 | 0 | 0 | 0 | 0 | 0 |
| ***Below Red Bluff | 5-01-01-09-0 | 10-Mar-94 | fall fry | 57084 | 40-60 | N/A | 23-Apr-94 | 28-Apr-94 | 3 | 1200 | 0.14 | 0.049 | 0 | 0 | 0 | 0 | 0 | 0 |
| total | | | | 111275 | | | 23-Apr-94 | 29-Apr-94 | 5 | 1400 | 0.14 | 0.042 | | | | | | |
| CNFH | 05-34-27 | 14-Apr-94 | fall | 54892 | 64 | N/A | 28-Apr-94 | 01-May-94 | 2 | 800 | 0.14 | 0.034 | 0 | 0 | 0 | 0 | 0 | 0 |
| CNFH | 05-34-28 | 14-Apr-94 | fall | 53430 | 71 | N/A | 28-Apr-94 | 04-May-94 | 8 | 1400 | 0.14 | 0.140 | 0 | 0 | 0 | 0 | 0 | 0 |
| CNFH | 05-34-29 | 14-Apr-94 | fall | 52483 | 76 | N/A | 24-Apr-94 | 08-May-94 | 12 | 3000 | 0.14 | 0.214 | 0 | 0 | 0 | 0 | 0 | 0 |
| total | | | | 160805 | | | 24-Apr-94 | 08-May-94 | 22 | 3000 | 0.14 | 0.128 | 0 | 0 | 0 | 0 | 0 | 0 |

FL = Fork Length, N/A = Not Available,

* Each of these recovery distributions had a single outlier recovery in March. The rest of the recoveries were made in December. Excluding the March outliers, the resulting indices would be 0.11 for Georgiana Slough (4 total recoveries), and 1.15 for Ryde (36 total recoveries).

** Chinook collected as predator removal or other special studies are reported separately

*** Number of fish released not adjusted for tag retention rates

Appendix 1 - - continued

| RELEASE INFORMATION | | | | | | | RECOVERED AT CHIPPS | | | | | | SALVAGED AT FACILITIES** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LOCATION | TAG CODE | DATE | RACE | # OF FISH | MEAN FL(mm) | TEMP | 1ST CATCH | LAST CATCH | # OF FISH | SAMPLE MIN | % TIME SAMP | SURVIVAL | SWP raw | SWP expanded | CVP raw | CVP expanded | SWP Predator | CVP Predator |
| **San Joaquin River basin:** | | | | | | | | | | | | | | | | | | |
| Merced hatchery | 6-01-11-02-1 | 22-Apr-94 | fall | 28315 | 88 | 51 | 01-May-94 | 02-May-94 | 2 | 400 | 0.14 | 0.066 | 2 | 2 | 2 | 24 | 1 | 0 |
| Merced hatchery | 6-01-11-02-1 | 22-Apr-94 | fall | 25328 | 88 | 51 | 01-May-94 | 01-May-94 | 1 | 200 | 0.14 | 0.037 | 1 | 1 | 4 | 48 | 0 | 0 |
| Merced hatchery | 6-01-11-02-1 | 22-Apr-94 | fall | 28532 | 88 | 51 | 01-May-94 | 08-May-94 | 2 | 1600 | 0.14 | 0.066 | 3 | 3 | 2 | 24 | 1 | 0 |
| Merced hatchery | 6-01-11-02-1 | 22-Apr-94 | fall | 17390 | 88 | 51 | 15-May-94 | 15-May-94 | 1 | 200 | 0.14 | 0.054 | 0 | 0 | 2 | 24 | 0 | 0 |
| total | | | | 99565 | | | 01-May-94 | 15-May-94 | 6 | 3000 | 0.14 | 0.056 | 8 | 8 | 10 | 120 | 2 | 0 |
| Lower Merced | 6-01-11-02-1 | 22-Apr-94 | fall | 35017 | 87 | 62 | | | 0 | | | 0.000 | 2 | 2 | 2 | 24 | 0 | 0 |
| Lower Merced | 6-01-11-02-1 | 22-Apr-94 | fall | 23324 | 87 | 62 | 01-May-94 | 03-May-94 | 2 | 600 | 0.14 | 0.080 | 3 | 6 | 4 | 48 | 0 | 0 |
| Lower Merced | 6-01-11-03-0 | 22-Apr-94 | fall | 23750 | 87 | 62 | | | 0 | | | 0.000 | 0 | 0 | 0 | 0 | 0 | 0 |
| total | | | | 82091 | | | 01-May-94 | 03-May-94 | 2 | 600 | 0.14 | 0.023 | 5 | 8 | 6 | 72 | 0 | 0 |
| Upper Tuolumne | 6-01-11-03-0 | 23-Apr-94 | fall | 58859 | 85 | 51 | 05-May-94 | 14-May-94 | 2 | 2000 | 0.14 | 0.032 | 2 | 7 | 1 | 12 | 0 | 0 |
| Upper Tuolumne | 6-01-11-03-0 | 23-Apr-94 | fall | 4281 | 85 | 51 | 12-May-94 | 12-May-94 | 1 | 200 | 0.14 | 0.219 | 3 | 40 | 1 | 12 | 0 | 0 |
| Upper Tuolumne | 6-01-11-03-0 | 23-Apr-94 | fall | 20274 | 85 | 51 | | | 0 | | | 0.000 | 2 | 4 | 0 | 0 | 0 | 0 |
| total | | | | 83414 | | | 05-May-94 | 14-May-94 | 3 | 2000 | 0.14 | 0.033 | 6 | 33 | 2 | 24 | 0 | 0 |
| Lower Tuolumne | 6-01-11-03-0 | 24-Apr-94 | fall | 36429 | 82 | 62 | 06-May-94 | 06-May-94 | 1 | 200 | 0.14 | 0.026 | 0 | 0 | 4 | 48 | 0 | 0 |
| Lower Tuolumne | 6-01-11-03-0 | 24-Apr-94 | fall | 13626 | 82 | 62 | 08-May-94 | 08-May-94 | 1 | 200 | 0.14 | 0.069 | 2 | 14 | 2 | 24 | 0 | 0 |
| total | | | | 50055 | | | 06-May-94 | 08-May-94 | 2 | 600 | 0.14 | 0.037 | 2 | 14 | 6 | 72 | 0 | 0 |
| **Upper Sacramento River:** | | | | | | | | | | | | | | | | | | |
| Caldwell Park | 5-01-01-09-0 | 27-Jan-94 | winter | 4699 | 74 | N/A | 21-Apr-94 | 21-Apr-94 | 1 | 200 | 0.14 | 0.199 | 0 | 0 | 0 | 0 | 0 | 0 |
| CNFH | 05-33-16 | 03-Jan-94 | late fall | 52984 | 129 | N/A | 18-Jan-94 | 18-Mar-94 | 15 | 5358 | 0.06 | N/A | 6 | 25 | 4 | 48 | 3 | 2 |
| CNFH | 05-33-17 | 03-Jan-94 | late fall | 55231 | 122 | N/A | | | 0 | | | | 1 | 4 | 1 | 12 | 3 | 0 |
| CNFH | 05-34-08 | 03-Jan-94 | late fall | 87645 | 134 | N/A | 31-Jan-94 | 09-Mar-94 | 11 | 3358 | 0.06 | N/A | 4 | 8 | 3 | 36 | 0 | 2 |
| CNFH | 05-34-09 | 03-Jan-94 | late fall | 72236 | 130 | N/A | 31-Jan-94 | 25-Feb-94 | 8 | 2362 | 0.06 | N/A | 1 | 4 | 4 | 48 | 0 | 2 |
| total | | | | 248096 | | | 18-Jan-94 | 18-Mar-94 | 34 | | | | 12 | 41 | 12 | 144 | 3 | 6 |
| CNFH | 05-34-11 | 04-Jan-94 | late fall | 78506 | 124 | N/A | 31-Jan-94 | 09-Mar-94 | 7 | 3358 | 0.06 | N/A | 1 | 2 | 2 | 24 | 1 | 0 |
| CNFH | 05-34-12 | 04-Jan-94 | late fall | 69894 | 129 | N/A | 02-Feb-94 | 18-Mar-94 | 6 | 3958 | 0.06 | N/A | 6 | 18 | 2 | 24 | 0 | 0 |
| CNFH | 05-34-13 | 04-Jan-94 | late fall | 78561 | 136 | N/A | 28-Jan-94 | 07-Mar-94 | 22 | 3362 | 0.06 | N/A | 3 | 18 | 7 | 84 | 1 | 1 |
| CNFH | 05-34-14 | 04-Jan-94 | late fall | 65609 | 128 | N/A | 02-Feb-94 | 23-Feb-94 | 3 | 1962 | 0.06 | N/A | 5 | 12 | 2 | 24 | 0 | 1 |
| total | | | | 292570 | | | 28-Jan-94 | 18-Mar-94 | 38 | | | | 15 | 50 | 13 | 156 | 2 | 2 |
| CNFH | 05-34-10 | 05-Jan-94 | late fall | 73882 | 127 | N/A | 07-Feb-94 | 15-Mar-94 | 7 | 3171 | 0.06 | N/A | 2 | 5 | 0 | 0 | 1 | 0 |
| CNFH | 05-34-15 | 05-Jan-94 | late fall | 54248 | 123 | N/A | 28-Jan-94 | 15-Mar-94 | 13 | 3958 | 0.06 | N/A | 2 | 3 | 12 | 144 | 0 | 5 |
| total | | | | 128130 | | | 28-Jan-94 | 15-Mar-94 | 20 | | | | 4 | 8 | 12 | 144 | 1 | 5 |