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ABUNDANCE AND SURVIVAL

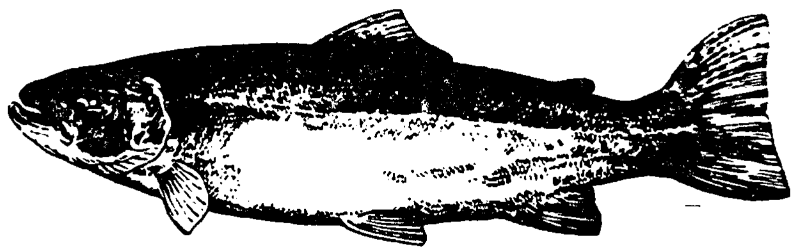
OF

JUVENILE CHINOOK SALMON

IN THE

SACRAMENTO-SAN JOAQUIN

ESTUARY



1991 ANNUAL PROGRESS REPORT

FY 91 WORK GUIDANCE

JUNE, 1992

SACRAMENTO-SAN JOAQUIN ESTUARY

FISHERY RESOURCE OFFICE

U.S. FISH & WILDLIFE SERVICE

STOCKTON, CALIFORNIA

WRINT-USFWS-9

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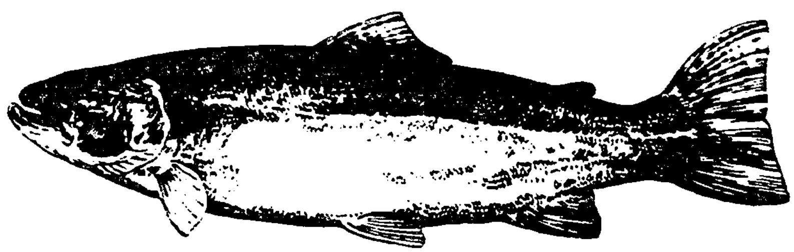

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1991 Annual Report

Sacramento/San Joaquin Estuary Fishery Resource Office

U.S. Fish and Wildlife Service

I. Introduction

Work in 1991 by the Sacramento/San Joaquin Estuary Fishery Resource Office, was conducted to update and refine our knowledge of the factors influencing young salmon abundance, distribution and survival in the Sacramento/San Joaquin Estuary. This information is being used to develop recommendations to water users and the State Water Resources Control Board on how impacts from the present operation of the Delta can be lessened.

During 1991 special emphasis was placed on broadening our understanding of salmon smolt survival through the San Joaquin Delta and specifically how a barrier in the South Delta at Upper Old River could improve San Joaquin salmon smolt survival.

Overall objectives of the Interagency Salmon Study are to:

1. Monitor the abundance of fry and smolt chinook salmon rearing and migrating through the Delta.

2. Determine the impacts ~~of~~ of water development within the Delta on the abundance, distribution and survival of juvenile fall run salmon.

3. Identify management measures that could lessen the impacts of water project operations on salmon using the Delta and lower embayments of the Estuary.

Elements of the Study in 1991 were:

- Continue our Beach Seining survey to estimate the abundance of fall run fry January through March as in past years.
- Continue our midwater trawl surveys in the North Delta (Sacramento) and Chipps Island to estimate the abundance of fall run smolts both entering and leaving the Sacramento Delta and Central Valley respectively.
- Use mark and recapture studies to determine the survival of fall run smolts under varied environmental conditions.

Specific questions were:

a. What is the survival of fish released in the Sacramento River under extremely low flow conditions and low temperatures?

b. Where is the greatest mortality taking place in the South Delta?

c. Could a barrier placed at the head of Upper Old River increase smolt survival through the San Joaquin Delta?

d. What is the role of exports on survival with and without a barrier in place?

e. What is the impact of bringing more water to the export pumps via Lower Old and Middle Rivers with such a barrier in place on both the Sacramento and San Joaquin basin fish migrating through the South and Central Delta?

- Use data generated by the ocean fishery to confirm past conclusions based on trawl recovery information.

II. Program Elements

SACRAMENTO RIVER DELTA

Fry Abundance

Abundance of fall run fry in the North and Central Delta was extremely low during January - March of 1991, and the lowest we have observed since 1977 (Table 1). The 1991 North Delta data continues to support past findings that fry abundance in the North Delta in general decreases as inflow to the Delta declines (Figure 1).

Table 1. Average catch per seine haul of Chinook salmon fry in the Northern and Central Delta and Lower Sacramento River, January through April, 1977 through 1991.

FALL RUN

Northern Year	Central Delta	Lower Delta	Sacramento
1991*	3	3	32
1990*	31	4	11
1989*	11	4	25
1988*	11	5	9
1987*	14	4	18
1986	30	10	27
1985	10	3	2
1984	11	4	9
1983	39	9	30
1982	21	4	23
1981	12	2	23
1980	17	2	ns
1979	33	6	ns
1978	16	ns	ns
1977	0.4	ns	ns
n =	12	9	7

n = The number of seining stations in respective areas of the Delta or Sacramento River.

* = January through March sampling period.

ns = Not sampled.

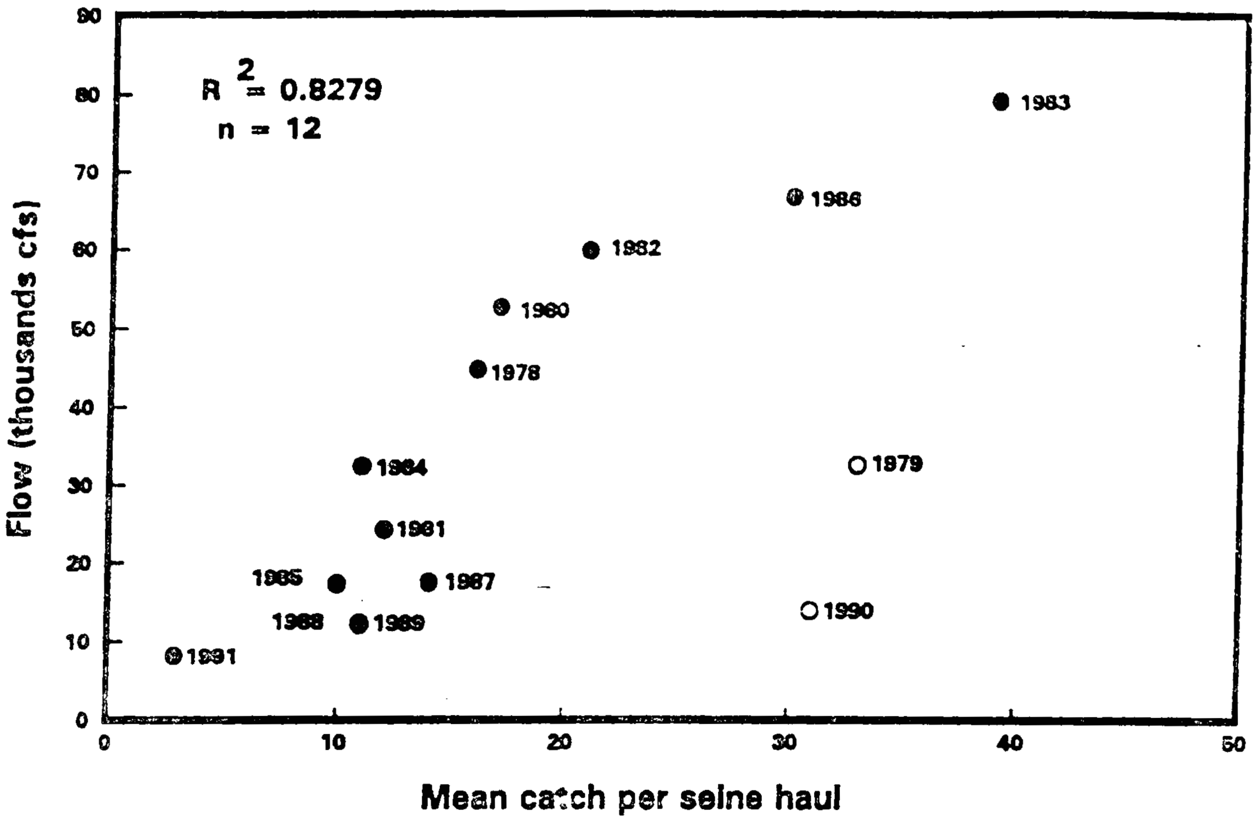

Figure 1. Mean chinook fry catch per seine haul in the North Delta versus mean Feburary Sacramento River flow at Freeport. ○ Outlier values were not used in regression calculation.

In 1991 our abundance index in the Lower Sacramento River was the highest ever measured since the sampling began there in 1981. This estimate was high mainly due to an unusually high catch of 648 fry at one of our stations (Ward's Landing) on March 20. Catches in all areas of the Delta and at most stations increased during March after heavy storms and precipitation increased river flows around the 5th and 6th of March. Presumably the fry recovered in late March in the Lower Sacramento River area entered into the North Delta after our seining concluded on March 22 or moved through the North Delta later in the season as smolts.

The data appears to show that the majority of fall run salmon fry in 1991 remained and reared upstream until the flows increased in March (Figure 2). This conclusion is further supported by the change in mean size of salmon fry in our beach seining catches over time (Figure 3). Generally there were two fry populations present in 1991, with the first group entering the Delta with a slight increase in flow in early February, at an average size of about 38 millimeters. These fry grew to an average size of about 53 millimeters by the first of March. The second group of small fry (also around 38 millimeters) entered the Delta after the large increase in flow in early March and increased in size to about 48 mm by the end of March.

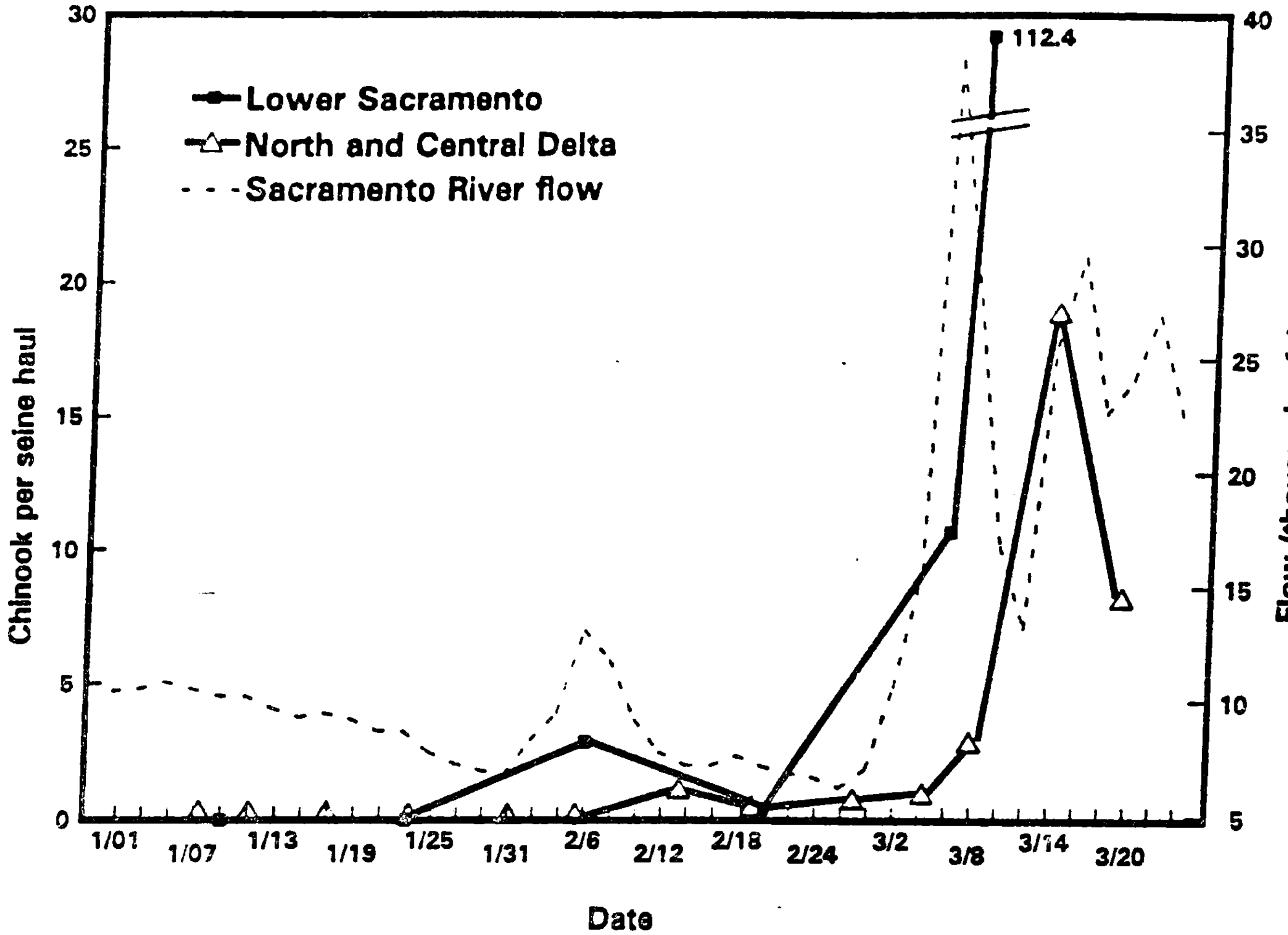

Figure 2. Chinook fry captured per seine haul during beach seining at three areas in the Delta and Lower Sacramento River in 1991. North and Central Delta catches were combined and averaged. Mean daily river flow was measured at Freeport from January 1 to March 24, 1991.

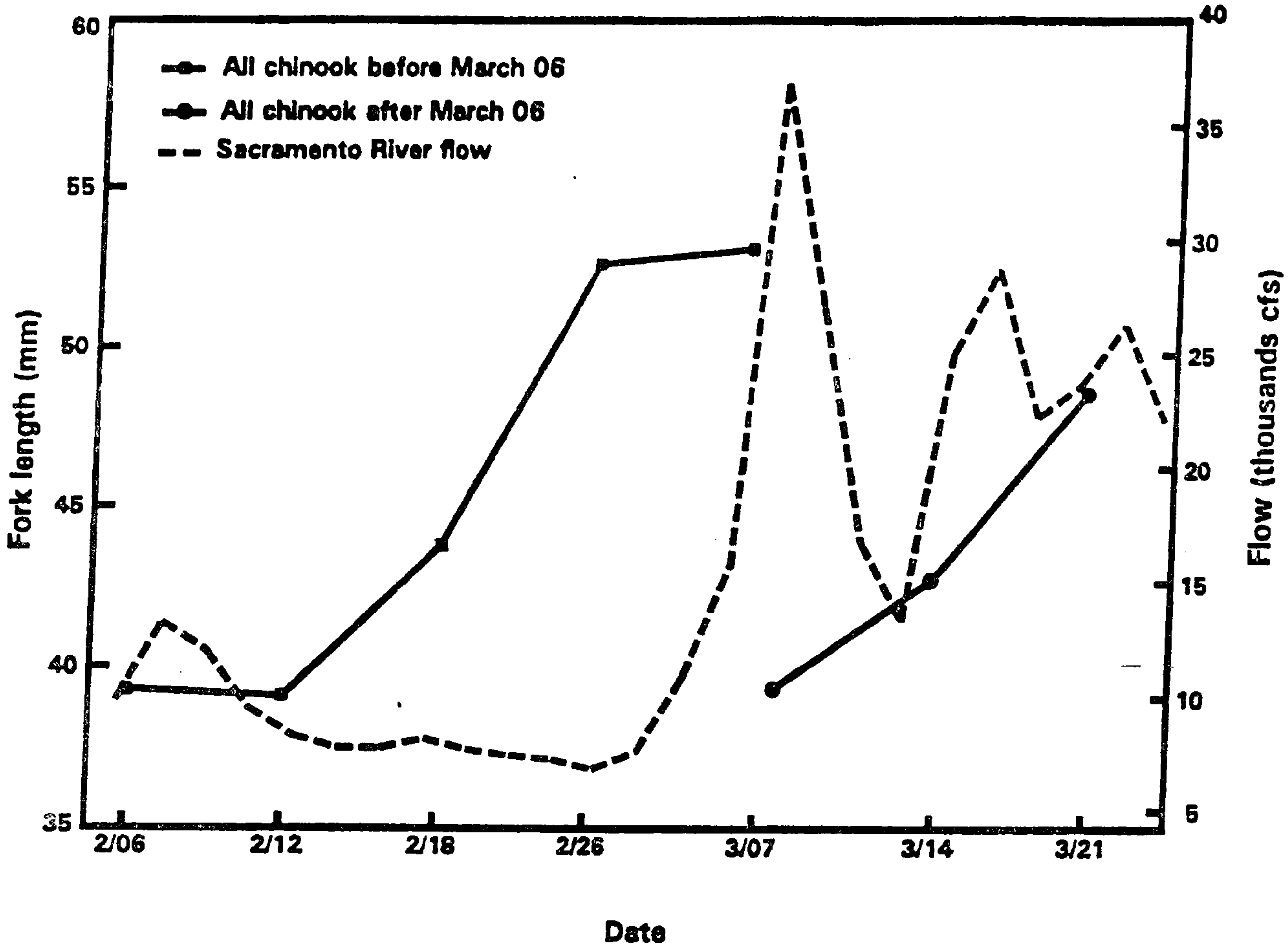

Figure 3. Mean fork length of chinook captured in all areas of the 1991 beach seining survey. Winter-run chinook were excluded from length calculations. Mean daily river flow was measured at Freeport (DAYFLOW).

During February and March of 1991 about 11 million fry from Coleman National Fish Hatchery were released at various locations in the Upper Sacramento River. It would be helpful in understanding the behavior of both the "natural" and hatchery fish if it was possible to separate out the two stocks in our sampling. In the future marking at least part of this production may help us to identify the "natural" and hatchery components.

It is very difficult to assess the absolute abundance of fry within the Delta and their relative significance to the total production of the Central Valley. From December of 1991 until June of 1992 a pilot program will be initiated to answer this question by indexing all the fall run production (both fry and smolts, concurrently) moving into the Sacramento Delta over the course of the season. By estimating the number of fry and smolts passing by Sacramento over the entire season, and by estimating the differential survival between smolts and fry we will attempt to determine the significance of the Delta on each life stage.

Fry Survival

During 1991, no marked fry were released in the Delta in order to increase the number of marked smolts available for release during April and May. However, ocean recovery rates from fry released in past years are provided in Appendix 1.

Smolt Abundance

Abundance at Sacramento

In 1991, a fourth year of trawling in the North Delta was done on the Sacramento River about five miles downstream of Miller Park, the same site used in 1988 and 1989. The sampling site in 1990 was near the town of Courtland, about 21 miles closer to Chipps Island, than the Miller Park site.

Approximately ten, 20 minute tows were made 3 times per week between April 15 and June 12 to index the number of smolts migrating into the Sacramento Delta.

The annual mean (fish per 20 minute tow) of salmon smolts passing Sacramento in 1991 was 41.6, about one-half that observed in 1988 and 1989, but greater than that observed in 1990 (Table 2). We would perhaps expect to see a greater number at Sacramento than at Courtland (1990 trawling site) because the fish experience some mortality as they migrate downstream from Sacramento to Courtland. We also believe that the estimate in 1990 was low because we inadequately sampled the Coleman fish as they were passing Courtland that year.

Table 2. Mean catch of salmon smolts per 20 minute tow at Sacramento during April through June of 1988 through 1991 and at Courtland in 1990.

Year	April	May	June	Annual Mean 1/
1991	59.3	60.9	4.8	41.6
1990	26.3	43.3	10.9	30.7
1989	22.0	137.3	6.4	80.0
1988	27.4	208.4	4.8	80.1

1/ Annual mean = Index for April, May, and June divided by 3

This would indicate that in general, smolt abundance in 1991 was less than in the last few years. Considering both low Sacramento basin escapement in the fall of 1990 and the continued drought conditions this is not surprising.

In 1991 we estimated the absolute abundance of smolts passing Sacramento, based on the efficiency of our trawl and the number of unmarked fish caught in our trawl during our sampling season.

We estimated the efficiency of our trawl by recovering fish in our Sacramento trawl that were released at Miller Park. Although we only released two groups at Miller Park in 1991, we actually used four unique tag codes (two codes per release group). Our efficiency estimates are based on the recovery of the two tag codes released at Miller Park on April 25. We restricted ourselves to these two codes because our sampling effort was not as great for the group released on the 29th.

Recoveries were only used that occurred on the 26th of March and we assumed the majority of fish were vulnerable to our trawl on that day.

We also took into account our sampling effort (180 minutes) on March 26, which was 12.5% of the total number of minutes that day (1440). Dividing the number of fish recovered from each tag group by y, where y = the number released times the fraction of time sampled (.125), we estimated the efficiency of the Sacramento trawl to be .0064.

Following the same methodology we used for expanding our Chipps Island catch (Appendix 12, p. 125, USFWS Exhibit 31, 1987) results in an absolute estimate at Sacramento of around 33 million smolts.

This is the first year we have made these estimates. However, if you assume the efficiency of our trawl is the same between years, it would be possible to estimate absolute estimates for past years.

Additional efficiency work is also warranted to confirm our absolute abundance estimates.

Because there is considerable variability in our catches between days at Sacramento, sampling only 3 days per week may not be adequate to estimate absolute numbers. We have been limited by the numbers of available Interagency boat operator personnel and are exploring the possibilities of obtaining a smaller trawling or push net vessel to use at Sacramento that both our boat operator staff as well as biologists could operate.

The distribution of fish recovered at Sacramento in 1991 is shown in Figure 4. We found a greater percentage of the total

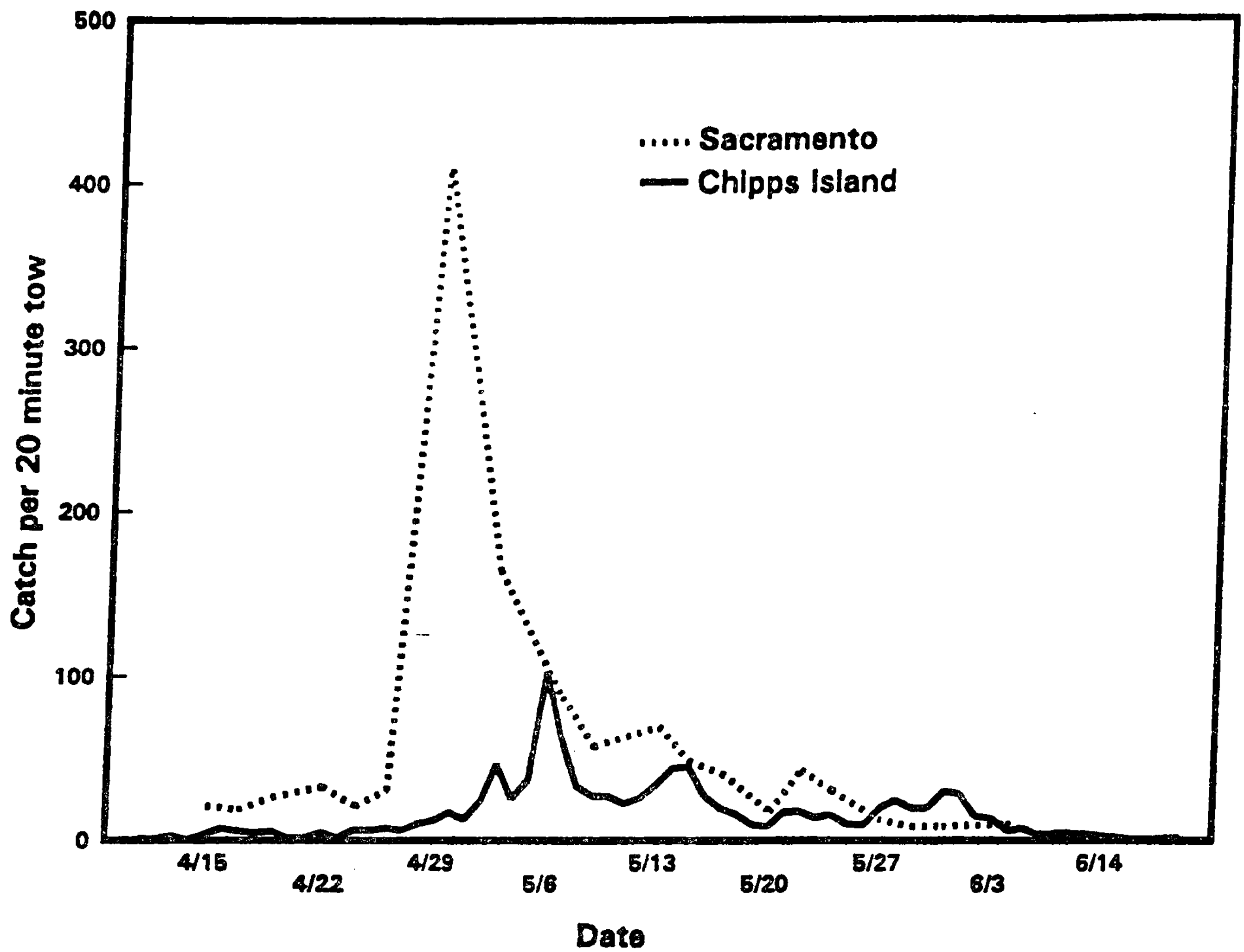

Figure 4. Catch per 20 minute tow of unmarked smolts passing at Sacramento and Chipps Island in 1991.

production migrating in April (Table 3) than in past years and is undoubtedly due to approximately 6 million smolts released at Princeton between April 22 and May 6. The peak of these hatchery fish were observed on April 29 and was 409.8 fish per 20 minute tow.

Knowing when the peak influx of smolts enter the Delta is critical to evaluating the benefit of varied salmon protective measures and to scheduling implementation of the measure.

It was interesting to note that a total of 8 CW1/2T smolts were recovered at Sacramento that were released as fry on March 4 and 8 at Coleman National Fish Hatchery and Red Bluff Diversion Dam, respectively. We recovered them between April 15, our first day of trawling at that site for the season and May 3, which would indicate that perhaps some of these fry had migrated past our trawling site before April 15. Additional sampling at Sacramento in 1992 may allow us to better track when up river released marked fry are moving into the Delta and perhaps estimate survival for them as a group. Inferences could also be made about the survival of unmarked fry released from Coleman NFH and their relative contribution to the production.

Abundance at Chipps Island

Table 3. Distribution (percent) of total midwater trawl catch of Chinook smolts by month at Sacramento from 1988 through 1991 and at Courtland in 1990.

Year	April	May	June
1991	47	49	4
1990	33	54	13
1989	6	91	3
1988	14	83	3
$\overline{X}$ (1988-1991)	26	68	6

The mean catch/per 20 minute tow at Chipps Island for April, May and June of 1991 was 14, 72 and 12, respectively. The annual index was 12.5. The lowest index observed since 197~~8~~ was 10 in 1984 and the highest was 48 in 1983.

The annual index in 1991 was lower than that obtained in 1989 and 1990 (19 and 20 fish per tow, respectively) and similar to that obtained in 1988 (12 fish per tow). All four years have been dry or critical water year types.

The comparison of indices at Chipps Island and Sacramento in 1989 and 1991 supports the conclusion that abundance at both sites was lower, by about half, in 1991 of what it was in 1989 (Table 4).

The catch distribution over time at Chipps Island also is provided in Figure 4. The majority of fish passed Chipps Island in May (72%) and the least in June (12%) (Table 5). In June of 1990 and 1991, we had more outmigrants passing Chipps Island than we had in recent past years. Temperatures in early June of 1990 and 1991 were somewhat more favorable (66°F and 68°F, respectively for June 4th of both years) and may have allowed the protracted migration to occur.

Since 1985, we have found a smaller percentage of the annual number of outmigrants in June and a greater percent in April (Table 5 and Figure 5). This may be due to the fact the warmer,

Table 4. Smolt Abundance indices at Sacramento and Chipps Island from 1988 to 1991.

	Sacramento	Chipps Island
1988	80	12
1989	80	19
1990	31*	20
1991	42	12

* Actual sampling site was Courtland in 1990.

Table 5. Distribution (percent) of total midwater trawl catch of chinook smolts by month at Chipps Island from 1978 to 1991.

Year	April	May	June
1978	27	40	33
1979	19	52	29
1980	14	34	52
1981	34	50	16
1982	18	49	33
1983	19	49	32
1984	11	66	23
1985	26	63	11
1986	37	55	8
1987	44	54	2
1988	27	70	3
1989	29	62	9
1990	31	56	12
1991	14	72	12
$\bar{x}$ (1978-1991)	26	54	20

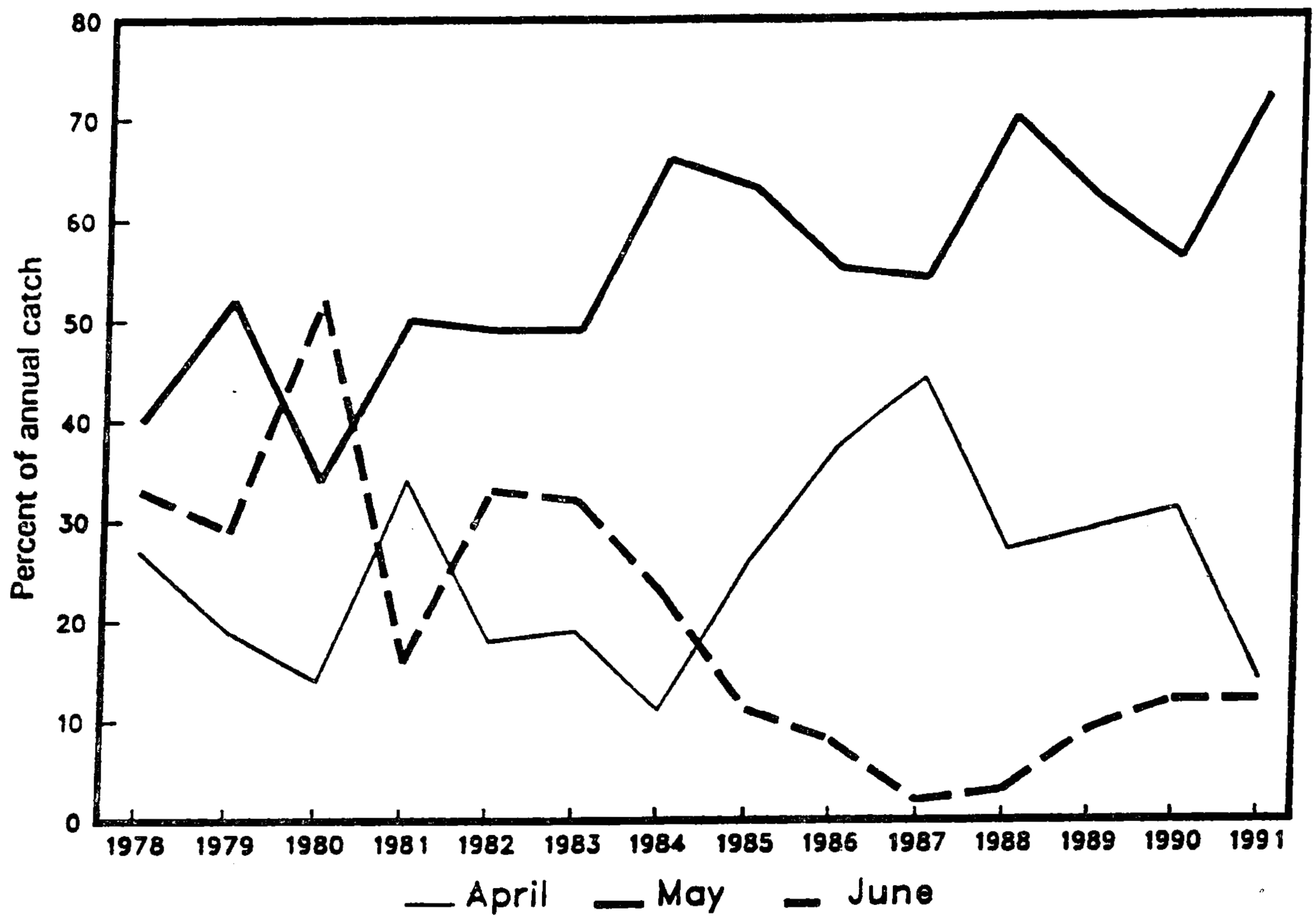

Figure 5: Percent of Chipps Island Catch by month between 1978 to 1991.

drier years which account for 6 out of the last 7 years, cause fish to grow faster and thus migrate out sooner, or perhaps the fish that historically migrated later are having high mortality and thus have been genetically removed from the population. The primary reason appears to be that the mass release of Coleman hatchery fish beginning in 1985 shifted the hatchery release schedule to earlier in May and in 1991 to late in April.

Absolute Smolt Production

We estimated the total number of fall-run smolts passing Chipps Island from April through June in 1991 to be about 17 million (See Appendix 12, p. 125, USFWS Exhibit 31 for methods), which was somewhat less than that estimated in 1989 and 1990 (21 million). Average efficiency of the Chipps Island trawl for years 1980 to 1984 was .0055. This value is used in calculating absolute abundance and compares to a value of .0068 for the Sacramento trawl.

Since our sampling at Chipps Island began in 1978, we have found our lowest measure of absolute smolt abundance in 1984 (12 million) and the highest measure in 1983 (53 million). If our estimate of smolt survival to adult in the ocean fishery is approximately 2% then the number of adults in the ocean fishery from the 1991 Central Valley juvenile outmigration would be around 340,000. Between 1980 and 1990, Central valley stocks have averaged 365,000 fish in the ocean fishery (Central Valley Salmon and Steelhead Restoration and Enhancement Plan, 1990). Fall run accounts for about 80% of the total Central Valley escapement (Central Valley Salmon and Steelhead Restoration and Enhancement Plan, 1990), (Appendix 2), thus we would estimate that about 300,000 of the ocean catch was from fall run stocks.

However, our estimate at Chipps Island does not include any juveniles reared at Feather and American River hatcheries and released downstream of the Delta, thus we are either overestimating the number of juveniles at Chipps Island or the survival rate in the ocean is actually lower than estimated. Ocean recovery estimates for fish released at Port Chicago has ranged between .3 to 3 percent from 1978 to 1988 reflecting the full variability (Appendix 3).

It is important to note that releasing hatchery fish downstream of the Delta since the early 80's has allowed escapement back to the American and Feather Rivers to be relatively stable over time (Appendix 4 and 5). Only the first 2 years (1987 and 1988) of the 6 year drought has been exhibited by the generally lower returning adult populations in 1989 and 1990.

Coleman National Fish Hatchery has been able to increase their production which is reflected by the larger returns to Battle Creek in the last few years (Appendix 6). The Sacramento River naturally spawning populations are experiencing significant reductions in escapement and production since the 1950's and 60's (Appendix 2 and 7).

Smolt Survival-Unmarked Fish

Our trawling at Sacramento began on April 15 and we estimated a total of 33 million smolts at that site. We also estimated 17 million smolts at Chipps Island and if we assume very few of the smolts at Chipps Island are the result of fry rearing in the Delta (substantiated by our low North Delta beach seine index), and few are the result of production in the San Joaquin basin, then we estimate average survival through the Delta for the season to be 52 percent.

Most likely very few of the smolts recovered at Chipps Island were from the San Joaquin basin as the 1990 escapement in the San Joaquin basin accounted for less than 1 percent of the total fall run Central Valley escapement (Appendix 8).

"Natural" Smolt Migration Rate

Migration rate was estimated in 1991 for the unmarked "natural" smolts migrating from Sacramento to Chipps Island. We estimated that the unmarked "natural" smolts migrated between those two locations at about 5.5 miles/day. This was calculated based on the early apparent peaks at Sacramento on 4/22 and at Chipps Island on 5/3 (Figure 4).

Unmarked Hatchery Smolt Migration Rate

About 6,600,000 unmarked hatchery smolts were released at Princeton between 4/22 and 4/29 and on 5/6. We observed a large peak of unmarked fish at Sacramento on April 29 and a peak at Chipps Island on May 6. This translates to a migration rate of 8.5 miles per day. This is similar to that measured in 1990 and slightly slower than for groups released in 1988 and 1989 (Table 6).

Marked Hatchery Smolts

The peak of the marked group of fish released at Princeton on May 2, was recovered at Sacramento and Chipps Island 5 and 9 days after release, respectively. This would yield a migration rate of 15 miles per day from Sacramento to Chipps Island. It is unclear why the unmarked hatchery fish would migrate so much slower than the marked fish. Most likely the two groups migrated at similar rates and that the peak we observed at Chipps Island for the unmarked hatchery fish may have included some "natural" fish and thus biased our estimates low. Even at 15 miles per day, migration rates for the unmarked hatchery fish were slower in

Table 6. Migration Rates (miles/day) for unmarked "natural" and hatchery fish migrating through the North Delta from Sacramento to Chipps Island in 1988, 1989 and 1991 and from Courtland to Chipps Island in 1990 and mean Sacramento River flow at Freeport during migration.

Year	"Natural"	Mean (A-J) Sac flow	Unmarked "Hatchery"	Mean Sac Flow
1991	5.5	9047	8.5 (15)	6471
1990	4.3	11901	18.5	8618
1989	9.5	16119	19.0	16020
1988	5.7	12813	16.0	11800

1991 compared to 1988 and 1989. Estimates for the "natural" fish also are slower than in past years when our trawling site was at Sacramento (Table 6).

Flows were extremely low in the Sacramento River at Freeport during 1991 during migration for both the wild and hatchery fish and may have caused the decrease in the 1991 migration rates. Past data from 1988 and 1989 also seems to confirm that lower flows decrease the migration rate through the Sacramento Delta. In the four years that we have measured the migration rate of Coleman hatchery and "natural" fish in the North Delta, we have found that hatchery fish tend to migrate substantially faster than the "natural" fish. There are several reasons why this may occur. Possibly the fish migrating in the large hatchery group tend to migrate together as a group and thus arrive sooner to Chipps Island than the "natural" fish. Also there may be a stimulating effect by releasing the fish into the warmer water of the Delta in comparison to that of the hatchery or transport truck. Generally, more of the fish released from the hatchery are of smolt size and actively migrate whereas the "natural" fish may be somewhat smaller and their migration slower.

In reality, it is very difficult to accurately measure the migration of "natural" and unmarked hatchery fish migrating through the Delta. The method we have used is very simplistic and is based on number of days between the peak catches at both locations. The results should be viewed with caution until hatchery and natural stocks can be separated with a high degree of confidence.

Coleman Hatchery Smolt Contribution

We estimated that smolts released at Princeton from Coleman National Fish Hatchery survived at a rate of .45 between Sacramento and Chipps Island, based on comparisons of survival to Chipps Island and Sacramento of a coded wire tagged group of smolts released at Princeton (Table 7). (This compares with estimates of .64 and .69 for the Red Bluff and Battle Creek tag groups, respectively.) We also estimated a 79 percent survival rate between Princeton and Sacramento for the Coleman production released at Princeton. Given that our survival estimates are reasonable we estimate that about 5.1 of the 33 million fish (about 15%) recovered at our Sacramento trawl site, and 2.3 million of the 17 million (about 14%) estimated at Chipps Island were smolts of Coleman origin.

To further evaluate Coleman's total contribution to chinook production in the Central Valley we need to include the smolts derived from fry released from Coleman NFH. For CNFH fry and smolts released at Red Bluff Diversion Dam in 1987 and 1988 we estimated that smolts survived an average of three times that of fry (a 1 to .29 smolt to fry ratio), and if that is similar to

Table 7. Survival estimates to Sacramento and Chipps Island for fish released at Battle Creek, Red Bluff and Princeton. Survival was also estimated between Sacramento and Chipps Island for the three groups.

Code	Released Site	Date Released	Survival at Chipps	Survival at Sacramento	Estimate of survival between Sacramento & Chipps Is.
5-1-11-1-13	Battle Creek	4/30	.2058	.3077	.69
5-1-11-1-12	Red Bluff	5/01	.3526	.5516	.64
5-18-45	Princeton	5/02	.3556	.7865	.45
5-18-47					
5-18-48					

the survival rate of fry in 1991 than the 11 million fry Coleman planted in February and March of 1991 would equate to about 3.2 million smolts. This would increase Coleman's contribution to the overall production at Sacramento to be about 25%.

Winter Run Recoveries

One juvenile salmon within the winter run size criteria (revised criteria by Frank Fisher, CDFG-Red Bluff, 2/26/92) was caught in our beach seine sampling in 1991. It was 95 mm and was recovered at Elkhorn (Lower Sacramento River area) on March 6.

Between April 15 and May 20, we recovered 11 juvenile salmon in our Sacramento midwater trawl that were in the winter run size criteria, which ranged between 101 and 155 millimeters.

In our midwater trawl at Chipps Island, 25 fish within the winter run size criteria were collected between April 2 and May 24. They ranged in size between 100 and 178 millimeters. All winter run fish that were collected were measured and promptly returned to the river.

In 1991, 5 out of a total of 946 coded wire tagged smolts were recovered at Chipps Island that were also in the winter run size criteria, which were known fall run hatchery fish. The fall run fish ranged between 110 and 115 millimeters and were kept for tag

recovery and decoding purposes. This illustrates the problem of only using size to determine what is a winter run fish. With this more recent winter run criteria there was substantially less overlap with our marked fall run fish than we estimated with previous criteria (January, 1992) (5 versus 72).

Coded Wire Tagged (CWT) Survival- North Delta

In 1991, the Interagency salmon program released two groups (100,000 per release group) of coded wire tagged fish into the Sacramento River. Both groups of fish were released in late April at Miller Park (site 1 on Figure 6) to evaluate the effect of very low flows under low temperatures on smolt survival in the Sacramento Delta.

Recoveries of the tagged fish were made by daily midwater trawl sampling at Chipps Island and at the CVP and SWP fish facilities. Recoveries at Chipps Island were converted to survival indices and facility recoveries were expanded to account for the fraction of time sampled to estimate the total number of marked fish passing through the salvage facilities. Additional recoveries will be made in the ocean fishery in future years.

Releases were made in 1991 on April 25 and 29 at the same release temperature (62 degrees fahrenheit), and resulted in a survival index of .78 and .49 respectively (Table 8). Flows at Freeport

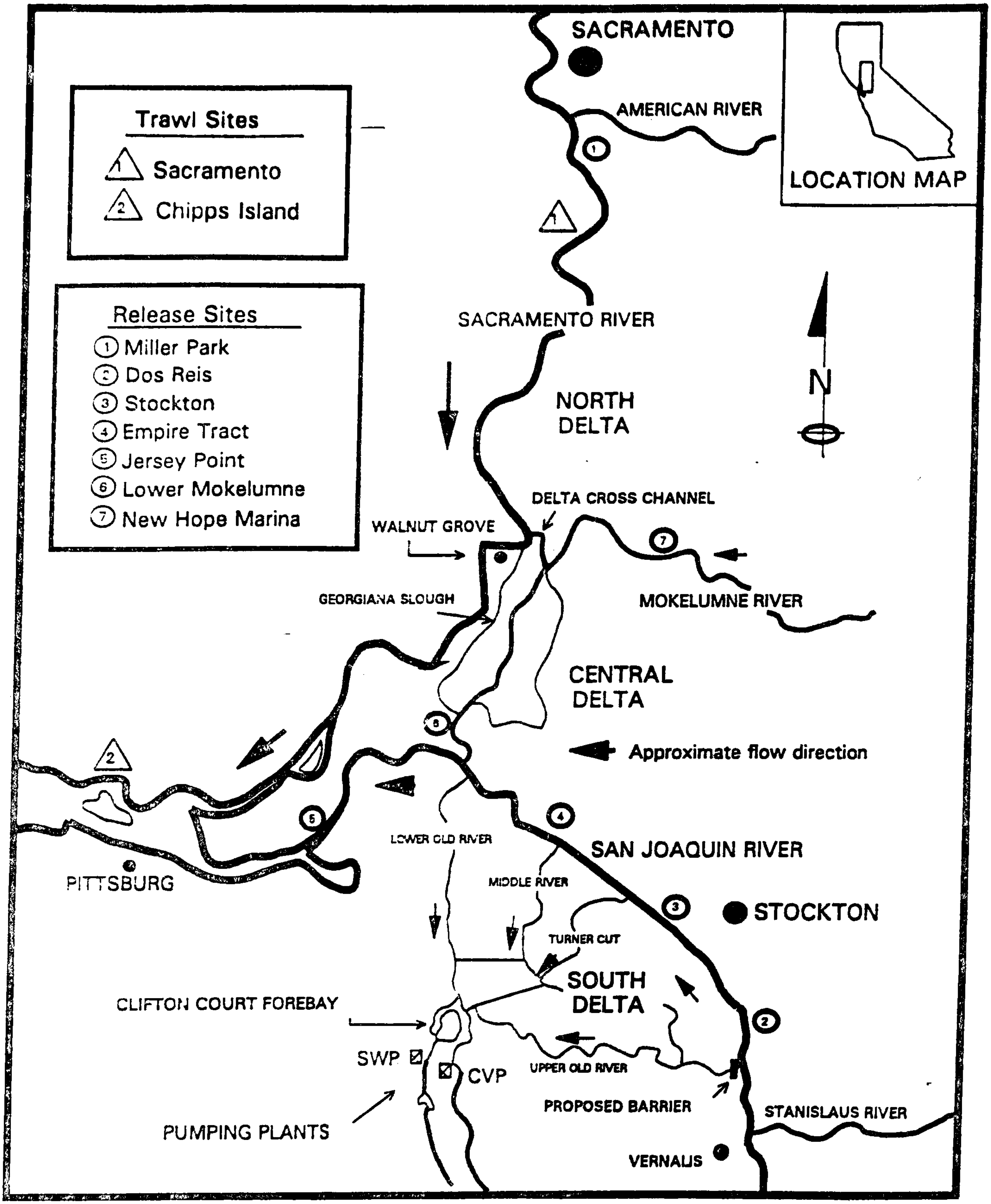

Figure 6. CWT salmon release sites and trawling locations used in 1991.

TABLE 8: CHIPPS ISLAND TAG SUMMARY, SURVIVAL CALCULATIONS AND EXPANDED FISH FACILITY RECOVERIES FOR CODED WIRE TAGGED FISH RELEASED IN 1991.

CODE	SITE	DATE	TEMP	RELEASED	SIZE (MM)	RECOVERED	SAMPLED	SURVIVAL	ESTIMATED SURVIVAL	FIRST DAY RECOVERED	LAST DAY RECOVERED	EXPANDED NUMBER RECOVERED CVP	SWP
Sacramento Releases													
H6-01-14-02-07	MILLER PARK	4/25	62	51392	80	35	0.1389	0.637		01-May-91	06-May-91	0	8
H6-01-14-02-08	MILLER PARK	4/25	62	51272	83	50	0.1389	0.913		30-Apr-91	09-May-91	0	0
TOTAL				102664		85	0.1389		0.775	30-Apr-91	09-May-91		
H6-01-14-02-09	MILLER PARK	4/29	62	53430	81	21	0.1371	0.373		27-Apr-91	16-May-91	0	0
H6-31-24	MILLER PARK	4/29	62	54158	79	34	0.1349	0.605		04-May-91	10-May-91	0	1
Total				107588		55	0.1371		0.485	27-Apr-91	16-May-91		
San Joaquin Releases - April													
H6-01-14-01-14	DOS REIS	4/15	60	52097	80	8	0.1374	0.145		23-Apr-91	11-May-91	2302	1282
H6-01-14-01-15	DOS REIS	4/15	60	50902	80	9	0.1389	0.166		23-Apr-91	02-May-91	3170	1244
TOTAL				102999		17	0.1374		0.156	23-Apr-91	11-May-91		
H6-01-14-02-01	BUCKLEY COVE	4/16	59	51128	80	15	0.1389	0.275		24-Apr-91	06-May-91	272	1860
H6-01-14-02-02	BUCKLEY COVE	4/16	59	48213	78	11	0.1389	0.214		25-Apr-91	02-May-91	66	775
TOTAL				99341		26	0.1389		0.245	24-Apr-91	06-May-91		
H6-01-14-02-03	EMPIRE TRACT	4/17	61	48255	79	25	0.1389	0.485		24-Apr-91	09-May-91	74	792
H6-01-14-02-04	EMPIRE TRACT	4/17	61	47347	77	29	0.1370	0.581		24-Apr-91	12-May-91	57	609
TOTAL				95602		54	0.1370		0.536	24-Apr-91	12-May-91		
H6-01-14-02-05	L. MOKELUMNE	4/18	61	47289	79	79	0.1389	1.564		23-Apr-91	03-May-91	0	276
H6-01-14-02-06	JERSEY POINT	4/19	63	52139	82	94	0.1375	1.705		23-Apr-91	17-May-91	20	274

TABLE 8 (Continued): CHIPPS ISLAND TAG SUMMARY, SURVIVAL CALCULATIONS AND EXPANDED FISH FACILITY RECOVERIES FOR CODED WIRE TAGGED FISH RELEASED IN 1991.

CODE	SITE	DATE	TEMP	RELEASED	SIZE (MM)	RECOVERED	SAMPLED	SURVIVAL	ESTIMATED SURVIVAL	FIRST DAY RECOVERED	LAST DAY RECOVERED	EXPANDED NUMBER RECOVERED CVP	SWP
San Joaquin Releases - May													
H6-31-25	BUCKLEY COVE	5/6	65	49393	78	7	0.1368	0.135		11-May-91	30-May-91	12	31
H6-31-26	BUCKLEY COVE	5/6	65	50427	85	13	0.1376	0.244		11-May-91	16-May-91	40	33
Total				99820		20	0.1368		0.190	11-May-91	30-May-91		
H6-31-27	L. MOKELUMNE	5/9	64.5	45706	84	31	0.1378	0.640		12-May-91	18-May-91	22	13
H6-31-28	JERSEY POINT	5/13	61	49184	86	89	0.1389	1.694		14-May-91	23-May-91	6	0
Subsystems Releases													
H6-48-37to 45	NEW HOPE MAR	4/23	60	80041	95	139	0.1389	1.630		27-Apr-91	06-May-91	8	112
H6-48-57 to 63 H6-49-01 to 03	NEW HOPE MAR	5/6	65	101980	96	48	0.1359	0.45		10-May-91	21-May-91	0	0
Total													
Up River Releases													
H5-1-1-1-10	COLEMAN	3/4		52567	50	6				23-Apr-91	22-May-91	0	0
H5-1-1-1-11	RED BLUFF DD	3/8		53792	50	3				26-Apr-91	04-May-91	0	0
H5-1-1-1-12	RED BLUFF DD	5/1		64700	76	24	0.1368	0.353		11-May-91	30-May-91	0	0
H5-1-1-1-13	BATTLE CREEK	4/30		64698	74	14	0.1368	0.206		11-May-91	28-May-91	0	0
H5-18-45	PRINCETON	5/2				4				14-May-91	19-May-91		
H5-18-47	PRINCETON	5/2				10				11-May-91	21-May-91		
H5-18-48	PRINCETON	5/2				10				10-May-91	30-May-91		
TOTAL				64737	74	24	0.1356	0.356		10-May-91	30-May-91	0	0

for each group, on the day of release were 7220 and 5760 cfs respectively and may account in part for the greater survival we observed from the April 25 group. As mentioned earlier — increased flows may increase the migration rate which in turn may increase overall survival. Additional analyses is warranted on the role of very low flow on the survival of salmon migrating through the Sacramento Delta.

Combined exports at the CVP and SWP on April 25 and 29 were 4810 and 4686 cfs respectively and would not appear to account for the greater survival we observed from the first release group. The Delta cross channel was open during both releases. Sampling variability alone potentially could account for the differences in survival we saw for the two groups.

In 1991 a total of 9 marked fish, expanded for the fraction sampled (8 and 1 from the April 25 and 29 releases respectively) were recovered at the fish facilities from coded wire tagged fish released at Miller Park into the Sacramento River. This translates to .004 percent of the total number released of the Sacramento groups. Although this percent is low many more fish are potentially lost due to the various indirect impacts of tne pumps before they reach the actual salvage facilities.

Model Verification

When using our smolt survival model (Kjelson et al., 1989) to predict survival through the Delta given the environmental conditions in 1991, we found that our model predicted survival for the April 29 group very closely, but underestimated the actual survival index observed on the 25th (Table 9).

Observed estimates of survival were divided by 1.8 to approximate actual survival as was done in the development of the Kjelson et. al., model.

Model estimates of annual survival between April and June averaged .28. This compares to our .52 based on the number of salmon caught throughout the season and an average estimate of net efficiency. However, in our model we had to divide all our estimates by 1.8 to obtain survival indices between 0 and 1 and if we similarly divide our observed annual estimate by 1.8 we estimate smolt survival through the system to be .29.
It may be necessary to divide all our abundance indices and estimates at Chipps Island by 1.8 to make comparisons between the model and our observed values compatible.

However, the difference between our original .52 annual estimate and the one generated through our model may be accounted for by smolts migrating past Chipps Island that were not sampled at our

Table 9. Predicted versus observed survival estimates and flow, temperature and combined CVP and SWP exports on release date for CWT'd fish released in the North Delta in 1991.

Release Date	Release Site	Observed	Predicted	Flow at Freeport Release Date	Temp	Export
4/25	Sacramento	.78/1.80=.43	.29	7220	62	4810
4/29	Sacramento	.49/1.80=.27	.28	5760	62	4686

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Sacramento trawl, because they entered the Delta as fry before our Sacramento trawling began in April. In addition some of the smolts may have originated in the San Joaquin basin and thus biased our survival estimate high.

In May of 1992, the model was rerun incorporating new data generated since the original model was constructed in 1989. The equations changed somewhat, but the variables within in the model (temperature, exports and the percent of water diverted at the Delta Cross Channel and Georgiana Slough) did not change. The new equations are as follows:

Mortality in Reach 3 (Walnut Grove to Chipps Island via the Sacramento River)

$$y= -1.613493 + (\text{Freeport temp.} * 0.0319584),\ r^2=.39$$

Mortality in Reach 2 (Walnut Grove to Chipps Island via the Central Delta)

$$y= -0.5916024 + (0.017968 * \text{Freeport temp.}) +(0.0000434 * \text{Exports}),\ r^2=.69$$

Mortality in Reach 1 (Sacramento to Walnut Grove)

$$y= -2.45925 * (0.0420748 * \text{Freeport temp.}),\ r^2=.32$$

These new equations have not been used to generate any estimates of smolt survival in this report.

Smolt Migration Rate

Our estimates of smolt migration rates of CWT fish released at Sacramento on April 25 and 29th, in 1991 was 7.5 and 8.6 miles per day, respectively and was similar to other groups released from Sacramento in the previous three years (Table 10). Migration rates in 1991 for CWT groups released at Sacramento may have decreased because the flows were low and temperatures were favorable.

Ocean Recovery data from past experiments

Most of the conclusions generated from our salmon work have been based on tag recovery information obtained with our midwater trawl at Chipps Island. In order to confirm these conclusions it is necessary to wait 3 to 4 years to obtain information via adult recoveries made in the ocean fishery. The "ocean index of survival" is based on the recovery rates of the marked fish in the ocean fishery. For example the estimates of survival through the Delta are based on the differential recovery of the upstream release site (usually Sacramento or Courtland) and a group released in the Western Delta (Port Chicago or Benecia). The latter group serves as a control and factors out the influence of the Bays and ocean residence.

Table 10. Summary of migration rates (miles per day as estimated from CWT salmon released at Sacramento and recovered by trawl at Chipps Island from 1988 to 1991. Freeport flow is the mean daily flow in cfs during the migration period to Chipps Island.

Year	Migration Rate (miles/day)	Flow @ Freeport (cfs)
1988	8.9	11792
	12.0	12259
1989	11.4	13604
	11.4	12748
1990	9.5	5958
1991	7.5	7220
	8.6	5760

Since 1978, we have been releasing fish near Sacramento and in later years at Courtland to estimate survival through the Delta. Figure 7 shows how our ocean index of survival through the Delta compares with our trawl index of survival. The two indices are significantly correlated to each other which in turn lends credibility to both indices for measuring survival (Appendix 3 and Appendix 9). It is uncertain why both indices at times estimate survival over 1 but could be due to the sampling error and variability associated with both sampling methods.

To date, we have determined that fish diverted off their main migration path into the Delta cross channel and Georgiana Slough have much higher mortality than those allowed to migrate down the main Sacramento River. Coded wire tagged fish released above the cross channel and Georgiana Slough with the cross channel gates open survived about twice that of those released with the gates closed (Tables 11 and 12). We found similar difference using both our trawl (3.4 to 1.6) and ocean (2.2 to 1.2) index of survival.

In addition, the difference in survival of fish released above versus below the Cross Channel with the gates closed, is due to the diversion impact of Georgiana Slough alone. The difference between being diverted into Georgiana versus being allowed to stay in the main channel, is greatest using our trawl estimate (1 to 1.6) but is confirmed with the ocean index (1 to 1.2).

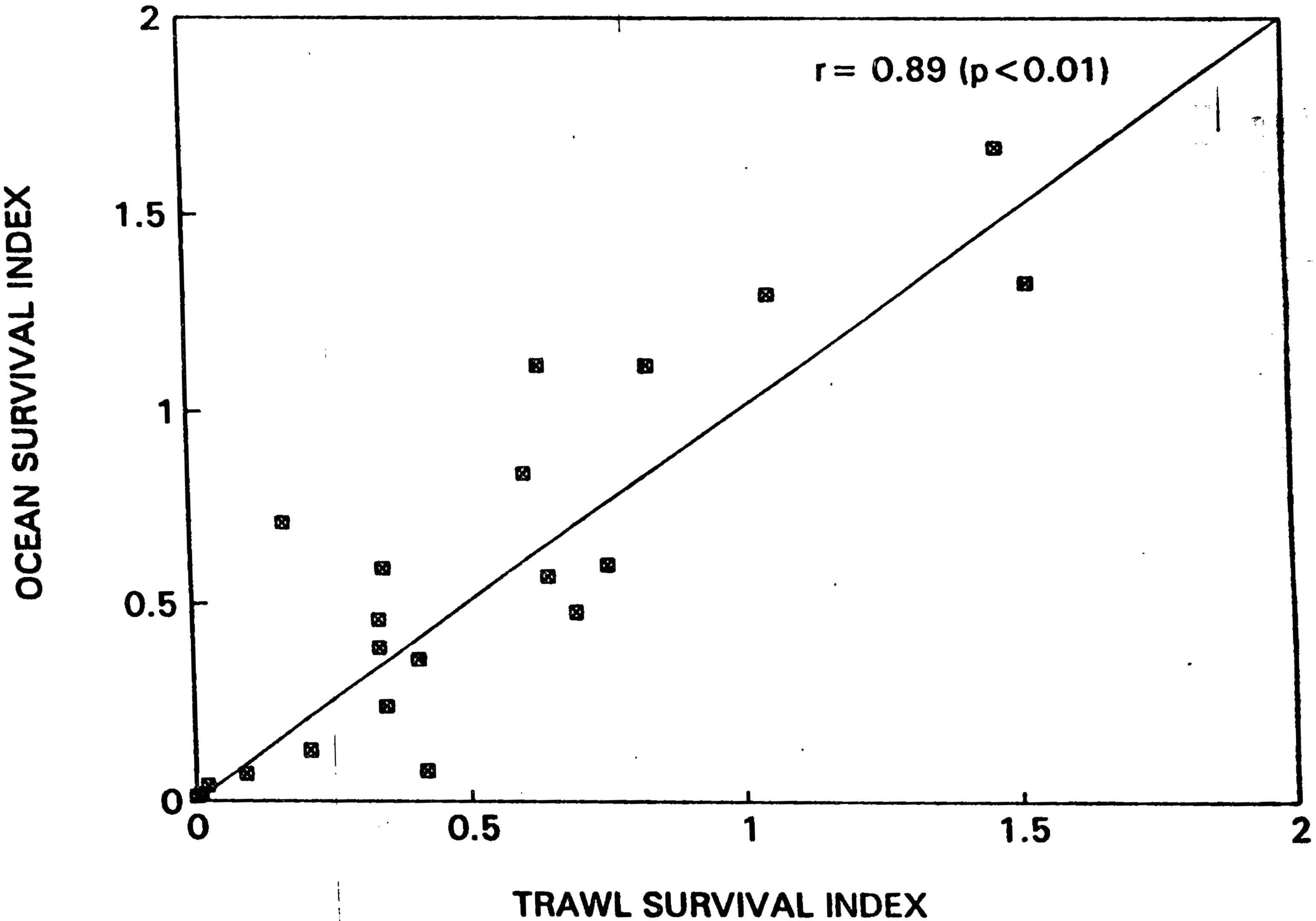


Figure 7: Survival through the Delta for fish released at Miller Park, Sacramento and Courtland (gates open and closed) as indexed by our trawl and ocean index from 1978 to 1989.

Table 11. Comparisons of the survival indicies (S_T) for CWT chinook smolts released in the Sacramento River above and below the Delta Cross Channel and Georgiana Slough diversion channels between 1983 and 1989.

	Year	Above[1/]	Below[2/]	Below/Above
Cross Channel Open	1984	0.61	1.05	1.7
	1985	0.34	0.77	2.3
	1986	0.35	0.68	1.9
	1987	0.40	0.88	2.2
	1988	0.72	1.28	1.8
	1988	0.02	0.34	17.0
	1989	0.84	1.19	1.4
	1989	0.35	0.48	1.4
	1989	0.21	0.16	0.8
				Ave. = 3.4
Cross Channel	1983	1.06	1.33	1.3
	1987	0.67	0.85	1.3
	1988	0.70	0.94	1.3
	1988	0.17	0.40	2.4
				Ave. = 1.6

1/ Courtland Site (3.S miles above Walnut Grove)

2/ Ryde Site (3.0 miles below Walnut Grove)

Table 12: **Ocean Recovery rates for fish released above and below the Delta cross channel and Georgiana Slough, from 1983-1989 with and without the cross channel gates closed. The ratio between Above and Below are also shown.**

Open	**Above**	**Below**	**B/A**
1984	.0058	.0042	.72
1985	.0039	.0085	2.18
1986	.0169	.0194	1.14
1987	.0142	.0201	1.42
1988 May June	.0091 .0007	.0249 .0053	2.74 7.6
1989	.0048 .0008 .0008	.0076 .0016 .0002	1.60 2.00 .25
			$\bar{X}$= 2.18
Closed			
1983	.0039	.0038	.97
1987	.0196	.0312	1.59
1988 May June	.0114 .0134	.0202 .0046	1.77 .34
			$\bar{X}$= 1.16

Both our trawl and ocean data supports our previous conclusions that their would be substantial benefits to migrating Sacramento salmon smolts if both the cross channel and Georgiana Slough were closed. This is a potential structural method for increasing salmon smolt survival through the Delta.

Other variables significant to Sacramento smolt survival are included in our model (Kjelson et. al., 1989). Since our ocean survival index corresponds so closely to our trawl index, general conclusions probably would not change. It is more difficult to use the ocean index of survival in our model as we do not have control groups for releases in each of the three reaches identified in the model. We hope to rerun at least part our model at a future date using our ocean indices of survival to validate our conclusions.

SAN JOAQUIN DELTA

Past coded wire tag data generated since 1985 has shown in general that fish released in the San Joaquin River downstream of the Upper Old river junction, survive about 50% greater than those released into Upper Old River (Table 13), as demonstrated by both ocean and trawl data. This infers that any natural smolts diverted into Upper Old River would have greater mortality than those migrating down the mainstem San Joaquin. A full

Table 13. CWT smolt survival indices for smolts released at Dos Reis on the main San Joaquin River and in Upper Old River between 1985 and 1991. Ocean recovery rates are in parenthesis.

Upper Old River Release Date	Survived to Chipps Island	(DR/UOR)
4-29-85	.62	
5-30-86	.20 (0.011)	1.9
4-27-87	.16 (0.005)	2.4
4-21-89 (High Export)	.09 (0.00073)	.8
5-03-89 (Low Export)	.05 (0.00044)	2.2
4-17-90 (High Export)	.02	
5-13-90 (Low Export)	.01	
Mean	.16	1.8

Dos Reis[1/]		Flow at Stockton	CVP & SWP Export	Temperature on Release Day
4-22 and 4-23, 1982	**.70	7861	5598	65
4-30-85	.59	513	6311	70
5-29-86	.34 (0.021)	2514	5386	70
4-27-87	*.38 (0.012)	471	6093	70
4-20-89 (High Export)	.14 (0.00062)	112	10297	69
5-02-89 (Low Export)	.14 (0.00096)	790	2470	71
4-16-90 (High Export)	.04	0	9549	68
5-02-90 (Low Export)	.04	490	2461	68
4-15-91 (High Export)	.16	60	5153	60
Mean (85-87, 89-90)	.24			

1/ 5 day averages after release date.

* Original survival estimate modified based on the ratio of recovery rates between the Dos Reis and Upper Old River releases.

** Original survival estimate modified (.60) based on the ratio of recovery rates between the Dos Reis and Merced River release.

barrier has been proposed for installation into the head of Upper Old River as a management alternative to improve fall run smolt survival down the San Joaquin River. This would force all of the migrating salmon down the mainstem San Joaquin and prevent them from being diverted into Upper Old River and directly towards the State Water Project (SWP) and Central Valley Projects' (CVP) pumping plants (Figure 6).

Modeling Efforts in 1991

During the scoping phase of the Bay Delta Water Quality/Water Rights hearings we were asked to model the potential benefits to salmon smolts migrating through the San Joaquin Delta of a barrier at the head of Upper Old River under different flow and export conditions. For comparison purposes we also needed a model to represent conditions and smolt survival without the barrier. Two separate models were derived to use with the DWR hydraulic operational studies to estimate the benefits and costs of installing a full barrier at the head of Upper Old River. This section will summarize how these models were constructed.

The model estimating smolt survival without the barrier was derived using past adult escapement data from the San Joaquin basin because we did not have adequate smolt survival data to develop meaningful relationships. Adult production is generally representative of smolt abundance 2 1/2 years earlier. In our analyses we assumed that smolt survival was an indicator of smolt abundance and it was linearly related to adult production. This assumption is generally true as less of the overall natural mortality occurs after the smolts enter the ocean.

The index of adult production that was used in our analyses was defined as adult escapement in year i divided by parental escapement in year i-3. The index also was adjusted to reduce high escapement contribution by grilse salmon (Bill Loudermilk, Region 4- CDFG, unpublished draft report, 1988).

In order to relate adult production to smolt survival we divided each adult production index (api) value by 12 to get values into a typical smolt survival range of between 0 to 1. The adult production index from 1969 to 1986 ranged between .2 to 11.09. Consequently the smolt survival index for the years 1967 to 1984 (year i-2) ranged between .017 to .924.

The smolt survival model was used in conjunction with California's Department of Water Resources' operational studies to reflect flow and export conditions under different levels of demand and resulting salmon smolt survival in the San Joaquin Delta without the installation of a barrier. Inflow and exports were the hydraulic conditions experienced by the juveniles during their outmigration.

A multiple regression analyses was conducted on smolt survival data from 1967 to 1984 (not including 1979) using Vernalis flow (mean daily flow from March 15 to June 15), combined CVP and SWP exports (mean daily exports from March 15 to June 15).

The multiple regression was significant ($p < 0.01$) and the adjusted r squared was .80 (Figure 8). The data in 1979 (year i-2) was not included as it was an obvious outlier. This was the relationship used to evaluate the effects of flow and exports on salmon smolt survival without a barrier (Figure 9).

In order to estimate the benefits on smolt survival of varied export and flow conditions with a barrier another model was developed.

In several years since 1985, coded wire tagged experiments have been conducted to evaluate the difference in survival between smolts released into Upper Old River and into the main San Joaquin River at Dos Reis. Since Dos Reis is downstream of the junction with Upper Old River it served as our best and only data to estimate survival of smolts migrating down the San Joaquin River with a barrier in place. We have noted in past years that fish do get pulled upstream and are diverted into Upper Old River to the pumps, thus our estimates of survival to Chipps Island from Dos Reis are probably biased low.

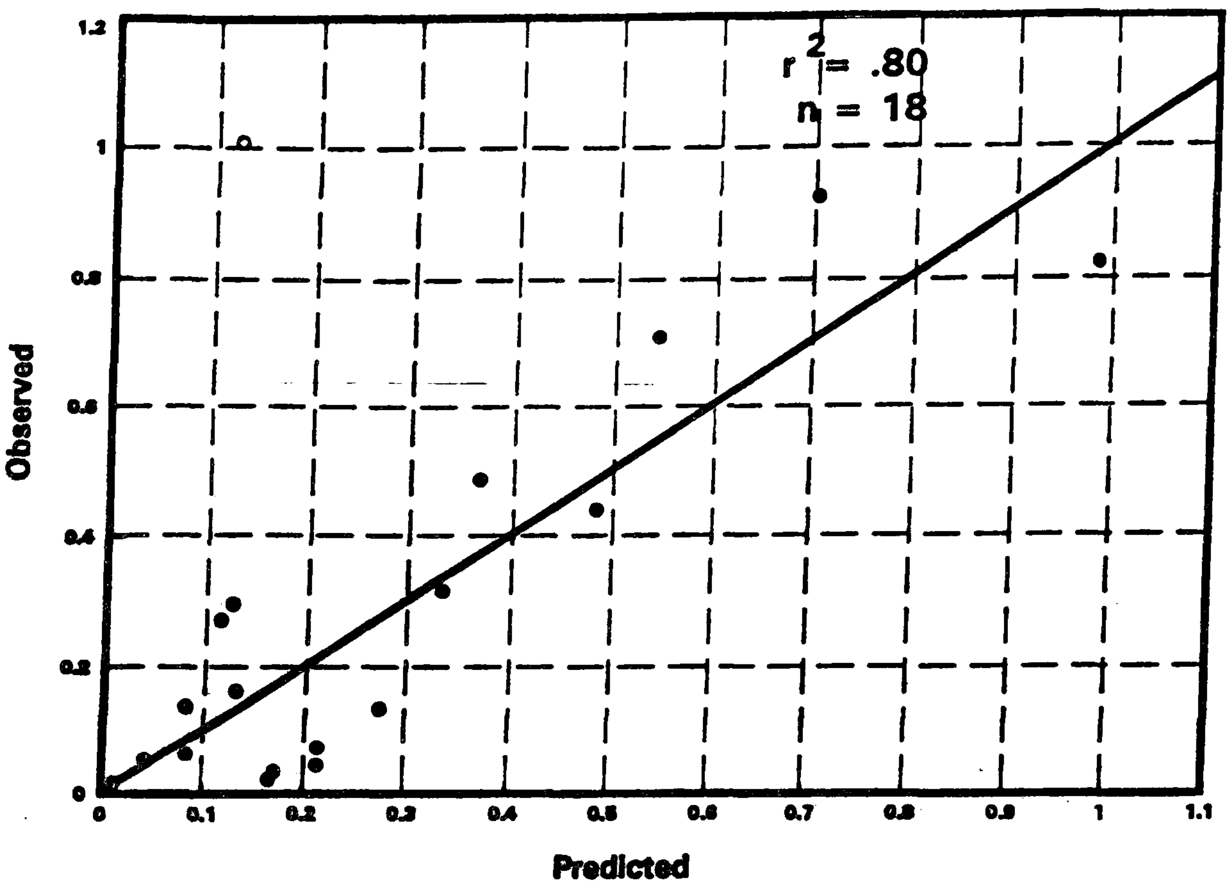


Figure 8: Observed versus predicted survival, of the relationship between San Joaquin smolt survival, flow at Vernalis and exports at the CVP and SWP pumping plants between 1967 to 1984.

° Indicates oulier (not used in regression).

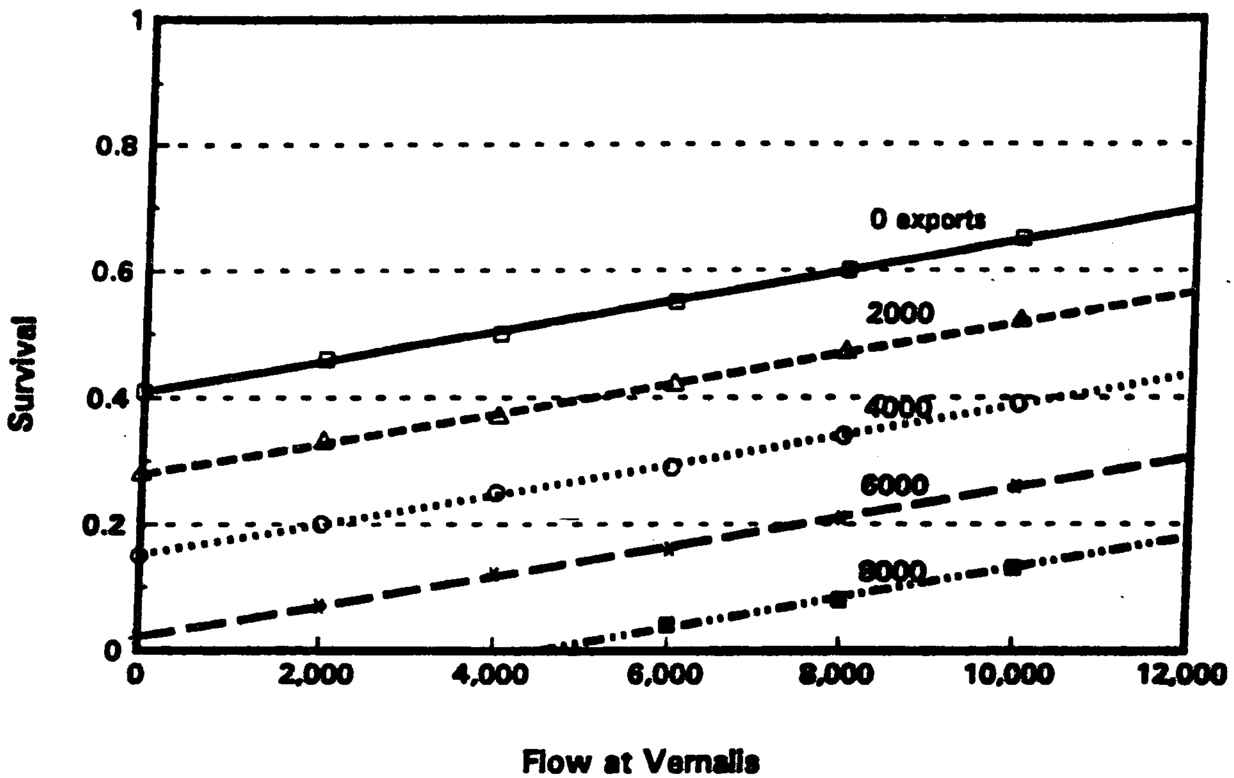


Figure 9. Relationship between San Joaquin smolt survival, flow at Vernalis, and exports at the CVP and SWP pumping plants without a barrier at the head of Upper Old River.
y= (4.90106+.000286 (flow) - (.000774(exports)))/12

Our data was limited to 8 data points (1982, 1985-1987 and 1989 to 1990) so standard multiple regression analyses was not possible. In a linear regression, smolt survival (from Dos Reis releases) was correlated to flow at Stockton and a r squared was obtained of .477 (Table 13). Although this is not significant at the .95% confidence level, it was significant at the .90% level.

We also believed that export levels affect smolt survival and but we could not detect a relationship, possibly due to our data set being so small. Theoretically we desired to estimate the change in the survival-flow relationship for various export levels. The historical data was obtained when combined CVP and SWP exports averaged 6000 cfs (range between 2,400 and 10,200). We hypothesized that a similar relationship with flow probably would exist at other export levels and only the intercept of the relationship would change.

The range between bands in the relationship without a barrier varied by about .10 survival units per 2000 cfs increase in exports (Figure 9). We have theorized that exports would not have as great an effect on survival with a barrier as they would without a barrier because the fish are further downstream where there is more tidal influence before they encounter channels diverting water south towards the pumping plants. This hypotheses affected the relationship by narrowing the bands between export levels at any specific flow level.

Data in 1989 and 1990 also supports a narrower band, as the difference in survival ratios of the Dos Reis group divided by the Upper Old River group in those years, between high (~ 10,000 cfs) and low export (~ 2000 cfs) at generally low flow levels at Stockton (0 to 800 cfs), indicated roughly a doubling in smolt survival (.05 units) not a quadruple change (.1 units).

There is risk with relying on the 1989 and 1990 data, as the results were so low they may not be representative of the true relationship between smolt survival, exports and flow. However, it was the best available data and thus we used it along with our best professional judgement. We estimated that the constant of the linear regression would change by .05 units of survival for every 2000 cfs increase in exports (Figure 10).

We supplied the SWRCB our best estimates of the potential benefits to San Joaquin smolt survival under different environmental conditions using a barrier at the head of Old River. However, it is quite apparent there is a need to measure survival under different conditions with the actual barrier in place to fully understand the benefits and costs of such a measure.

South Delta CWT Experiments

Although there was an effort in April of 1991 to install the

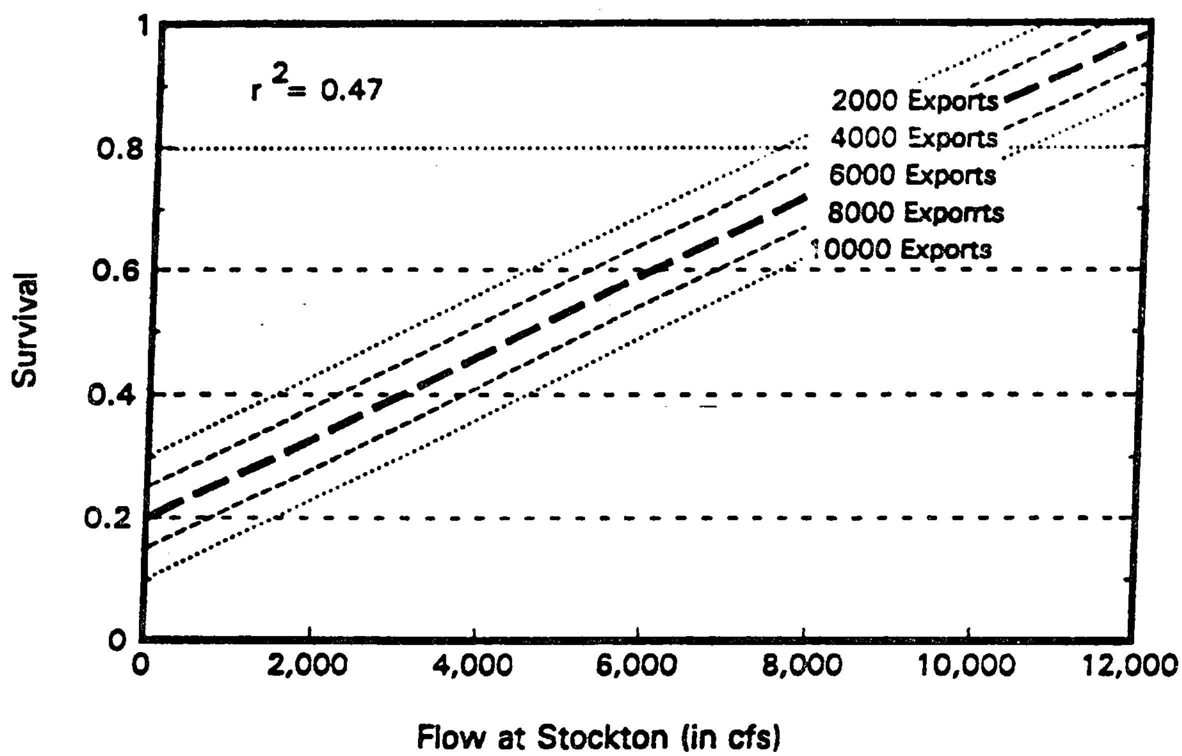


Figure 10: Relationship between San Joaquin smolt survival, flow at Vernalis, and combined exports at the CVP and SWP pumping plants with a barrier at the head of Upper Old River.

Upper Old River barrier for testing purposes, it was unsuccessful. An attempt is being made to install it in 1992 to evaluate its impact on smolt survival under different export conditions.

Our 1991 coded wire tag smolt survival experiments in the South Delta were designed to measure smolt survival during periods of high and low exports. Our releases were made in an attempt to assess the changes in survival due to the increased flow of water (and presumably fish) towards the pumping plants in Old and Middle River and Turner Cut which would occur if a barrier was present and exports were not curtailed. Potentially, this increase in flow towards the pumps could increase downstream mortality and needs to be weighed against the benefits of the barrier, to assess its net value.

Additional groups of fish also were released at Jersey Point on the lower San Joaquin River to evaluate the effect of reverse flows on smolts migrating through the Western delta.

Groups of coded wire tagged fish were released on the mainstem San Joaquin at Dos Reis, Stockton-Buckley Cove, Empire Tract and Jersey Point and in the Lower Mokelumne at Lighthouse Marina (see sites 2, 3, 4, 5 and 6 respectively on Figure 6). Fish were released at sites 2-6 from April 14 to April 19 during a period of higher pumping and low water temperatures. The second group of fish were released at sites 3,5 and 6 between May 6 and May 13 during a period of lower pumping and slightly higher water temperatures than those ~~observed~~ in April (Table 8).

Figure 11 illustrates that, during our first release, export and reverse flow conditions were changing dramatically in a matter of just a few days whereas migration of all of the fish of a particular group to Chipps Island takes a minimum of a week, thus making analyses and interpretation of the data difficult.

Average total exports during the time the release groups were migrating past Chipps Island were 3222 cfs between April 23 to May 17 and 2329 cfs between May 11 to May 30. Average San Joaquin inflow at Vernalis was 978 and 1102 cfs respectively for the two time periods.

Throughout our analyses we have used the average conditions during time periods that most closely represent what the individual groups of fish were exposed to.

With the exception of the Jersey Point site, releases were made on an ebbing tide or high slack for consistency and to assure immediate downstream migration. Due to the short distance from Jersey Point to Chipps Island (12 miles) and potential short travel time, we had concern that we might miss sampling the Jersey Point group. Therefore, we released both Jersey Point

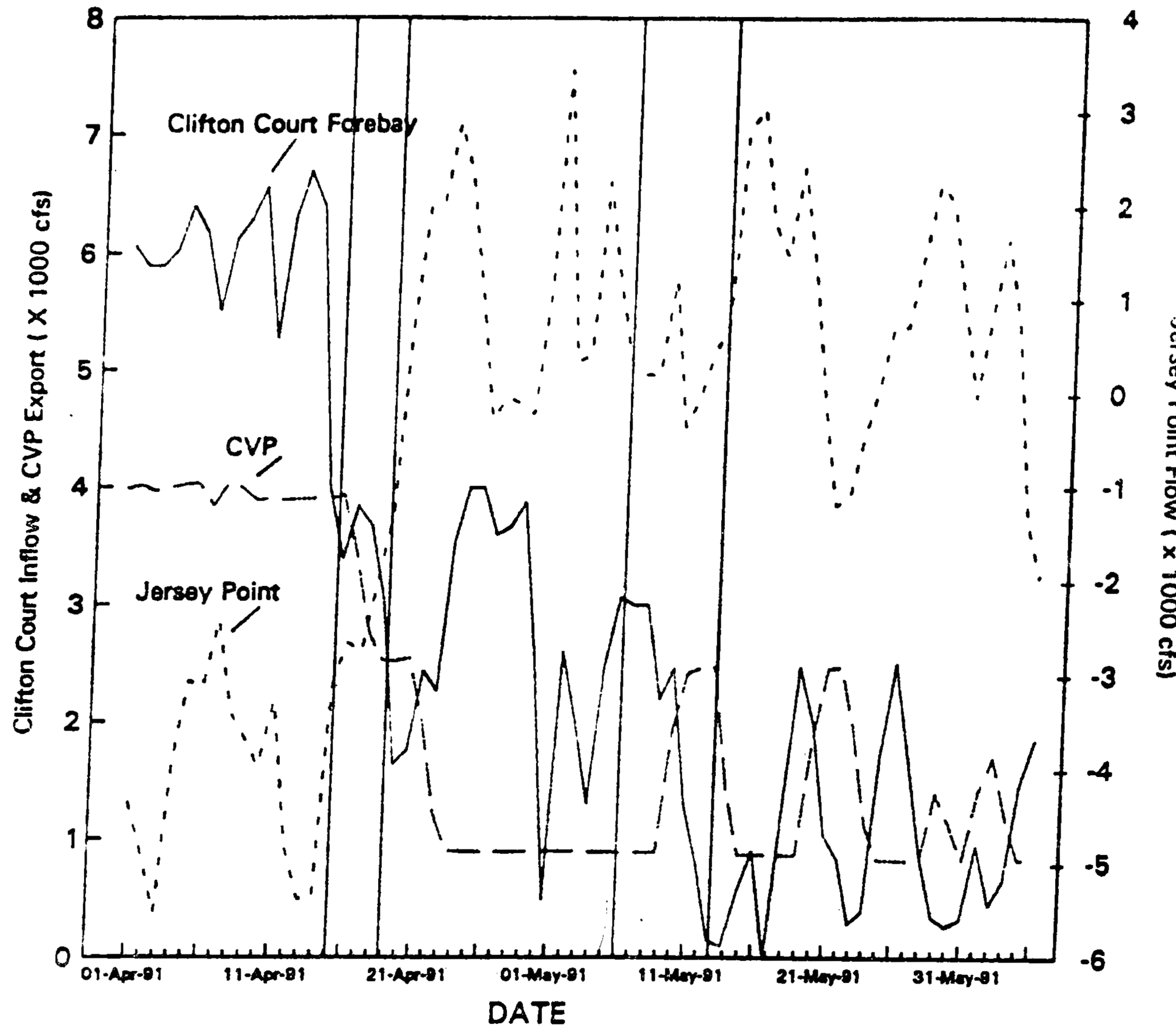


Figure 11: Flows into Clifton Court Forebay, Central Valley Project and at Jersey Point from April 1 to June 5, 1991. The two release periods are bounded by solid vertical lines.

groups on a flooding tide in an attempt to spread their distribution and to increase their chance of being adequately sampled at Chipps Island.

RESULTS

Chipps Island Recoveries

April Release Groups

Survival of fish released in April in the San Joaquin Delta and recovered at Chipps Island showed that those released closer to the western Delta consistently had better survival (Table 14). Survival from fish released at Dos Reis was the poorest whereas fish released at Jersey Point survived the best. This seems to imply that smolts have mortality throughout their migration to the western Delta.

Since Dos Reis is the furthest away from Chipps Island and may reflect only higher mortality because of the greater distance to Chipps Island, we attempted to correct our survival indices to reflect the survival rate in each reach of the San Joaquin River between Dos Reis and Jersey Point. This was done by dividing the further upstream survival index by the next lower downstream site.

Table 14. 1991 temperature corrections to 59 degrees fahrenheit with effect on survival indices for marked chinook released in April and May.

Month	Release Site	River Mile	Temp. (F)	Uncorrected Survival Index	Corrected Survival Index [1]
April	Dos Reis	50	60	0.156	0.122
	Stockton	39	59	0.245	0.136
	Empire Tract	29	61	0.536	0.368
	L. Mokelumne	19	61	1.564	0.939
	Jersey Point	12	63	1.705	1.087
May	Stockton		65	0.190	0.315
	L. Mokelumne		64.5	0.640	0.547
	Jersey Point		61	1.694	1.011
April	New Hope	26	60	1.630	0.940
May	New Hope		65	0.460	0.465

[1] Uncorrected survival indices were divided by 1.8 before standardizing for temperature.

Also among the five release groups, there was some variability between temperatures on the day of release which ranged between 59 and 63 degrees fahrenheit. Work on the Sacramento Delta has shown that temperature is an important variable affecting smolt survival in that area of the Delta. To factor out the potential bias of temperature in our South Delta experiments, we assumed the relationship between temperature and survival was similar between basins.

South Delta survival indices were standardized to one temperature (59 degrees fahrenheit), using the temperature/mortality relationship for Reach 3 of the Sacramento River between Ryde and Chipps Island in the Kjelson et. al. model (1989). In order to standardize for temperature we needed to bring all our survival estimates to values between 0 and 1, as has been done in the model. Thus we have divided all our survival indices by 1.8 before standardizing for temperature.

In Figure 12, we have shown the temperature standardized survival of smolts in each reach throughout their migration to Chipps Island. The survival rate per mile, also shown in Figure 12, was calculated by dividing the survival for each reach by the number of miles in each reach.

The April survival rate per mile between Dos Reis and Stockton (.08) was actually twice as good as the survival rate per mile

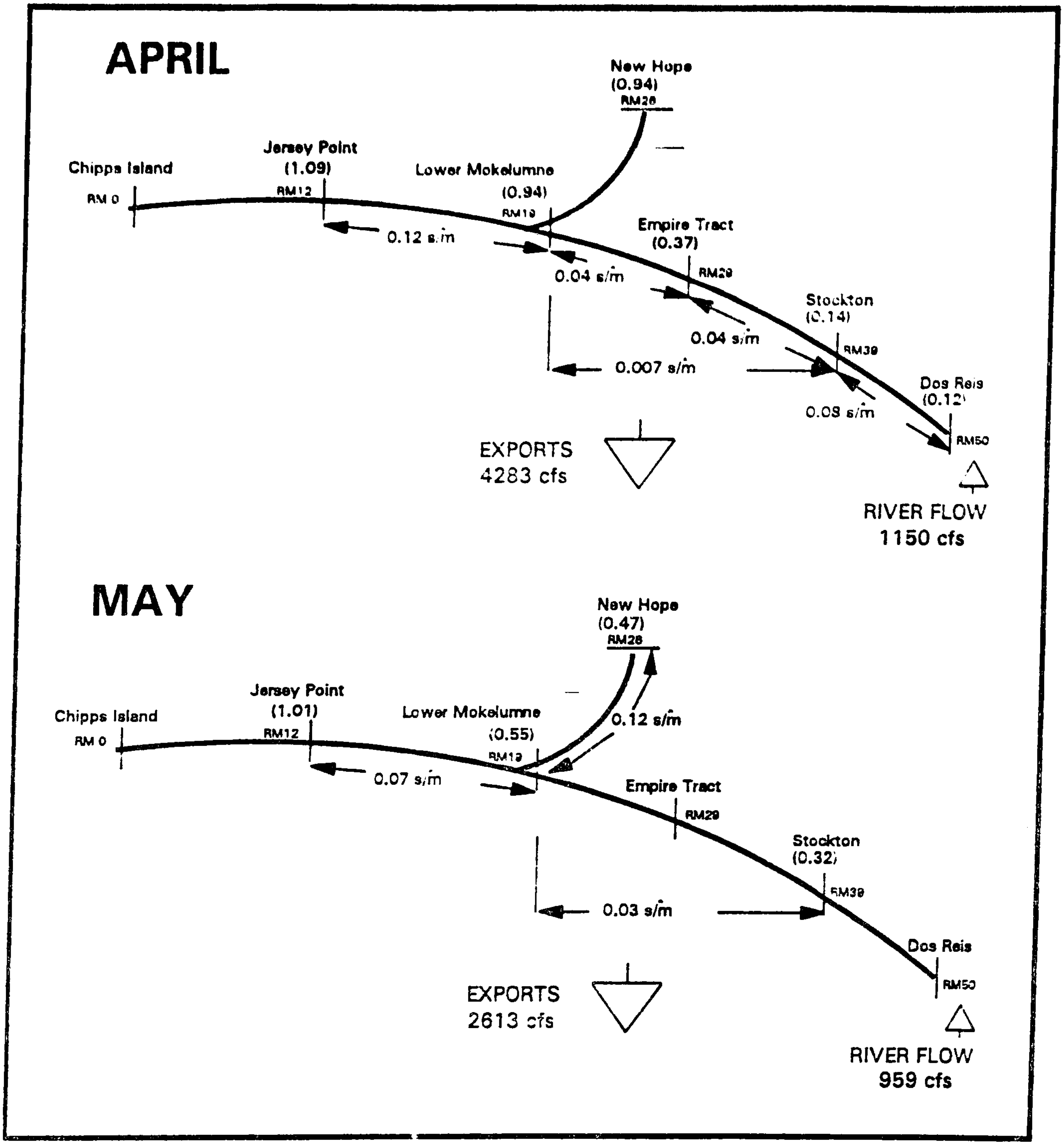


Figure 12: Diagrammatical representation of the San Joaquin River Delta area. Temperature corrected survival per release group to Chipps Island and survival per mile (ŝ/m) provided between designated release locations. April exports and river flow encompass period 4/16 to 5/6 (release date to final capture at Chipps Island of Stockton release in April). May exports encompass period 5/6 to 5/30. Exports are combined CVP/SWP and river flow measured at Vernalis.

between Stockton and Empire Tract and between Empire Tract and the Lower Mokelumne junction (.04).

The survival rate on a per mile basis was the greatest between the Lower Mokelumne site and Jersey Point and was 17 times greater than that between Stockton and the Lower Mokelumne release site. This analyses demonstrates that the greatest mortality in the South Delta in 1991 was on the main San Joaquin River between Stockton and where the Lower Mokelumne River enters the San Joaquin. This mortality is even greater than that experienced between Dos Reis and Stockton.

It is not a surprising that the reach between Stockton and the Lower Mokelumne junction has the greatest mortality, considering that in that reach the number of diversion channels off the main river taking water south to the pumps is greater than in other areas. Once the fish are diverted towards the pumping plants their migration is delayed and they are exposed to potentially greater temperatures, high in channel and Clifton Court predation and direct impacts of the pumping plants. This analyses suggests that once salmon smolts reach the Lower Mokelumne junction mortality is significantly reduced.

Potentially our trawls may be biasing our survival estimates of fish released nearest to Chipps Island (Lower Mokelumne and Jersey Point releases) by catching clumps of these fish. It is likely that the closer the fish are released to Chipps Island the less they are able to spread out thoroughly at our sampling site. Confirmation of these survival estimates will be made by ocean recoveries.

Biosystems Inc., a consulting firm working in the area, released a group of coded wire tagged chinook smolts into the Mokelumne River near New Hope Marina (see site 7 on Figure 6) on April 23. Although these fish were somewhat larger that our Mokelumne River release, (Table 8) the raw survival index was similar (1.63) to that experienced by our Lower Mokelumne release group (1.56), which would lessen our concern that the survival index for the Lower Mokelumne and Jersey Point releases are biased high. In Figure 12, the April temperature corrected survival estimates showed no apparent mortality between the New Hope and the Lower Mokelumne release site, but may be because larger fish were released at New Hope which typically survive better.

May Releases

The uncorrected survival indices of fish released at Stockton, Lower Mokelumne and Jersey Point in early May also showed greater survival the closer the release group to the western Delta, with the Jersey Point group surviving the best and Stockton group the worst (Table 14). If we again evaluate survival in each reach of the San Joaquin River at a constant temperature, we find that survival was the lowest between Stockton and the Lower Mokelumne release sites and about 2.5 times greater between the Lower Mokelumne and Jersey Point (Figure 12).

An additional group of fish was released by Biosystems, Inc. at the New Hope Marina on the Mokelumne River on May 6. This group of fish showed high survival (temperature corrected) on a per mile basis down the Mokelumne River in May, even greater than for the reach between the Lower Mokelumne and Jersey Point. Again these New Hope fish were somewhat larger which would perhaps increase their survival relative to the other CWT groups of fish. The New Hope raw survival indices appeared reasonable thus supporting the results we obtained from the Lower Mokelumne and Jersey Point release groups.

Unadjusted mortality for the Jersey Point group was again very low in May, as it was in April (Table 14).

April versus May Releases

In Figure 12, we have illustrated the difference in survival rates, corrected for temperature, between reaches for the two separate months. The survival rate, between Stockton and the Lower Mokelumne junction in May (.03), under lower export conditions was significantly better (4.2 times) than the survival rate for the similar reach in April (.007) when exports were greater (4283 versus 2613) (Table 15). Inflows during the same time period in the San Joaquin River at Vernalis were greater in April (1150 cfs) than they were in May (959 cfs) and thus would not account for the higher survival we saw in May after correcting for temperature.

Positive flow past Stockton for the Stockton groups during both April and May was about 100 to 150 cfs and is a function of flow at Vernalis and exports (DWR, Bulletin #76) We have attributed the additional mortality in April to the higher exports.

Survival between the Lower Mokelumne site and Jersey Point was greater in April than in May (about 2 times). It appears all conditions seemed more favorable in May than in April for the Lower Mokelumne groups with the exception of flows through the Central Delta, which were slightly greater in April.

Survival down the Mokelumne River between New Hope Marina and our Lower Mokelumne release was greater in April than in May. Conditions, such as exports, Jersey Point flow and flow into Georgiana and the cross channel, appeared to be more favorable in May, and would not explain the survival differences we observed (Table 15).

Temperatures were lower in April by 3.5 degrees fahrenheit at the time of release. Although we attempted to correct for the

Table 15: Average daily flow in cfs at Vernalis, Freeport, Delta Cross Channel and Georgiana Slough during between the date of release and until the last fish was recovered at Chipps Island for each release group.

Release group	SJ River @ Vernalis	Sac River @Freeport	CVP	SWP	& X-Channel Georgiana	Jersey Point	CVP+SWP
MILLER -APRIL 25	1334	6396	896	2167	3726	1049	3063
MILLER-APRIL 29	1127	6345	1203	1916	3784	925	3119
APRIL							
DOS REIS	1079	7051	1611	2697	4068	314	4308
STOCKTON	1150	7034	1552	2731	4038	496	4283
EMPIRE TRACT	1090	6867	1466	2548	4010	564	4014
LOWER MOKELUMNE	1210	6798	1410	2731	3933	760	4141
JERSEY POINT	1057	6730	1325	2079	3858	1010	3404
MAY							
STOCKTON	959	7490	1371	1242	3589	831	2613
LOWER MOKELUMNE	763	6942	1504	902	3695	1347	2406
JERSEY POINT	1063	7662	1540	803	3159	969	2343
BIOSYSTEMS							
NEW HOPE-APRIL	893	7864	1353	1041	3451	695	2395
NEW HOPE-MAY	927	7303	1609	1013	3568	1027	2622

influence of temperature, we may be underestimating the influence of temperature in the San Joaquin Delta.

Fish released at Jersey Point in both April and May survived at high levels and were very similar to each other (Table 15). Although initially we suspected that reverse flows would be greater during the higher pumping period, comparison of conditions during the time the fish were observed at Chipps Island indicated that flow at Jersey Point was very similar (Table 15). This may be why the groups of fish also survived similarly.

In both months it is clear that the vast majority of mortality is associated with the area between Stockton and the Lower Mokelumne junction and that during times of higher pumping survival through that area is much less.

Generally survival for the Dos Reis group of fish released in April in the San Joaquin Delta in 1991 was better than experienced by similar release groups in 1989 and 1990 and most likely is attributable to the generally lower temperatures in 1991 (Table 13). Survival in 1991 was still lower than that observed in 1982 and 1985-1987.

Fish Facility Recoveries

We found that the greatest number of fish recovered at the fish facilities were from the further upstream groups, both in April and in May - generally the inverse relationship from that observed in survival at Chipps Island (Figure 13). The New Hope releases by Biosystem had fewer recoveries at the fish facilities than for our similar Lower Mokelumne releases and may be due to their larger size and the fact that they were released further from the facilities than the other release groups (Figure 6).

We also saw between 6 and 56 times more marked fish at the Fish facilities from the April groups then we did for the corresponding groups released in May, and may reflect the greater indirect or direct affects of the pumps on migrating salmon during periods of higher exports (see Table 16).

Both our recoveries at the fish facilities and estimates of survival in 1991 would support a conclusion that being diverted towards the pumps and fish facilities especially upstream of the lower Mokelumne junction, increases mortality of San Joaquin smolts migrating to Chipps Island.

It is interesting to note that a greater number of marked fish for all groups, with the exception of the Dos Reis group, were recovered at the State Water Project (Table 8). This is not

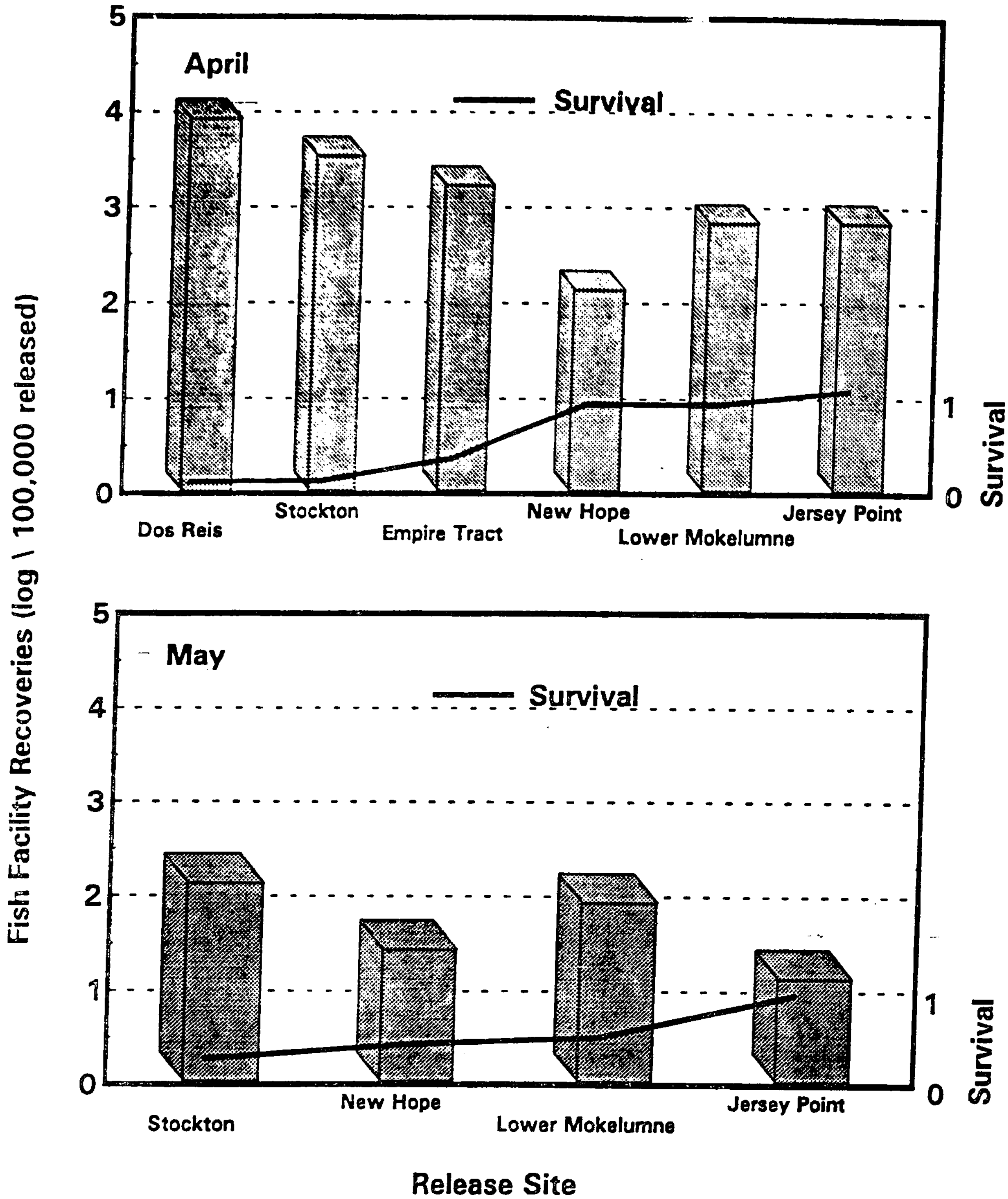


Figure 13. Combined CVP and SWP fish facility recoveries (log per 100,000 released) and temperature corrected survival to Chipps Island for groups of CWT'd fish released in the South Delta in 1991.

Table 16. Proportion of tags recovered at the CVP and SWP fish facilities. Proportions calculated by expansion of tag recoveries for groups released in the South Delta divided by the number released.

Release site	APRIL CVP+SWP	MAY CVP+SWP	RATIO April/May
Jersey Point	.0056	.0001	56
Lower Mokelumne	.0058	.0008	7
New Hope	.0012	.0002	6
Empire Tract	.0160		
Stockton	.0299	.0012	25
Dos Reis	.0776		

unexpected since the State Water Projects' Clifton Court Forebay is the nearest diversion facility to which the salmon smolts are exposed when drafted south in south delta channels other than Upper Old River.

We have some indication from trawling at Mossdale that a large group of the Dos Reis fish (the number recovered in the trawl was 296) were actually carried upstream past the junction of Upper Old River and most likely were diverted to the Federal Fish Facility via Upper Old River and thus that may be why we saw a larger proportion of this group at the Federal Facility than at the State Facility (Figure 11). This also would have a tendency to underestimate survival for this group since some of this group was diverted via Upper Old River where survival has historical been less. All of our past data from the Dos Reis releases during low inflow conditions likely suffer this survival bias and would indicate that the differences between survival of the Dos Reis and Upper Old River groups are greater than the raw survival indices would reflect.

Past research by the Fish Facility Program on predation rates in Clifton Court Forebay has indicated that losses through the Forebay for chinook smolts can be a high as 85%. If this is true, the expanded number of fish diverted to the State Fish Facility would be much higher. For instance, for the Stockton group released in April, 2635 and 338 marked fish (expanded for effort) were recovered at the State and Federal Fish Facility, respectively. The total number of fish released from this release group was 99,341. Approximately, 3.0 % of the group was recovered at the Fish Facilities and survival indices to Chipps Island was about 25%. To standardize our Chipps Island estimates to absolute estimates we divide by 1.8. This results in an survival estimate of 14%. So far we have been able to account for less than 20% of the total release group. Given that predation in Clifton Court is 85 % we can then account for 17,566 more fish, another 18% of the release group for a total accounting of the group of 35%. This would indicate that the indirect pumping mortality (that occurring in delta channels), before they get to the facilities and Clifton Court Forebay is significant (in this example 65%).

Model Verification

If we assume that the Stockton release group most represents the survival of fish migrating down the San Joaquin River if a barrier was in place, we can then verify the model we have developed to represent survival with a barrier present. Flow at Stockton averaged about 100 cfs while exports averaged about 4283 cfs and 2613 cfs in April and May respectively. Our model estimates that under these conditions survival was predicted to be .24 in April and .28 in May. If we divide these estimates by 1.8, as we have to obtain absolute survival in the Sacramento

Delta, we obtain .13 and .16 for April and May respectively. Our observed survival estimates (corrected for temperature) was .14 in April and .31 in May. This comparison appears to tell us that we may have underestimated the impact of exports on salmon smolt survival through the San Joaquin Delta in our theoretical model. Additional data gathering and refinement of this model is warranted to estimate the benefits of installing a barrier for San Joaquin smolts under various flow and export conditions.

After including our 1991 data and deleting our 1985 data point we were able to find a significant ($p<0.01$) relationship between flow at Stockton and smolt survival in the San Joaquin Delta ($r=0.89$) (Figure 14). We were still unable to see a relationship with exports at this time.

During the Scoping session of the Phase II Bay Delta Hearing Process in 1991, we estimated smolt survival through the San Joauqin Delta during different time periods based on the two models discussed above and one based on escapement in the Tuolumne River in tho 1940's. The average estimate for smolt survival for a critical year without a barrier between 1978 and 1990, was .07. Our average measured survival for 1987, 1989, 1990 and 1991 for fish released in Upper Old River and Dos Reis was .11. In our recent analyses we have divided all estimates of survival obtained using our Chipps Island trawl, by 1.8.

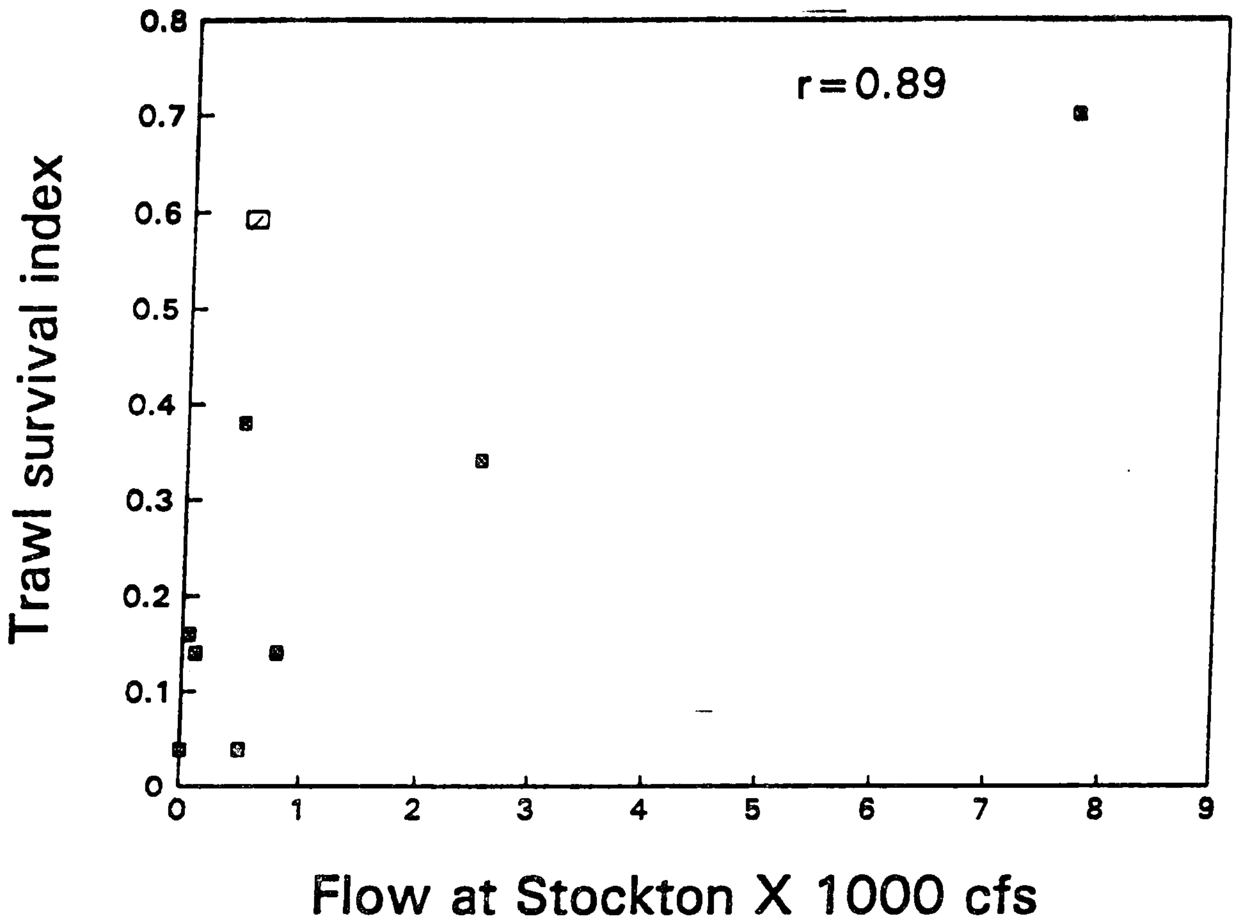


Figure 14: Flow at Stockton vesus San Joaquin smolt survival as indexed by our midwater trawl.

□ Indicates an outlier not used in the regression.

y= 0.12257 + .000076 (flow at Stockton)

Dividing .11 by 1.8 gives an estimate of survival through the San Joaquin Delta of .06. This is very close to that estimated using our without barrier model. This is reassuring considering the assumptions we made to generate smolt survival from historical escapement estimates.

Conclusions

When evaluating the results of our 1991 study as a means to predict the benefits of a barrier at the head of Upper Old River, we reached the following conclusions.

1) The group of fish most representative of fish migrating down the San Joaquin River with a barrier in place would be the Stockton release group. Releases were made in both April and May when exports were 4283 and 2613 cfs respectively. Survival after corrected for the differences in temperature was about twice as good for the low export period. This would indicate that additional benefits with a barrier can be obtained by decreasing exports simultaneously.

2) The impact of increasing the amount of water drafted from the Sacramento into the Central Delta towards the Pumping Plants did not appear to decrease survival of fish diverted into the Mokelumne from the Sacramento River in 1991. In fact the increase in flow itself in the Mokelumne system may account for

the increase in survival we saw for the group released in April in the Central Delta during the higher drafting period.

3) Although our data infers that the installation of a barrier will likely improve smolt survival through the San Joaquin Delta, it is imperative to recognize that a barrier alone most likely will not be a panacea to the mortality problems for smolts migrating down the San Joaquin. As we documented in 1991, significant smolt mortality occurs downstream of the proposed barrier. Additional measures such as increased flows and decreased exports also are needed to ensure adequate survival through the San Joaquin Delta system.

4) It also is critical that the actual barrier be placed into Upper Old River and the survival of smolts migrating down the river be measured over a wide range of environmental conditions.

FUTURE NEEDS

Results of these and previous studies in the Sacramento-San Joaquin Delta are being used in the evaluation of the benefit and costs of both operational and structural salmon protective measures for the Scoping and Water Rights phases of the Bay-Delta Water Quality Hearings and in planning for future Interagency Salmon Studies. This information also is being used in the

Article 7 negotiations called for in the Two Agency Agreement between DWR and CDFG and in the proposed State Water Project's Delta Water Management Programs.

At the present time, additional work is needed in the Southern and Central Delta where a greater uncertainty remains in our understanding of smolt survival. Also additional evaluation is needed on the impacts of the pumping plants on fry entering the Delta and the apparent relationship between adult runs and the amount of water being exported.

Additional studies on the San Joaquin Delta should include the following:

1) Evaluating San Joaquin smolt survival under a wide range of inflow and export conditions.

2) Test the benefit of a full barrier in Upper Old River to CWT smolt survival under high and low export conditions between April 15 and May 15. This is scheduled to be tested in 1992.

3) Define the likely pattern of migration through the South Delta under varied flows, export rates and tidal conditions using hydraulic modelling.

4) Continue evaluating the effect of high cross delta flow on smolt survival through the San Joaquin Delta as would occur if the SWP would utilize their full pumping capacity of 10,300 cfs. A full barrier in upper Old River with high exports would cause more reverse flows in Turner Cut, lower Old and Middle river and more closely represent conditions proposed in the SWP delta alternative projects.

5) Evaluate smolt survival in the San Joaquin Delta at varied temperatures (60° to 70°F).

The information we have to date implies that the indirect mortality associated with the pumps is significant. Perhaps under certain conditions those that live to be salvaged are a large proportion of those we see that survive to Chipps Island. During 1992, the fish facilities committee will be releasing marked fish into Clifton Court Forebay which may provide a way to measure the number of survivors at Chipps Island that are a product of the salvage process.

Our Sacramento River Delta smolt modeling and recent field studies have been successful in helping us to gain a better understanding of the potential factors influencing smolt survival in the Sacramento side of the Delta. This work has identified data gaps in need of further research. There is a need in the future:

1) to expand our knowledge to other races of salmon and the impacts of the pumping plants on their survival and distribution,

2) to evaluate smolt survival in the Central Delta under various temperature and flow conditions, and

3) to evaluate further the reasons for the high unexplained mortality in the Central Delta.

In early 1992 the cross channel gates were closed to protect winter run salmon from being diverted into the Central Delta and being impacted by the pumps. Additional work is being proposed to release late fall marked fish in February and March of 1993 to evaluate the differential mortality of being diverted into the Central Delta for the endangered winter run.

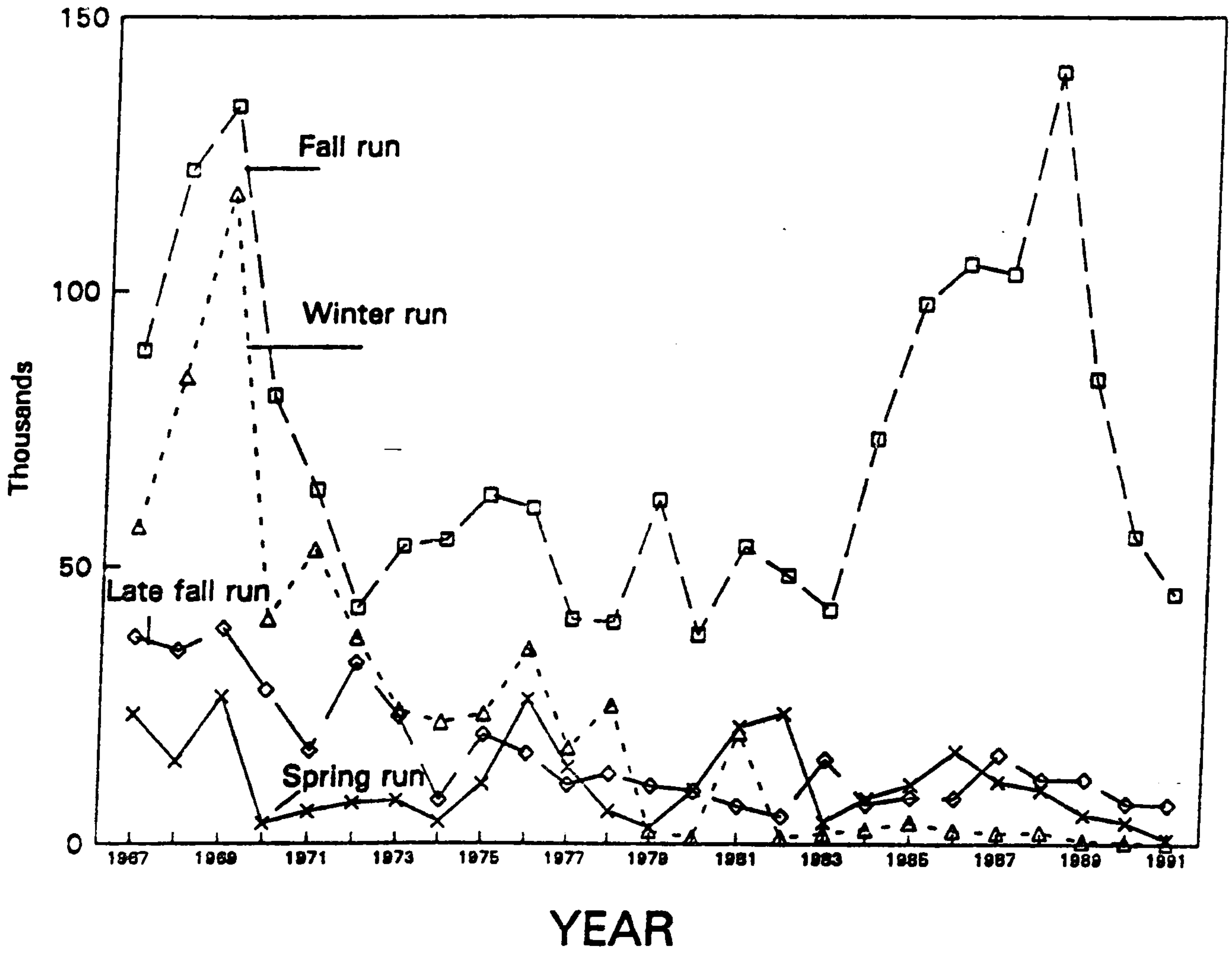
The Interagency Fisheries Committee has shown interest in an expanded salmon monitoring program for all races through out the Central Valley to run year round. The specific proposal is to be developed in early 1992 to be implemented by September of that year. Part of that proposal will evaluate other methods for monitoring the movement and distribution of juvenile salmon within the Delta.

A critical need for the salmon program that is not presently being met is the need for programming assistance in getting our past data edited and stored in a useable manner. We will explore other ways outside of the Interagency program to accomplish this task as the priorities within the Interagency have ranked this item low. It has been typical in past years, that pieces of the data set have been extracted and limited editing by non-salmon project staff was conducted. With our field programs expanding, the need to address this issue is even more critical.

Appendix 1. Ocean tag recovery rates from CWT/2T salmon fry released in the Upper Sacramento River, Delta and San Francisco Bay, 1983-1988. (Updated 02-25-92).

Year Released	CWT Code	Number Released	Release Location	Release Date	Size at Release (in mm)	Number of Expanded Recoveries in Ocean by Age 2	3	> 4	Total Recoveries (Expanded)	Recovery Rate
1980	H5-3-1	25617	Below RBDD	2/29/80	47	31	149	23	204	.007963
	H5-3-2	22574	"	2/29/80	47	9	147	5	160	.007088
	H5-3-5	21786	"	3/12/80	45	28	89	24	142	.006517
	H5-3-6	21836	"	3/12/80	45	6	128	8	142	.006503
	Total*	91813							648	.007057
	H5-2-6	22215	Clarksburg	2/26/80	50	6	27	0	33	.001485
	H5-2-7	21624	"	2/26/80	50	2	65	0	71	.003283
	H5-3-3	26012	"	3/07/80	46	2	37	2	41	.001576
	H5-3-4	20808	"	3/07/80	44	9	42	1	52	.002499
	Total*	90659							197	.002172
	H5-2-4	21937	Berkeley	2/20/80	46.4	0	1	0	1	.0000455
	H5-2-5	20726	"	2/20/80	46.4	0	0	1	1	.0000482
	Total*	42663							2	.0000468
1981	H6-1-1	39905	Below RBDD	2/06/81	41	17	38	5	59	.001478
	H6-1-5	47019	"	2/27/81	40	6	53	3	80	.001701
	Total*	86924							139	.001599
	H6-1-2	40916	Isleton	2/12/81	45	1	19	0	20	.000489
	H6-1-6	45949	"	3/04/81	43	11	58	4	73	.001588
	Total*	86865							93	.001070
	H6-1-3	45193	Mokelumne R.	2/20/81	44	2	11	0	13	.000287
	H6-1-7	45796	"	3/06/81	43	10	26	0	36	.000786
	Total*	90981							49	.000539
	H6-1-4	49705	Berkeley	2/25/81	44	0	6	0	6	.0001207
	H6-2-1	36901	"	3/11/81	43	0	0	1	1	.0000271
	Total*	86606							7	.0000808
1982	H6-2-2	41753	Below RBDD	2/05/82	44	10	150	6	166	.003975
	H6-2-6	43673	"	2/25/82	44	9	115	23	147	.003365
	Total*	85426							313	.003664
	H6-2-3	43248	Isleton	2/11/82	44	12	20	2	34	.000786
	H6-2-7	40508	"	3/02/82	45	3	5	4	11	.000271
	Total*	83756							45	.000537
	H6-2-4	43849	Mokelumne R.	2/17/82	43	0	3	9	17	.000387
	H6-3-2	41470	"	3/10/82	44	3	14	5	21	.000506
	Total*	85319							38	.000445
	H6-2-5	40699	Berkeley	2/22/82	44	0	1	5	6	.000147
	H6-3-1	39321	"	3/08/82	44	1	0	0	1	.000025
	Total*	80020							7	.000087
1983	H6-3-3	45805	Isleton	3/04/83	45	0	7	1	8	.000175
	H6-4-2	47518	"	3/29/83	49	0	26	6	32	.000673
	Total*	93323							40	.000429
	H6-3-4	48541	Courtland	3/09/83	47	0	19	0	19	.000391
	H6-4-3	48501	"	3/31/83	51	0	41	20	61	.001257
	Total*	97042							80	.000412
	H6-3-5	45960	Mokelumne	3/14/83	48	0	12	0	12	.000261
	H6-4-1	47367	"	3/24/83	49	0	34	5	40	.000844
	Total*	93327							52	.000557
	H6-3-6	47677	Old River	3/17/83	49	10	35	10	55	.001153
	H6-3-7	48580	"	3/22/83	48	0	55	2	57	.001173
	Total*	96257							112	.001163
1984	H6-4-4	43883	Below RBDD	3/02/84	45	27	74	3	104	.002370
	H6-5-4	47855	"	3/23/84	48	9	218	11	238	.004970
	Total*	91738							342	.003720
	H6-4-5	48460	Courtland	3/05/84	45	11	46	8	65	.001341
	H6-5-3	48157	"	3/21/84	48	25	131	22	178	.003696
	Total*	96617							243	.002515

	H6-4-6	45465	Ryde	3/08/84	49	2	75	4	81	.001781
	H6-5-	46767	"	3/19/84	49	6	135	0	141	.003014
	Total	92232							222	.002406
	H6-4-7	42165	NF Mokelumne	3/12/84	50	0	54	7	61	.001446
	H6-5-1	45036	SF Mokelumne	3/14/84	49	0	33	6	39	.000865
1985	H5-3-7	29136	Battle Creek	3/13/85	47	3	9	0	12	.000412
	H5-4-1	23045	"	3/13/85	47	0	0	10	10	.000433
	Total*	52181							22	.000421
	H6-5-5	49155	Below RBDD	2/14/85	47	14	60	0	74	.001505
	H6-6-5	52313	"	3/14/85	48	13	126	58	197	.003765
	Total*	101468							271	.002670
	H6-5-6	51201	Courtland	2/19/85	49	12	81	6	99	.001933
	H6-6-4	51985	"	3/07/85	46	8	80	0	88	.001692
	Total*	103186							187	.001812
	H6-5-7	49183	Ryde	2/21/85	47	7	74	2	83	.001687
	H6-6-3	50550	"	3/05/85	47	5	77	15	97	.001918
	Total*	99733							180	.001804
	H6-6-1	50002	SF Mokelumne	2/26/85	48	6	39	18	63	.001259
	H6-6-2	51145	NF Mokelumne	2/28/85	46	6	63	7	76	.001485
									139	.001374
1986	H5-7-7	51371	Battle Creek	3/18/86	50	32	172	27	221	.004302
	H6-7-5	51426	Below RBDD	3/19/86	50	23	351	43	417	.008109
	H6-6-7	50961	Courtland	2/27/86	45	0	19	2	21	.000412
	H6-7-3	53831	"	3/10/86	50	9	59	17	85	.001579
	Total*	104792							106	.001012
	H6-7-2	52635	Ryde	3/04/86	47	1	65	17	83	.001577
	H6-7-4	52748	"	3/12/86	53	3	123	0	126	.002389
	Total*	105383							209	.001983
1987	B5-4-13	51075	Battle Creek	3/12/87	51	8	67	7	82	.001605
	H6-7-7	52977	Below RBDD	3/13/87	52	10	103	2	115	.002171
	H6-7-6	48733	Courtland	3/05/87	50	0	28	0	28	.000575
1988	B5-2-6	48299	Battle Creek	2/19/88	45	0	19	0	19	.000393
	B6-14-01	48280	Below RBDD	2/22/88	45	2	108	0	110	.002280



Appendix 2: Adult chinook salmon passing by RBDD (Red Bluff Diversion Dam) of fall, late fall, winter and spring races between 1967 and 1990.

Appendix 3: Coded wire tagged smolt release and recovery information for Delta survival (So) estimates using expanded ocean tag recoveries 1/. Updated 4/08/92 (Inland hatchery Recoveries Excluded)

Year Released Location and Tag Code	Number Released	Date of Release	Number of Expanded Recoveries in ocean by Age 2	3	> 4	Total Recoveries (Expanded)	Recovery Rate
1978							
Sacramento 6-62-2	162253	6/6	24	35	0	59	.0004
Port Chicago 6-62-3	164766	6/5	881	4549	87	5517	.0330
1979							
Sacramento 6-62-5	160151	6/5	1	80	20	101	.0006
Port Chicago 6-62-6	110122	6/6	53	713	89	855	.0077
1980							
Sacramento 6-62-8	98586	6/2&3	112	922	24	1058	.0107
Sacramento 6-62-11	84642	6/4&5	54	701	21	775	.0092
Port Chicago 6-62-9	88700	6/10	266	1746	47	2059	.0232
Port Chicago 6-62-12	79443	6/13	291	1687	32	2010	.0253
1981							
Sacramento 6-62-14	71932	6/2	21	4	0	25	.00034

Appendix 3 (cont.)

Year Released Location and Tag Code	Number Released	Date of Release	Number of Expanded Recoveries in ocean by Age 2	3	≥ 4	Total Recoveries (Expanded)	Recovery Rate
Sacramento 6-62-17	68318	6/5	4	15	3	22	.00032
Port Chicago 6-62-15	78339	6/8	318	1827	42	2186	.0279
1982							
Sacramento 6-62-18 (CNFH)2/	89780	5/12	25	770	279	1076	.0120
Sacramento 6-62-20	85885	5/11	26	1065	182	1284	.0150
Port Chicago 6-62-19 (CNFH)	86877	5/17	21	467	285	777	.0090
Sacramento 6-62-21	60822	6/5	7	277	112	396	.0065
Port Chicago 6-62-22	63221	6/8	5	273	90	368	.0058
San Joaquin River 6-46-28	48227	4/24	18	380	148	546	.0113
1983							
Courtland 6-62-24	96706	5/16	20	320	39	379	.0039
Port Chicago 6-62-30	43374	5/23	18	90	21	129	.0030

Appendix 3 (cont.)

Year Released Location and Tag Code	Number Released	Date of Release	Number of Expanded Recoveries in ocean by Age 2	3	> 4	Total Recoveries (Expanded)	Recovery Rate
Isleton 6-62-23	92693	5/20	9	289	57	355	.0038
Lower Mokelumne 6-62-25	83435	5/19	0	220	51	271	.0032
Lower Old River 6-62-26	89500	5/17	0	77	17	95	.0011
1984							
Courtland 6-62-27	62604	6/11	46	293	27	366	.0058
Port Chicago 6-62-37	23558	6/29	34	159	14	207	.0089
Port Chicago 6-62-31	18442	6/29	18	57	7	82	.0004
	42000					289	.0069
SF Mokelumne 6-62-28	41371	6/12	22	195	39	256	.0062
SF Mokelumne 6-42-08	14916	6/12	5	44	2	51	.0034
	56287					307	.0055
Ryde 6-62-29	44818	6/13	15	142	24	181	.0040
Ryde 6-42-09	15180	6/13	3	64	2	69	.0045
	59998					250	.0042
NF Mokelumne 6-62-32	59808	6/14	10	213	9	232	.0039

Appendix 3 (cout.)

Year Released Location and Tag Code	Number Released	Date of Release	Number of Expanded Recoveries in ocean by Age 2	3	≥ 4	Total Recoveries (Expanded)	Recovery Rate
Lower Old River 6-62-33	64896	6/15	0	13	5	36	.0006
Golden Gate 6-54-52	48677	7/25	70	949	304	1323	.0271
Port Chicago 6-54-51	50152	7/23	74	772	214	1060	.0211
1985							
Courtland 6-62-40	10901	5/10	19	26	5	50	.0046
Courtland 6-62-39	14753	5/10	3	24	0	27	.0018
Courtland 6-62-38	54457	5/10	61	168	0	230	.0042
Courtland 6-62-41	20550	5/10	10	74	0	84	.0041
	100661					390	.0039
SF Mokelumne 6-62-34	100386	5/7	29	281	5	315	.0032
Ryde 6-62-35	107161	5/11	139	746	26	911	.0085
NF Mokelumne 6-62-36	101237	5/9	90	473	0	563	.0056
Lower Old River 6-62-42	105289	5/8	39	161	31	231	.0022

Appendix 3 (cont)

Year Released Location and Tag Code	Number Released	Date of Release	Number of Expanded Recoveries in ocean by Age 2	3	≥ 4	Total Recoveries (Expanded)	Recovery Rate
Golden Gate 6-62-44	47518	5/14	70	433	34	537	.0113
Port Chicago 6-62-45	48143	5/13	58	404	1	463	.0100
CNFH 5-6-16	10209	5/31	0	0	0	0	0
1986							
Courtland 6-62-43	98866	5/27	127	1414	134	1675	.0169
Ryde 6-62-48	101320	5/30	166	1635	165	1966	.0194
NF Mokelumne 6-62-47	101949	5/29	88	1028	162	1278	.0125
SF Mokelumne 6-62-46	102965	5/28	95	796	96	987	.0096
Lower Old River 6-62-49	98869	5/31	23	572	49	644	.0065
Port Chicago 6-62-51	47995	6/2	116	1108	141	1365	.0284
Golden Gate 6-62-52	49583	6/3	78	1555	153	1786	.0360
Upper Old River 6-46-59	107215	5/30	36	524	17	577	.0054

Appendix 3 (cont.)

Year Released Location and Tag Code	Number Released	Date of Release	Number of Expanded Recoveries in ocean by Age 2	3	> 4	Total Recoveries (Expanded)	Recovery Rate
Dos Reis 6-46-58	91040	5/29	133	831	83	1046	.0114
1987							
Courtland (gate closed) 6-62-53	49781	4/28	50	864	69	983	.0197
Courtland (gate closed) 6-62-54	50521	4/28	90	836	57	983	.0195
	100302					1966	.0196
Ryde 6-62-55	51103	4/29	124	1318	153	1595	.0312
Courtland E. (gates open) 6-62-56	49083	5/1	44	645	47	736	.0150
Courtland W. (gate open) 6-62-57	51836	5/1	46	601	46	693	.0134
	100919					1429	.0142
Ryde 6-62-58	51008	5/2	89	840	96	1025	.0201
CNFH 5-18-39	51706	5/12	13	408	36	457	.0088
(RBDD)3/ 5-18-40	51807	5/13	16	341	9	365	.0071

Appendix 3 (cont)

Year Released Location and Tag Code	Number Released	Date of Release	Number of Expanded Recoveries in ocean by Age 2	3	> 4	Total Recoveries (Expanded)	Recovery Rate
Princeton 5-18-41	51271	5/14	2	154	19	176	.0034
Upper Old River 6-45-3,4&5	90952	4/27	48	410	37	495	.0054
Dos Reis 6-45-6, 7&8	92721	4/27	55	1050	98	1203	.0129
1988							
Miller Park B6-14-06	51005	5/5	87	477	9	573	.0112
Miller Park B6-14-07	51753	5/5	85	439	16	540	.0104
	102758					1113	.0108
Courtland (gates closed) B6-14-02	51388	5/3	88	495	7	590	.0115
Courtland (gates closed) B6-14-03	55861	5/3	82	545	8	635	.0114
	107249					1225	.0114
Courtland (gates open) B6-14-04	51274	5/6	62	348	2	412	.0080
Courtland (gates open) B6-14-05	51206	5/6	65	450	7	521	.0102
	102480					933	.0091

Appendix 3 (cont)

Year Released Location and Tag Code	Number Released	Date of Release	Number of Expanded Recoveries in ocean by Age 2	3	> 4	Total Recoveries (Expanded)	Recovery Rate
Ryde (gates closed) 6-31-1	52741	5/3	99	952	16	1068	.0202
Ryde (gates open) 6-31-2	53238	5/6	149	1151	25	1325	.0249
CNFH 5-19-39	51923	5/9	40	342	12	393	.0076
RBDD 5-19-40	52796	5/10	40	423	4	467	.0088
Princeton 5-19-41	52771	5/11	59	353	5	416	.0079
Benicia 5-18-42	51651	5/17	34	291	8	333	.0064
Miller Park 6-62-61	49245	6/23	7	70	2	80	.00162
Miller Park 6-62-62	48647	6/23	4	51	7	63	.00130
	97892					143	.00146
Courtland (gates closed) 6-62-59	54997	6/21	30	494	26	550	.01000
Courtland (gates closed) 6-62-60	51904	6/21	38	428	18	484	.00932
	106901					1434	.01341

Appendix 3 (cont)

Year Released Location and <u>Tag Code</u>	Number <u>Released</u>	Date of <u>Release</u>	Number of Expanded Recoveries in ocean by Age <u>2</u>	<u>3</u>	<u>≥ 4</u>	Total Recoveries <u>(Expanded)</u>	Recovery <u>Rate</u>
Courtland (gates open) 6-62-50	99827	6/24	10	60	0	70	.00070
Ryde (gates closed) 6-62-63	53961	6/22	30	210	8	249	.00461
Ryde (gates open) 6-31-3	53942	6/25	21	246	18	285	.00528
Steamboat Sl. 6-31-5	49342	6/24	7	171	4	182	.00369
Steamboat Sl. 6-31-6	<u>47975</u>	6/24	12	183	12	<u>206</u>	<u>.00429</u>
	97317					388	.00399
Port Chicago 6-31-4	54151	6/29	96	916	12	1024	.01890
<u>1989</u>							
Dos Reis 6-31-14	52962	4/20	7	26		33	.00062
Upper Old River 6-31-13	51972	4/21	11	27		38	.00073
Jersey Point 6-1-11-1-11	27758	4/24	3	77		80	.00288
Jersey Point 6-1-11-1-12	<u>29058</u>	4/24	11	73		<u>84</u>	<u>.00289</u>
	56816					164	.00289

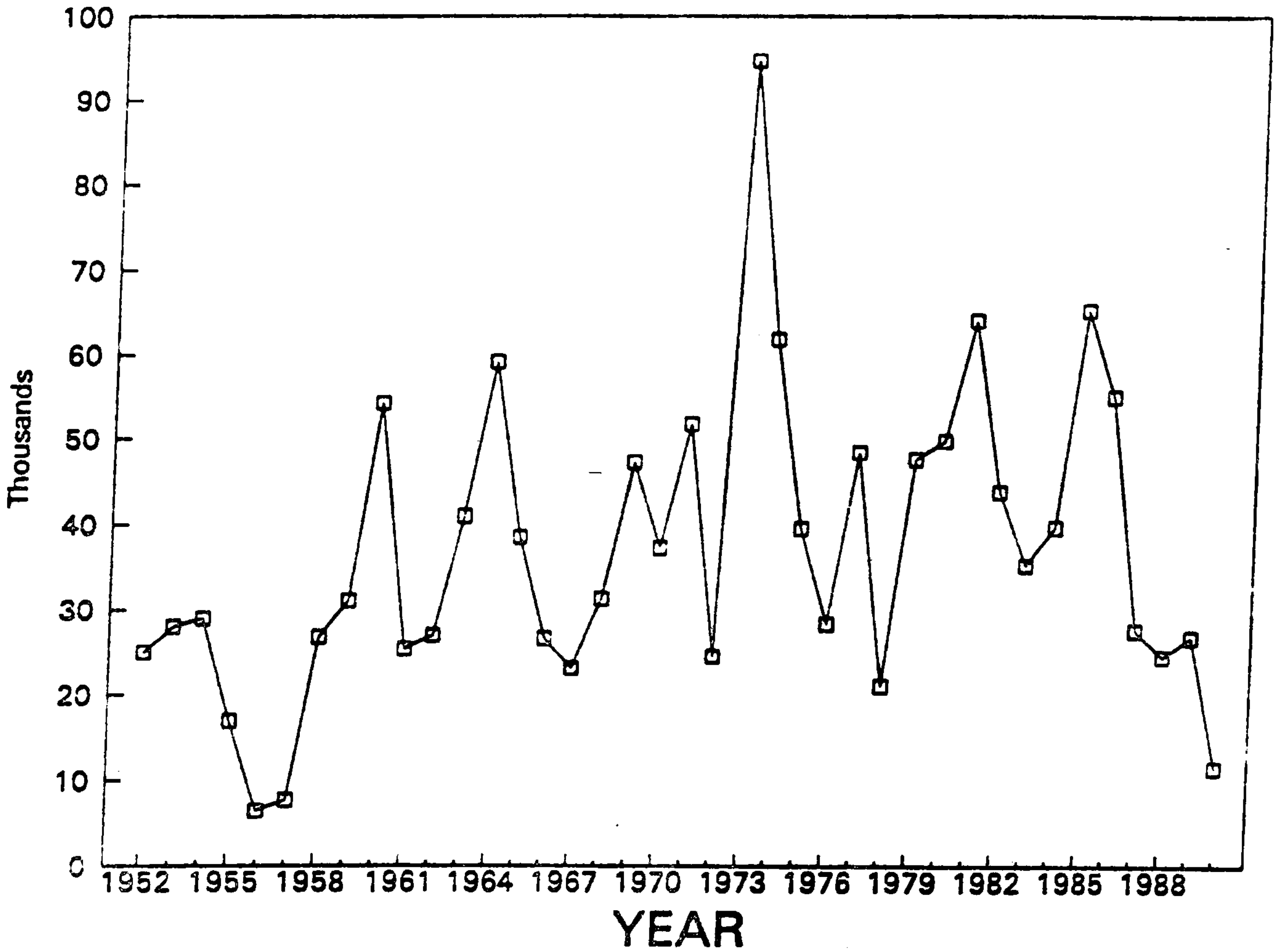
Appendix 3 (cont)

Year Released Location and Tag Code	Number Released	Date of Release	Number of Expanded Recoveries in ocean by Age 2	3	≥ 4	Total Recoveries (Expanded)	Recovery Rate
Dos Reis 6-1-11-1-7	25089	5/2	7	17		24	.00096
Courtland 6-31-11	51211	5/2	72	176		248	.00484
Upper Old River 6-1-11-1-6	24782	5/3	9	2		11	.00044
Ryde 6-31-12	51046	5/3	127	264		391	.00766
Jersey Point 6-1-11-1-9	27525	5/5	8	124		132	.00480
Jersey Point 6-1-11-1-10	28708	5/5	15	119		134	.00467
	56233					266	.00473
CNFH 5-20-37	51074	5/8	34	41		75	.00147
(RBDD)4/ 5-20-38	52677	5/9	25	62		87	.00165
Princeton 5-20-39	50842	5/10	11	73		84	.00165
Benicia 5-20-40	39379	5/15	2	169		171	.00434

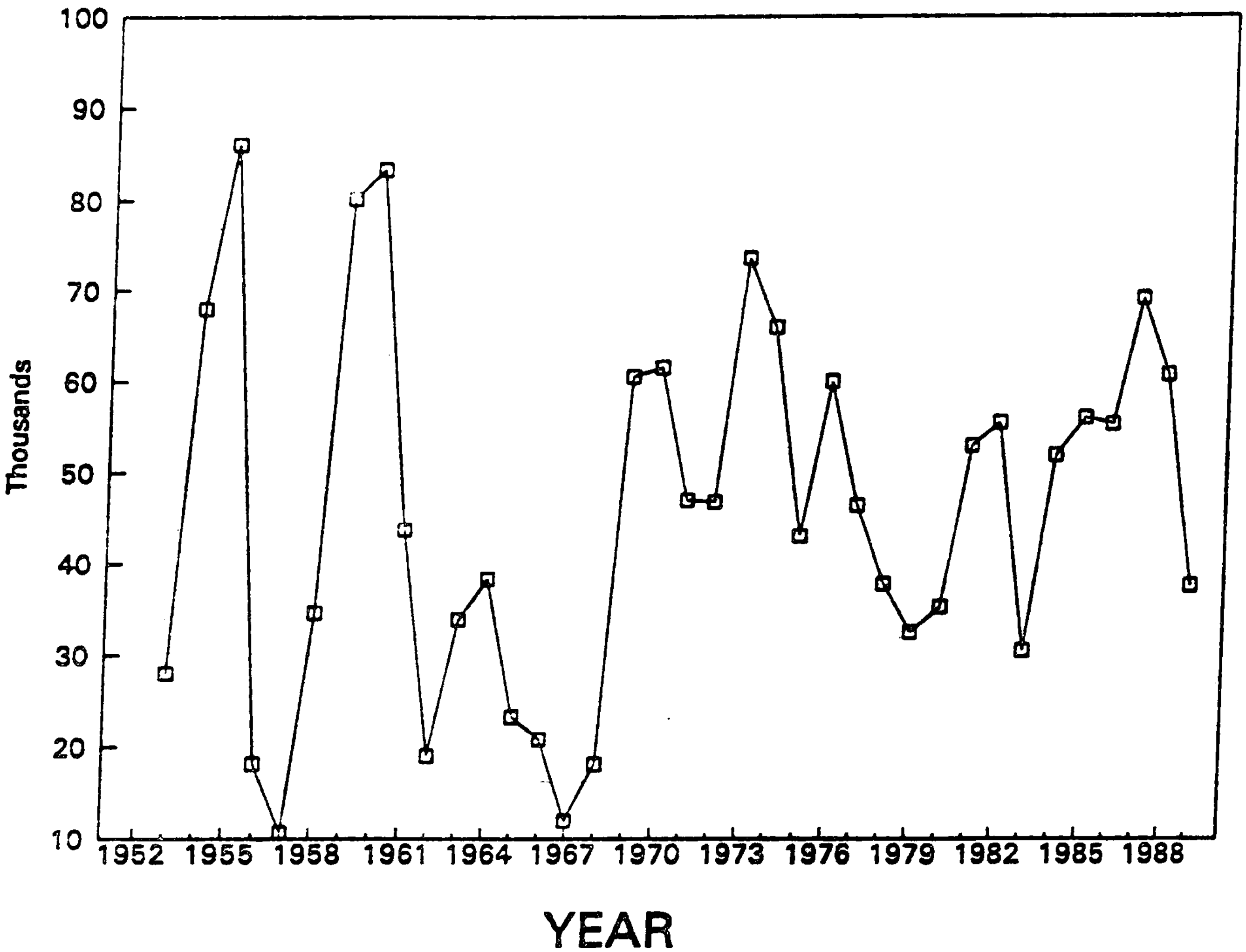
Appendix 3 (cont)

Year Released Location and Tag Code	Number Released	Date of Release	Number of Expanded Recoveries in ocean by Age 2	3	> 4	Total Recoveries (Expanded)	Recovery Rate
Miller Park 6-31-10	52612	6/1	18	59		77	.00146
Courtland 6-31-8	50659	6/2	5	37		42	.00083
Ryde 6-31-7	50601	6/2	27	55		82	.00162
Port Chicago 6-31-9	51760	6/5	23	153		176	.00340
Sutter Slough 6-31-16	49762	6/13	18	116		135	.00271
Steamboat Slough 6-1-14-1-1	51237	6/13	7	51		58	.00114
Miller Park 6-31-15	44695	6/14	10	23		33	.00074
Courtland 6-1-14-1-3	52907	6/15	10	37		47	.00089
Port Chicago 6-1-14-1-4	48329	6/19	62	273		336	.00695
Ryde 6-1-14-1-2	51134	6/16	10	0		10	.00020

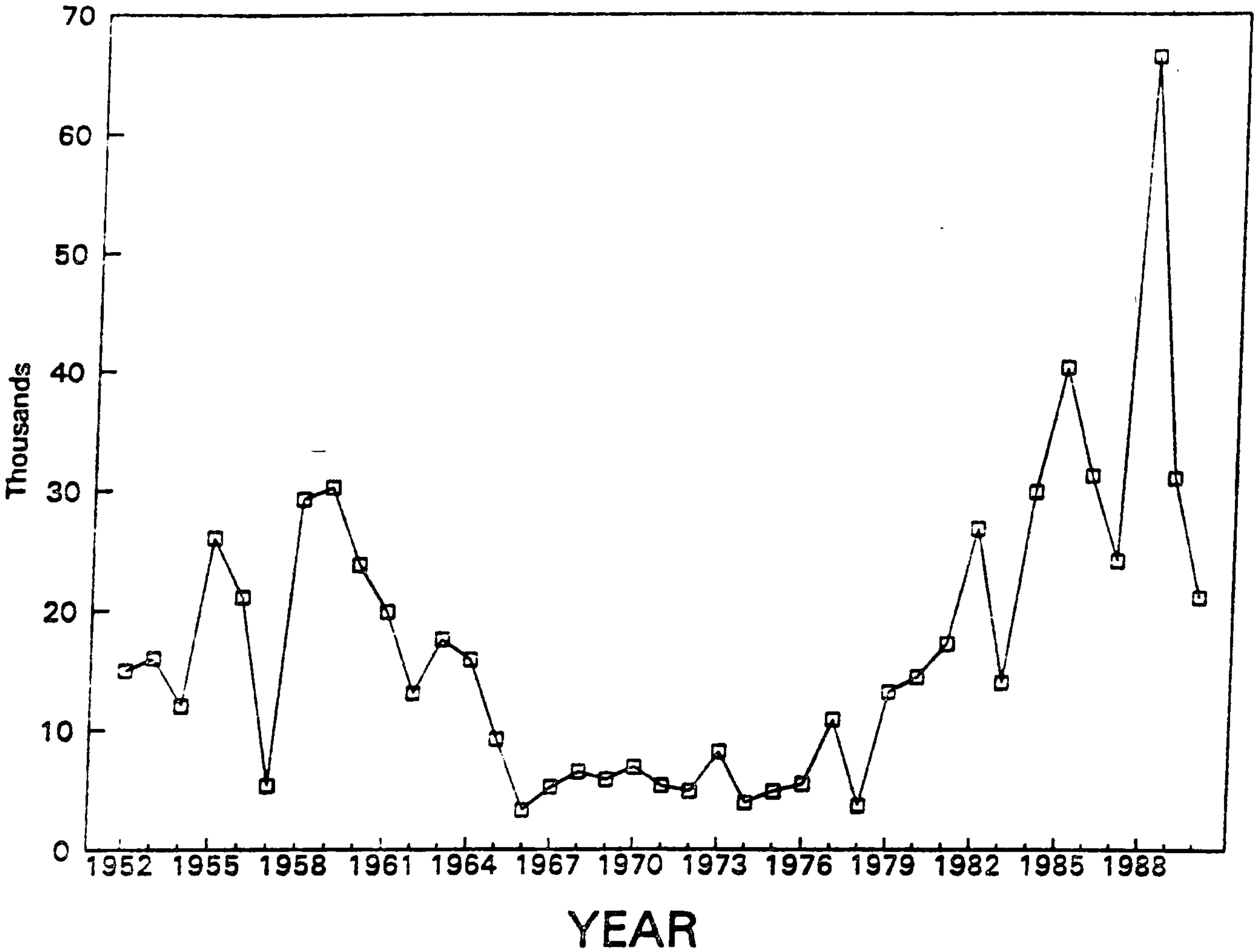
1/ All CWT salmon used in this experiment were from Feather River Hatchery (FRH) unless noted otherwise.
2/ Coleman National Fish Hatchery (CNFH)
3/ Fish released above Red Bluff Diversion Dam (RBDD)
4/ Fish released below RBDD



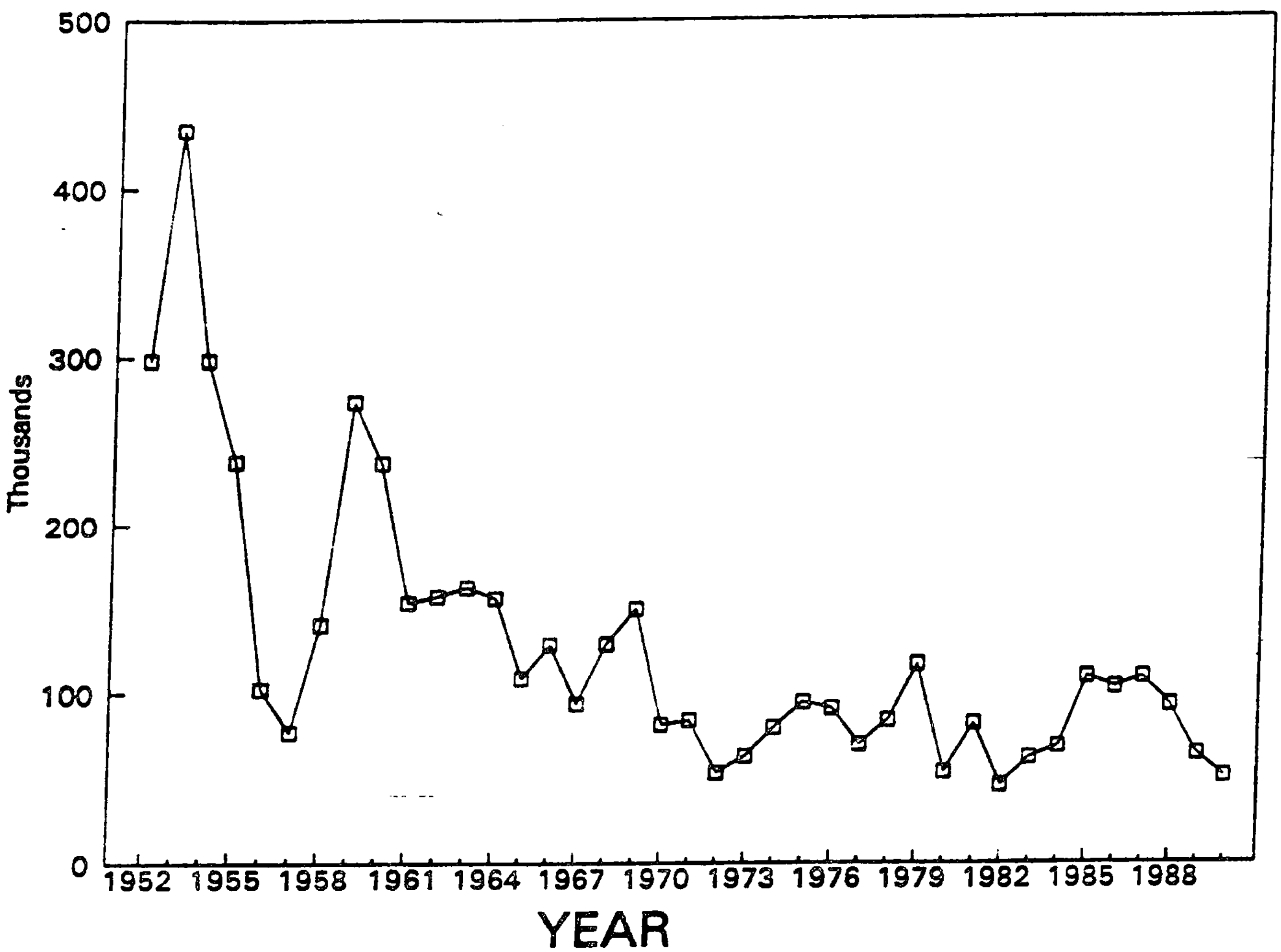
Appendix 4: **Fall-run chinook spawning escapements in the American River between 1952 and 1990.**



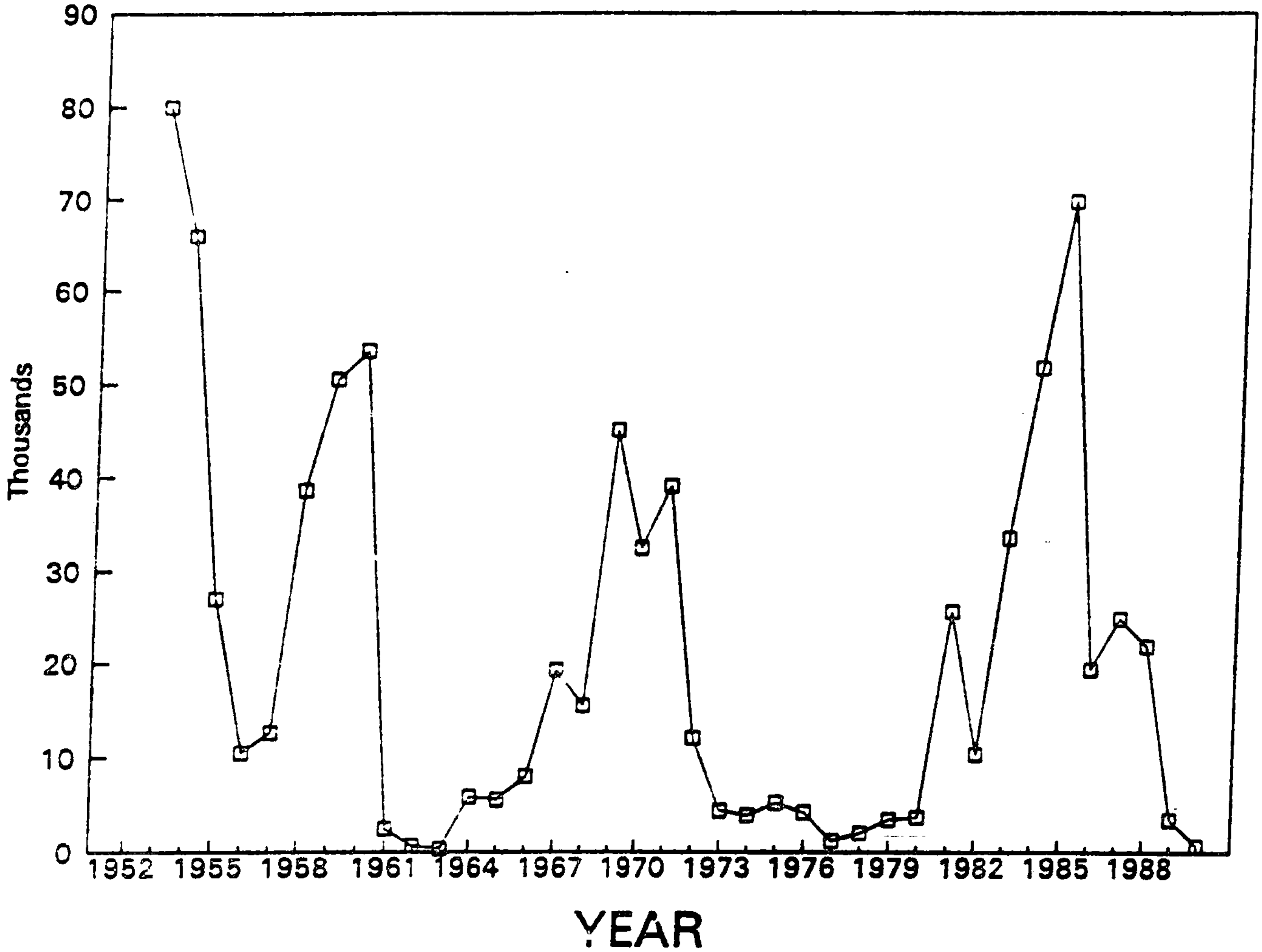
Appendix 5: Fall-run chinook spawning escapement in the Feather River between 1953 and 1990.



Appendix 6: Fall run spawning escapements in Battle Creek between 1952 and 1990.



Appendix 7: Natural fall run spawning escapement in the Sacramento River between 1953 and 1990.



Appendix 8: Total natural fall run spawning escapement

in the Stanislaus, Tuolumne and Merced Rivers between 1952 and 1990.

Appendix 9. Release, recovery and survival data (S_t) for Feather River coded wire tagged (CWT) for fish released throughout the Delta and recovered in the midwater trawl sampling at chipps Island, from 1978 to 1987.

Year	Tag Code	Release Site	Release Date	Number Released	Number Recovered at Chipps Island	Fraction of time sampled	Survival Index (S_{T}	Temp at Release °F	Size at Release (in mm)
1978	6-62-02	Sacramento	6/5,6/6	162,253	0		0	73°	91
1979	6-62-05	Sacramento	6/2-6/5	160,157	50	.0953	.42	68°	75
1980	6-62-08	Sacramento	6/5	98,586	34	.1360	.33		
1980	6-62-11	Sacramento	6/10	84,642	31	.1361	.35		
Total				183,228	65			62°	96
1981	6-62-14	Sacramento	6/4	71,932	1				
1981	6-62-17	Sacramento	6/4	68,318	0				
Total				140,249	1	.1111	.0083	76°	90
1982M	6-62-20	Sacramento	5/11	85,885	100	.1021	1.48	60°	76
1982J	6-62-21	Sacramento	6/4	60,822	31	.1028	.64	68°	76
1983	6-62-23	Isleton	5/20	92,693	95	10	1.33	61°	81
1983	6-62-24	Courtland	5/16	96,706	92	.1111	1.06	60°	79
1983	6-62-25	Lower Mokelumne	5/19	83,435	73	10	1.13	63°	75
1983	6-62-26	Lower Old River	5/17	89,500	23	10	.33	63°	76
1984	6-62-27	Courtland	6/11	62,604	37	.1175	.61	66°	82
1984	6-62-29	Ryde	6/13	44,818	37	10	1.05	66°	77
1984	6-62-32	NF Mokelumne	6/14	59,808	24	10	.51	67°	79
1984	6-62-28	SF Mokelumne	6/12	41,371	33	12	.86	67°	77
1984	6-62-33	Old River	6/15	64,896	9	11	.16	75°	73

Year	Tag Code	Release Site	Release Date	Number Released	Number Recovered	Fraction of Time Sampled	Survival Index (S^T)	Temp at Release °F	Size at Release (mm)
1985	6-62-38	Courtland	5/10	54,457	23		.395		
1985	6-62-39	Courtland	5/10	14,753	2		.126		
1985	6-62-40	Courtland	5/10	10,901	3		.258		
1985	6-62-41	Courtland	5/10	20,550	9		.410		
Total				107,162	37	.1388	.32	64°	78
1985	6-62-35	Ryde	5/11	107,162	88	14	.77	66°	78
1985	6-62-32	NF Modelumne	5/9	101,238	30	14	.28	65°	77
1985	6-62-34	SF Mokelumne	5/7	100,386	25	14	.23	64°	75
1985	6-62-42	Lower Old River	5/8	91,200	20	14	.21	68°	84
1986	6-62-43	Courtland	5/28	104,000	39	.1387	.35	73°	81
1986	6-62-48	Ryde	5/28	101,320	74	14	.68	74°	81
1986	6-62-47	NF Mokelumne	5/29	101,949	32	11	.36	72°	74
1986	6-62-46	SF Mokelumne	5/30	102,965	24	12	.26	68°	77
1986	6-62-49	Lower Old River	5/31	98,869	24	14	.23	74°	78
1987[1]	6-62-53	Courtland	4/28	49,781	32		.60		
1987[1]	6-62-54	Courtland	4/28	50,521	39		.72		
Total				100,302	71	.1383	.67	66.5°	81
1987[2]	6-62-56	Courtland	5/1	49,083	20		.39		
1987[2]	6-62-57	Courtland	5/1	51,836	23		.42		
Total				100,919	43	.1383	.40	66.5°	79
1987[1]	6-62-55	Ryde (gates closed)	4/29	51,103	46	14	.85	67°	79
1987[2]	6-62-85	Ryde (gates opened)	5/2	51,008	47	14	.88	64°	80

[1] Cross channel gates at Walnut Grove (diversion point) closed.
[2] Cross channel gates at Walnut Grove opened.