MEASURES TO IMPROVE THE PROTECTION OF CHINOOK SALMON IN THE SACRAMENTO/SAN JOAQUIN RIVER DELTA

EXPERT TESTIMONY OF
UNITED STATES FISH AND WILDLIFE SERVICE
ON
CHINOOK SALMON TECHNICAL INFORMATION

FOR

STATE WATER RESOURCES CONTROL BOARD
WATER RIGHTS PHASE OF THE
BAY/DELTA ESTUARY PROCEEDINGS
JULY 6, 1992

WRINT-USFWS-7

TABLE OF CONTENTS

Introduction

Chinook salmon constitute one of a variety of fish and wildlife public trust resources in the Bay/Delta Estuary. This exhibit provides information with which the State Water Resources Control Board can determine what immediate interim, near term actions should be taken that will help restore the environment for salmonid resources in the Delta, halt their long term decline and increase their overall protection in the estuary. While this testimony is submitted by the U.S. Fish and Wildlife Service, it reflects the results of studies conducted by the Service under the Interagency Ecological Study Program and incorporate evaluations by the Five Agency Salmon Management Group. This report is meant to be technical in nature. Service recommendations as to the specific choice of interim salmon protection measures to adequately protect the salmon resources in the Estuary, short and long term protection goals and testimony on other issues will be provided in separate Service exhibits.

The Five Agency Salmon Management Group was formed to evaluate the relative benefits and costs of operational and structural measures to improve the protection of salmon in the Central Valley (DFG Exhibit No. 65 - Department of Fish and Game, 1987). Members include the California Departments of Fish and Game (DFG) and Water Resources (DWR), U.S. Fish and Wildlife Service (USFWS), U.S. Bureau of Reclamation (USBR), and the National Marine Fisheries Service (NMFS). The Delta team of that group was assigned the task of evaluating protective measures to be implemented in the Delta. This included appropriate coordination with the San Joaquin and Sacramento River teams of the Five Agency Group.

The majority of technical information presented here has been presented, reviewed and discussed in numerous meetings and work sessions by the Five Agency staff since 1987. Service staff has recently updated some of the analysis after this information was provided to the Board staff during the Scoping Phase of these proceedings in the spring and summer of 1991. We also have provided new information based on the 1991 and 1992 sampling and coded wire tagged smolt experiments.

The Service itself assumes responsibility for this Exhibit and invites other members of the Five Agency Salmon Group to make any clarifying remarks or corrections on any information herein, should they deem it necessary.

Delta team reports of March 1991 and June 1991, along with exhibits from the 1987 Proceeding record (DFG Exhibit 15 and USFWS Exhibit 31) and Kjelson, et. al., 1989 (WQCP-USFWS-1). Annual Reports of 1988, 1989, 1990 (WQCP-USFWS-2 and 2a through 4 and EIRSP-USFWS-4), and 1991 (WRINT-USFWS-9) are the primary basis for this written testimony.

Kjelson, et. al., 1989 and Service Annual Reports 1988-1990 have been previously submitted to the Board since 1987. Additional useful information on Central Valley Salmon is provided in DFG, 1990 (Central Valley Salmon and Steelhead Restoration and Enhancement Plan, California Department of Fish and Game, April 1990, compiled by Reynolds, et. al). Additional escapement values provided by DFG, Red Bluff, Dick Painter, personal communication. The reader is directed to these documents for detailed background information.

The documents noted above that were submitted to the Board for the 1991 Water Quality Control Plan (WQCP-USFWS-1 through 4) and for the Scoping Phase (EIRSP-USFWS-4) are listed below for ease of reference.

WQCP-USFWS-1	Kjelson, M.; Greene S.; and Brandes, P: 1989, A Model for Estimating Mortality and Survival of Fall-Run Chinook Salmon Smolts in the Sacramento River Between Sacramento and Chipps Island, 50 pp.
WQCP-USFWS-2 WQCP-USFWS-2A	U.S. Fish and Wildlife Service. Survival and Productivity of Juvenile Salmon in the Sacramento-San Joaquin Estuary 1989 Annual Progress Report, Stockton, CA Fisheries Assistance Office. 59 pp. and Errata Sheet 2 pp.
WQCP-USFWS-3	U.S. Fish and Wildlife Service. Survival and Productivity of Juvenile Salmon in the Sacramento-San Joaquin Estuary 1988 Annual Progress Report, Stockton, CA Fisheries Assistance Office. 60 pp.
WQCP-USFWS-4	Kjelson, M.; Loudermilk, B.; Hood, D; and Brandes, P. The Influence of San Joaquin River Inflow, Central Valley and State Water Project Exports and Migration Route on Fall-Run Chinook Smolt Survival in the Southern Delta During the Spring of 1989. February 1990, 45 pp.

EIRSP-USFWS-4 U.S. Fish and Wildlife Service. Abundance and Survival of Juvenile Chinook Salmon in the Sacramento-San Joaquin Estuary, 1990 Annual Progress Report, Stockton, CA., Fishery Resources Office, 133 pp.

The purpose of this technical exhibit is to:

1. Provide an update on the status of Central Valley chinook salmon stocks and a brief review of salmon life history in the estuary.

2. Describe the approach of improving outmigrant juvenile salmon survival in the Delta as a measure to help restore salmon stocks in the Central Valley.

3. Describe the key problems for juvenile salmon in the Delta and a listing of operational and structural measures that would likely correct them.

4. Describe models that estimate juvenile salmon outmigrant survival in the Delta and their use in quantifying the benefits of varied protective measures and historic habitat protection goals.

5. Provide alternative sets of interim requirements that yield a range of protection for salmon.

6. Provide ideas on appropriate methods of defining long term goals for the protection of salmon in the Delta.

Status of Central Valley Chinook Salmon Stocks

The Central Valley has supported average annual runs of 272,000 chinook salmon during the last ten years and has contributed an average of 365,000 fish to ocean fisheries. Eighty-nine percent of the spawner escapement has been to the Sacramento Basin and 11 percent to the San Joaquin system. Fall-run now make up 88% of the Central Valley population. Historically, Valley populations were comprised mostly of spring-run chinook. Construction of dams prevented spring-run access to historic spawning areas and presently this race makes up only 5 percent of the total Valley run (DFG, 1990).

Sacramento Basin

There are four distinct races of chinook salmon in the Sacramento basin each one named for the time period they first enter fresh water (Figure 1). Fall-run fish in the upper Sacramento have increased in recent years attributed largely to improved production of hatchery fish with escapement averaging about 100,000 fish since 1985. Runs of wild fall run chinook remain low and are decreasing. Spring-run on the main stem Sacramento are included with fall-run counts as the two races now spawn in the same regions. A minor population of spring-run may remain in Mill and Deer Creeks. Late fall-run salmon in the Sacramento have declined by about two-thirds since the 1960's and now average about 10,000 spawners. Winter-run have suffered a major decline since the 1960's and in recent years spawner counts have been under 1,000 fish (191 in 1991). The drop in winter-run has caused them to be listed Federally as "threatened" and State as "endangered".

Stocks in the American and Feather Rivers are heavily supported by hatchery production on those two streams. Since the early 1980's, the majority of the hatchery production from the two State operated hatcheries has been released downstream of the Delta. Spawner counts on the Feather in the past five years have averaged 1,660 spring-run and 50,200 fall-run. Escapement of fall-run chinook in the Yuba River, considered to be primarily wild fish, has averaged 18,000 fall-run. The ten year average on the American River has been 46,700 fall-run fish (DFG 1990).

San Joaquin Basin

Fall-run chinook spawn in six tributary streams of the San Joaquin River. Annual escapements in the Mokelumne River have averaged 6,600 fall-run in the past decade. Consumnes River escapement has averaged 200 fish. Spawning on the Calaveras River for both fall and winter-run appears to be very low. These

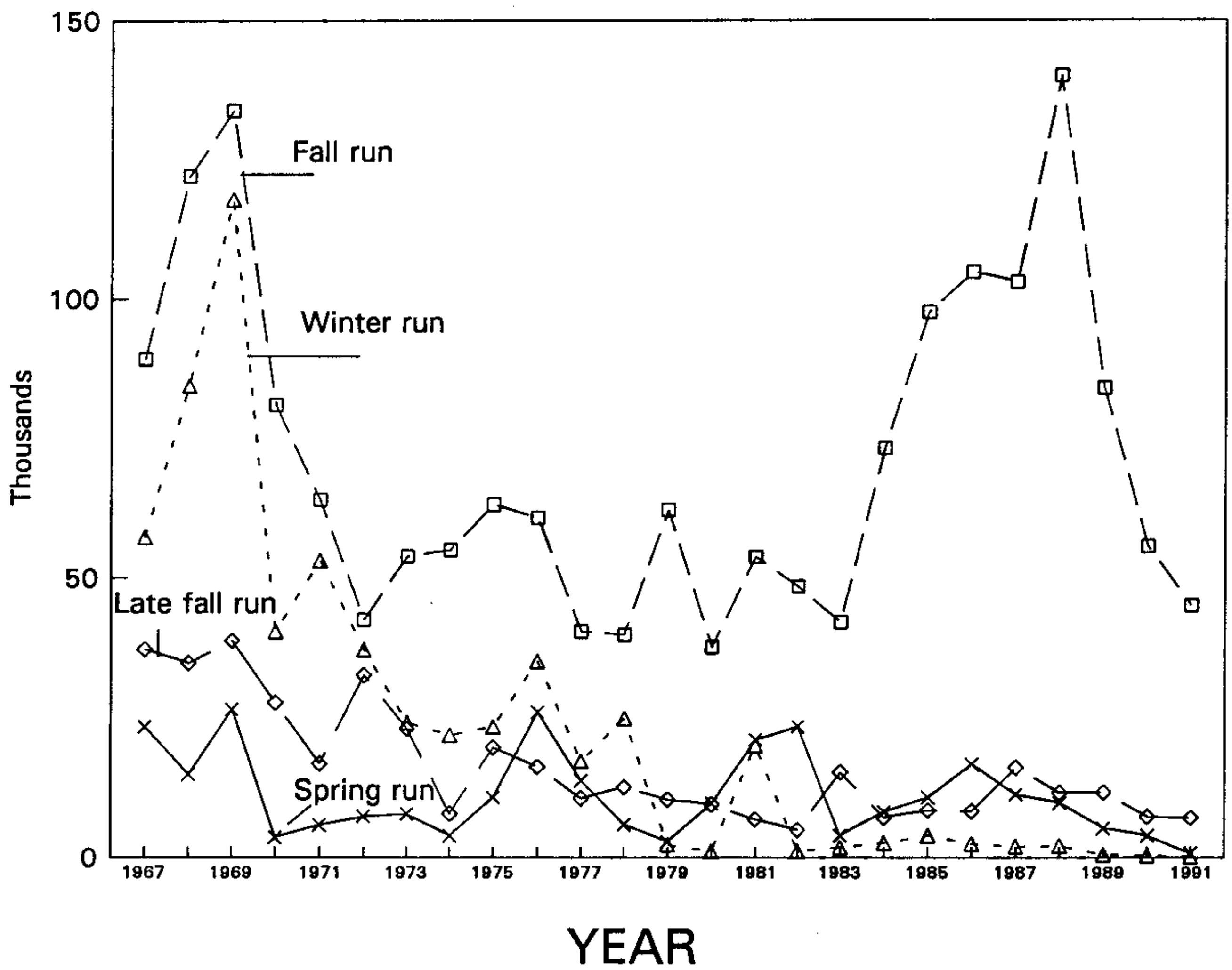

Figure 1: Adult salmon passing by RBDD (Red Bluff Diversion Dam) of fall, late fall, winter and spring races between 1967 and 1990.

three tributary streams, which enter the San Joaquin River in the Delta, have been impacted greatly in the recent six drought years and population levels are extremely low (100's of fish in the Mokelumne and no spawners in the Consumnes or Calaveras.

Average escapements to the Stanislaus, Tuolumne and Merced Rivers in the past decade have been helped by high stream-flow during several spring emigration periods 2½ years prior. Fall-run escapement during the 1980's have averaged 13,000 for the Merced, 14,000 for the Tuolumne and 5,500 for the Stanislaus (DFG 1990 and Figure 2). The Merced River is supported by a yearling hatchery production program. As with the Delta tributary population, recent drought years (since 1987) have resulted in poor spawner numbers in Stanislaus, Tuolumne, and Merced in 1989 and 1990 (total <3500 fish). Spawner numbers for these three streams further dropped to 620 in 1991 and reflect one of the lowest counts in history (1963 was 320).

Salmon Life History in the Delta

The four races of Chinook salmon found in the Central Valley utilize the Delta primarily as a juvenile and adult migration corridor from and to upstream spawning and rearing grounds. Rearing of chinook (particularly fall-run) also occurs in the Delta.

Adult salmon are migrating through the Delta during all months of the year with time frames specific to each run. The greatest numbers of adults are present between about July and November (Fall-run) while the endangered/threatened winter run adults are present in the late winter and early spring.

Rearing of chinook fry in the Delta is most common following periods of high river flows from January through March when fall-run fry are present. Winter-run fry may move into the Delta during the fall if river flows increase with early rains. Spring-run fry also may use the Delta for some rearing.

Migrating smolts are most abundant during the April through June period, again reflecting fall-run. Winter-run smolts appear most numerous in the Delta during the January to April period. We will subsequently use the term smolt, salmon that are migrating to the ocean, to represent all juveniles and yearlings.

Yearling salmon migration through the Delta is not well documented but likely occurs in the fall and winter months reflecting fall, late-fall and spring run fish that have "held over" in cooler upstream waters.

More specific information on the timing of runs in the Delta by life stage are provided in the aforementioned documents. The

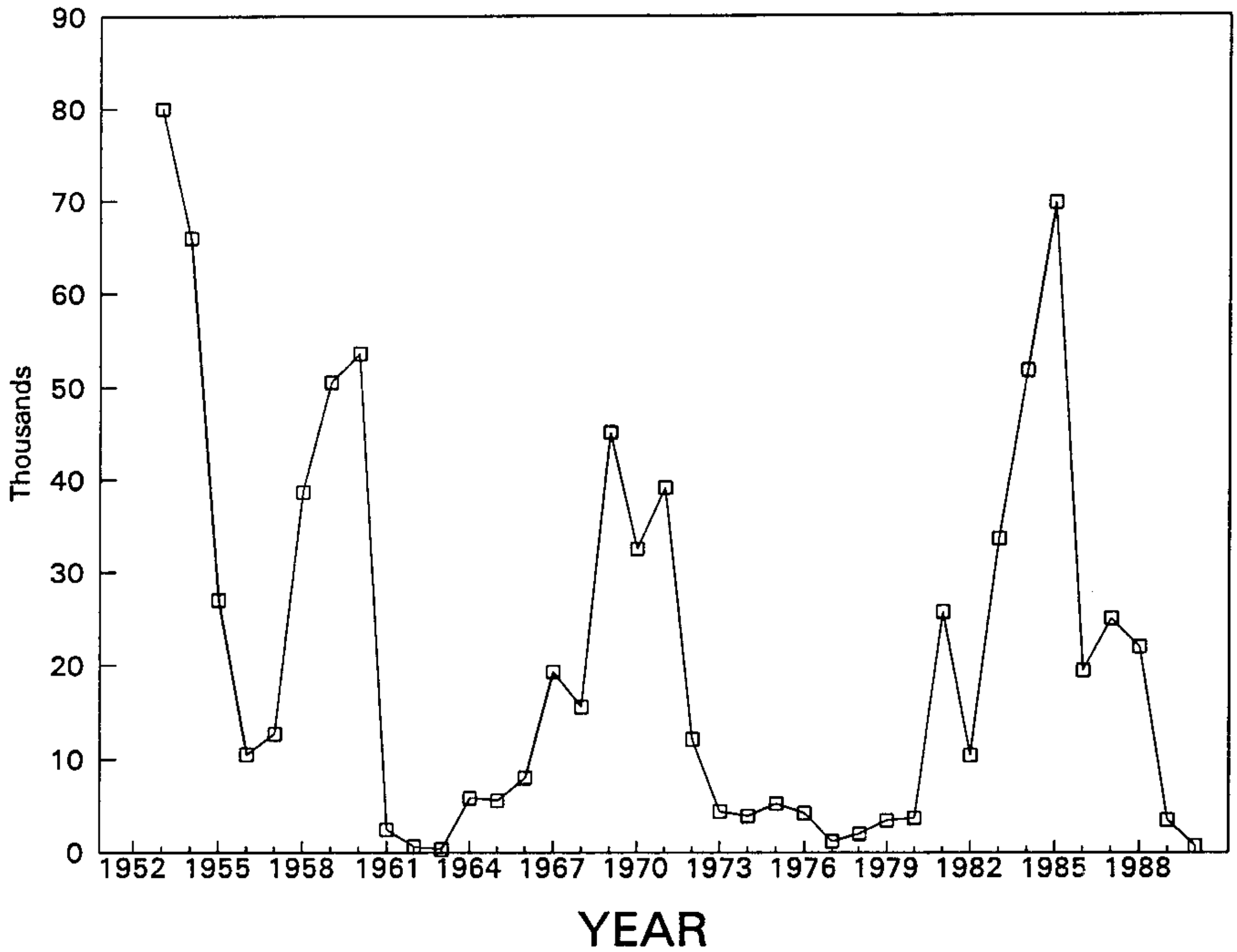

Figure 2: Total natural fall run spawning escapement in the Stanislaus, Tuolumne and Merced Rivers between 1952 and 1990.

specific time period of salmon presence in the Delta is of major importance in defining the implementation period of a given protective measure and in assessing the benefits of such action.

Restoration of Salmon Stocks Through Improved Delta Smolt Survival

The earlier discussion of the status of Central Valley salmonid resources indicates that essentially all of these runs have declined since records are available (Figure 1). This is particularly true for the natural (non hatchery) stocks (Figures 2 and 3). Adult salmon population abundance is related to what occurs not only in the estuary but also the ocean and upstream habitats. Hence, in determining means whereby salmon stock abundance can be restored there are a variety of possible choices in inland, estuarine and oceanic environments.

Regardless of this fact, it is important to understand that improved smolt survival through the Delta will produce an equal increase in adult ocean recruitment for that brood year unless bay and ocean survival are density dependent. Greater historic salmon runs provide reason to believe that bay and ocean survival is not limited by present salmon densities. An increase in ocean recruitment should result in improved catch and escapement.

Given the above and the scope of this proceeding and this exhibit (i.e., to identify interim actions to improve salmon protection), we concluded that concentrating our evaluation on measures to improve smolt survival through the Delta would be the most productive approach. These measures concentrated on smolt protection for fall-run chinook for the April-June period since we have the most data for this group of salmon. Protective actions for other races and life stages are generally the same as for fall-run smolts since we assume factors influence fall-run survival are applicable to the others. Some exceptions are evident, such as temperature, which does not appear limiting for salmon during the winter months. The timing of implementation of key protective actions for the varied races and life stages is the primary difference between the different populations and stages.

Problems for Juvenile Salmon Outmigrants in the Delta

Salmon at all life stages face a variety of problems to their survival and general well being during their residence in and migration through the Delta. Some of these, such as high water temperature and low dissolved oxygen have been addressed in part by the Board's Water Quality Control Plan of 1991.

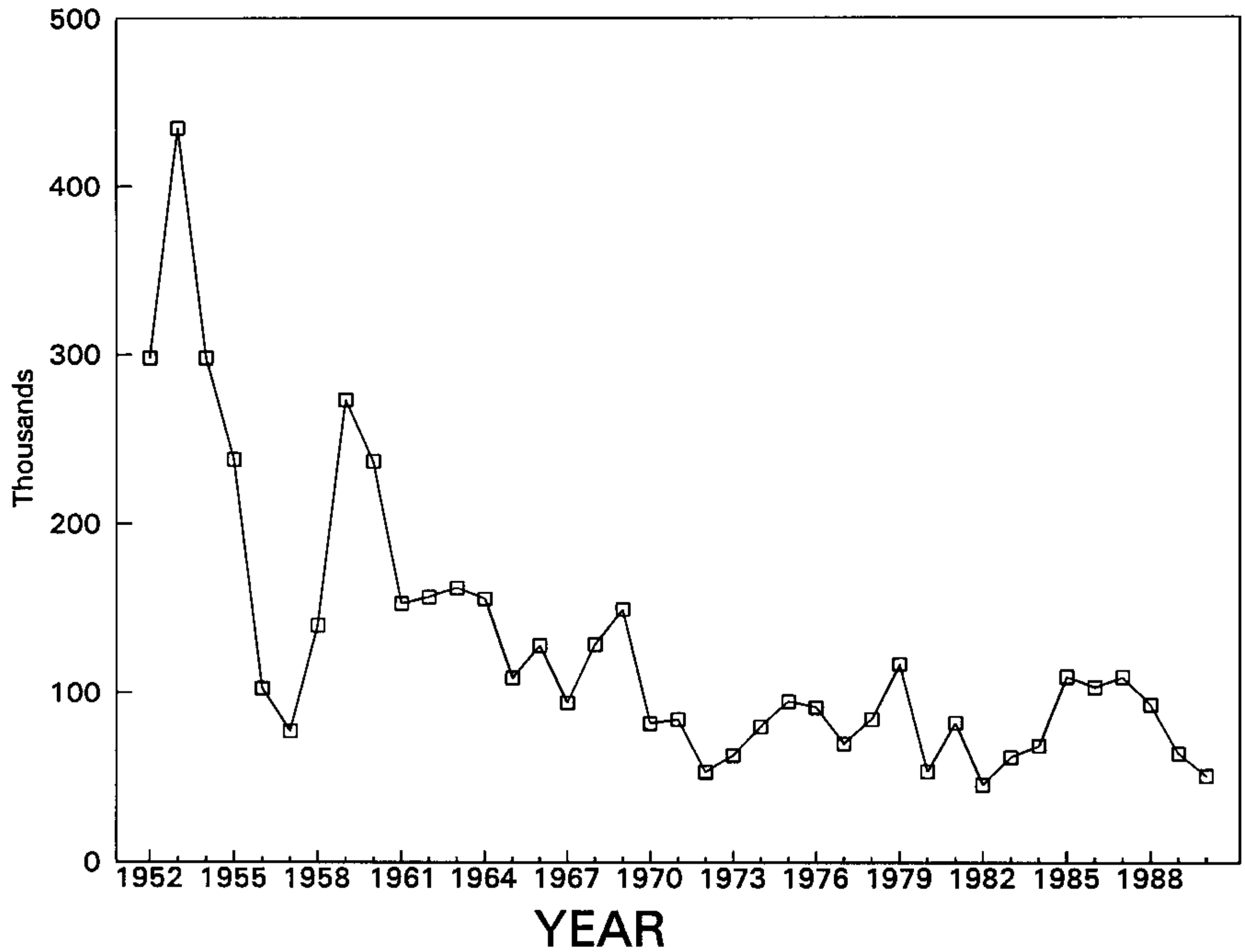

Figure 3: Natural fall run spawning escapement in the Sacramento River between 1952 and 1990.

Most Delta problems for salmon are caused by the present system of water management in the Delta. These problems are primarily related to changes in Delta hydrology, whereby the timing, quantity, export and distribution of water flow has been altered.

These alterations have caused two primary problems for salmon.

1. The diversion of juvenile, yearling and adult salmon off the mainstem Sacramento and San Joaquin Rivers migration pathways into less desirable regions of the Delta and to direct losses at the CVP/SWP Export Facilities in the south Delta.

2. A delay in the migration of juvenile, yearling and adult salmon through the Delta causing exposure to mortality agents (such as higher water temperatures or predation loss) for a longer time.

Sacramento River Problem Identification

Problem 1: Smolts Diverted Off the Sacramento River

Issue: Salmon smolts are diverted from the mainstream Sacramento River via the cross channel and Georgiana Slough into the Central Delta, where mortality is high. Reducing the percentage of smolts being diverted into the Central Delta would increase the survival of smolts migrating through the Sacramento Delta.

In addition fish are diverted into Montezuma Slough off their main migration path which may impede their successful outmigration to the ocean.

Description of Problem: The Delta Cross Channel is located at Walnut Grove, where in 1951 the U.S. Bureau of Reclamation connected the Sacramento river to the Mokelumne River system, via Snodgrass Slough. The main purpose of the channel was to improve the conveyance of higher quality Sacramento River water through the Central and Southern Delta to the Central Valley Project (CVP) pumping facility. Today, approximately 40% of the Sacramento River just upstream of the cross channel is diverted into this channel, when the gates are open.

Georgiana Slough is a second major diversion channel off the Sacramento River at Walnut Grove in the North Delta. It is a "natural" Delta channel and diverts water off the Sacramento River about a mile downstream of the cross channel diversion point. An additional 30% of the remaining water in the Sacramento River at this point is then diverted into Georgiana Slough. The water and presumably fish then travel down the North and South Fork's of the Mokelumne River and eventually enter the

San Joaquin River near San Andreas Shoul. When export pumping at the CVP and State Water Project (SWP) is high and San Joaquin inflow is low, reverse flows are typical in the Southern Delta channels and the western San Joaquin River. Under most dry year scenarios there is no net downstream flow past Antioch.

The cross channel and Georgiana Slough diversions, combined, take approximately 70% of the Sacramento River flow as it approaches Walnut Grove. Closing the cross channel gates during the time the fish are migrating would decrease the percent diverted at Walnut Grove from 70% to about 20-30%. Additional closure of Georgiana Slough would decrease the total percent diverted at Walnut Grove to 0%.

Through mark and recapture studies, we have found that salmon smolts diverted into the Central Delta via the cross channel and Georgiana Slough has a very significant, negative effect on the survival of salmon smolts migrating down the Sacramento River.

We have evaluated this impact by comparing the survival indices of Coded Wire Tagged (CWT) smolts released from 1983 to 1989, 3.5 miles above and 3 miles below the two diversion points at Walnut Grove. Tagged smolt releases also were made in the Central Delta (North and South Forks of the Mokelumne) from 1983 to 1986. Survival of the various groups was based on the recovery of these CWT smolts at Chipps Island a few weeks after release along with recoveries in the ocean fishery.

Between 1984 and 1989, nine groups of CWT salmon smolts were released above and below the open Delta cross channel and Georgiana Slough. We found that in eight of these releases that fish survived between 1.4 to 17.0 times better (average 3.4 times) when released below the two diversion points (Table 1).

Tagged experiments in 1983, 1987 and 1988, revealed that smolts released below the closed cross channel and Georgiana Slough had a 1.3 to 2.4 times better (average 1.6 times) survival index than those fish released above the cross channel (Table 1).

We have subsequently found similar results using an index of survival based on recoveries of the marked fish as adults in the ocean fishery (WRINT-USFWS-9).

CWT fish released into the Central Delta have lower survival than fish that migrate to Chipps Island via the mainstem Sacramento River. CWT smolts released in the north and south forks of the Mokelumne River in 1984 through 1986 and in the lower Mokelumne River in 1983, would represent the survival of smolts diverted off the Sacramento River. In 1985 and 1986 these smolts had survivals generally lower than those released above the point of diversion presumably because some fraction of the groups released above the diversion point remained in the Sacramento River and

Table 1. Comparisons of the survival indicies (S_T) for CWT chinook smolts released in the Sacramento River above and below the opened and closed 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 Closed	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 (3.5 miles above Walnut Grove)

[2/] Ryde Site (3.0 miles below Walnut Grove)

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experienced better survival as indicated by the survivals of those released below the diversion point (Table 2).

These findings also were supported by the preliminary results of three paired CWT groups released at Ryde and in Georgiana Slough, in April of 1992 (Table 3). On average we found that the Ryde fish survived about five times greater than the corresponding groups of fish released into Georgiana Slough. In 1989, a model (WQCP-USFWS-1) was developed to determine the relative importance of certain parameters on the survival of smolts migrating down the Sacramento River. The percent of water (and salmon smolts) diverted into the Central Delta via the cross channel and Georgiana Slough was found to be an important factor in determining the survival of smolts migrating through the Sacramento Delta.

It is not surprising that such a habitat alteration along their main migration route would increase the mortality of Sacramento River salmon outmigrants. Migration to the ocean via the Central Delta would be more difficult considering it is a longer route and would expose smolts to increased predation, higher temperatures, a greater number of agricultural diversions and to more complex channel configurations. In addition, upon reaching the mouth of the Mokelumne River on the lower San Joaquin River they are often exposed to upstream flow (reverse flows) that moves the net flow easterly in the San Joaquin and to the south in Old and Middle Rivers (see later discussion on reverse flow).

The smolt survival model for the Sacramento River Delta indicates that the reduction in the percent of water (and fish) diverted at Walnut Grove would increase smolt survival through the Delta (Table 4).

Sampling conducted in Montezuma Slough and Chipps Island concurrently in 1987 and 1992 showed that a small, yet equal percentage ($p<0.01$) of the fish leaving the western Delta were diverted into Montezuma Slough both with (1992) and without (1987) the Montezuma Slough Control Structure in place. In both 1987 and 1992, we found between 0 and 2.72 (average .70) percent of the fish leaving the western Delta were diverted into Montezuma Slough, where presumably their survival would be less, since their migration would be delayed or the distance to the ocean increased (Appendix 1).

Potential Solutions: The percent of fish diverted off the mainstem Sacramento River into the Central Delta could be reduced by closing the cross channel gates and by using some physical means to close Georgiana Slough. Increasing the flow in the Sacramento River also would result in a lower percentage of water and fish diverted into the Central Delta.

Problem 2: Smolt Mortality Due to CVP and SWP Exports

Issue: Exports at the CVP and SWP have been found to be related to survival of fish diverted into the Central Delta. Sacramento

Table 2: Survival indices of coded wire tagged (CWT chinook smolts released at several locations in the Sacramento-San Joaquin Delta from 1983 to 1986 and recovered by trawl at Chipps Island.

Release Site	1983	1984	1985	1986
Above Diversion [1/] gates opened		0.61	0.34	0.35
Above Diversion gates closed	1.06			
Below Diversion [2/] gates opened		1.05	0.77	0.68
Below Diversion gates closed	1.33[3/]			
N. Fork Mokelumne River [4/]	NR	0.51	0.28	0.36
S. Fork Mokelumne River [4/]	NR	0.86	0.23	0.26
Lower Mokelumne River [5/]	1.13	NR	NR	NR
Lower Old River River [6/]	0.33	0.16	0.21	0.23

1/ 3.5 miles above Walnut Grove on Sacramento River (Courtland site).

2/ 3.0 miles below Walnut Grove on Sacramento River (Ryde).

3/ Release at site at Isleton.

4/ Released site at Thorton Road.

5/ Release site 2 miles above the junction with the San Joaquin River.

6/ Release site at the southeast corner of Palm Tract.

NR= No Release

92TAB2.002

Table 3: **Preliminary survival indices and ratios for CWT salmon smolts released at Ryde and in Georgiana Slough in April of 1992.**

	Ryde		Georgiana Slough	
Date of Release	**Survival Index**	**Temperature at Release °F**	**Survival Index**	**Temperature at Release °F**
4/6	1.36	64	.41	64
4/14	2.15	63	.71	64
4/27	1.67	67	.20	67

Date of Release	**Ryde/Georgiana Slough Ratio**	**Flows at Antioch***	**CVP+SWP Exports****	**Sacramento River Flow at Freeport****
4/6	3.3	972	4999	9904
4/14	3.0	1321	1085	11212
4/27	8.3	736	1345	4615
	$\overline{X}$ = 4.8	--	--	--

* Average flow (cfs) at Antioch during the time the Ryde fish were recovered at Chipps Island.

** Five day mean flow or export (cfs) starting on the release date.

92TAB3.003

Table 4. **Estimated survival indices for salmon smolts migrating through the Sacramento River Delta under varied water temperatures, percents diverted at Walnut Grove and CVP/SWP export rates using the model described in WQCP-USFWS-1.**

Exports = 2000 cfs

Percent diverted	Temperature (°F) 60	62	64	66	68	70
0%	.64	.51	.40	.30	.22	.15
30%	.57	.46	.36	.27	.20	.14
70%	.47	.39	.30	.23	.18	.12

Exports = 6000 cfs

Percent diverted	Temperature (°F) 60	62	64	66	68	70
0%	.64	.51	.40	.30	.22	.15
30%	.52	.41	.32	.24	.17	.11
70%	.36	.28	.21	.16	.11	.07

Exports = 10000 cfs

Percent diverted	Temperature (°F) 60	62	64	66	68	70
0%	.64	.51	.40	.30	.22	.15
30%	.47	.37	.28	.21	.15	.10
70%	.25	.18	.13	.09	.07	.04

92tab4.004

river salmon are lost due to the direct and indirect mortality factors caused by export pumping.

Description of Problem: The CVP and SWP export more water than flows into the San Joaquin River at Vernalis. The balance of water needed by the projects comes from the Sacramento River via the cross channel, Georgiana Slough, the Mokelumne and Lower Old and Middle Rivers. This movement of water south to the pumping plants causes reverse flows in many of the Southern Delta channels. Conditions in the Southern Delta appear detrimental for salmon due to high temperatures, increased predation and complex channel configurations in which water is being drafted upstream toward the pumping plants. The water and many fish are then impounded into Clifton Court Forebay where predation on salmon smolts has been shown to be high. If the fish survive to this point, or bypass the entrance to CCFB and move toward the intake to the CVP, they are then exposed to the SWP or CVP pumping plant louver screens (which are not 100% efficient) and to the handling and trucking stresses associated with moving these fish to the Western Delta where they are released away from the influence of the pumps.

Recovery data from tagged smolts released into the South Delta (lower Old River) in 1983 through 1986 (Table 2) have shown that smolts that do get diverted into the South Delta have slightly lower survival than fish released in the Central Delta, presumably because more of the smolts released in the Central Delta are able to successfully find their way to the ocean via the eastern San Joaquin River. Smolts released in the mainstem Sacramento River below the diversion points (Ryde) survived at a higher rate of survival than either those fish released into the Central or Southern Delta (Table 2).

Coded wire tagged smolts released in the Sacramento Delta (Sacramento, Courtland and Ryde) have been salvaged at the CVP and SWP Fish Facilities (WQCP-USFWS-2 and Exhibit 31), indicating that Sacramento smolts are being directly impacted by the export pumping plants. Although the actual percentages of smolts from these release groups are low, given that significant mortality probably occurs in the Central and Southern Delta's before the fish actually reach the salvage facilities, the impact would be considerably greater than shown by the salvage rates. In addition, there are millions of smolts emigrating from the Sacramento Basin each year and consequently a small percentage at the salvage facilities also would indicate that a large number of smolts from the Sacramento River are being directly impacted by the project pumps (USFWS, Exhibit 31).

In the development of our multiple regression smolt survival model (WQCP-USFWS-1) we found that survival of smolts from Walnut Grove to Chipps Island via the Central Delta was related to temperature and to the combined exports at the CVP and SWP facilities. When the variability in survival from temperature for that reach of the river was removed, we found an additional 17% of the variability in survival was due to exports.

The Delta smolt survival model (WQCP-USFWS-1) allows us to quantify the benefits of reducing exports to salmon migrating through the Central Delta (Table 4).

Results from CWT fish released in Georgiana Slough on April 6 and 14 of 1992, suggests that higher Delta exports may have caused the lesser survival for fish released on April 6th when compared to the April 14 release which were exposed to lower exports (Table 3).

The effects of exports on smolts from the Sacramento Basin would be greatest when both the Delta Cross Channel and Georgiana Slough are open and decrease when one or both are closed since smolts diverted into the Central Delta would be exposed to greater reverse flows in the western San Joaquin than those at the tip of Sherman Island and Three mile Slough. As noted earlier, CWT smolts released at Ryde have higher survival than those representing fish diverted into the Central Delta (Table 3).

Since 1978, only a few CWT smolts released at Ryde have been observed at the SWP/CVP salvage facilities compared to up to several hundred from Central Delta releases (USFWS Exhibit 31). This suggests that, even though smolts remaining in the Sacramento River are exposed to reverse flow in the western San Joaquin River via their potential movement through the Three Mile Slough or around the tip of Sherman Island, they are probably affected to a much lesser degree.

Analyses on CWT fish released at Ryde, after correcting for temperature (all indices were standardized to 61 degrees fahrenheit), indicated that increased flows at Jersey Point was beneficial to survival ($r=0.49$, $p<0.10$) (Figure 4). The data from 1983 was not included in our analyses as it had flows at Jersey Point of about 35,000 cfs and made a relationship at the lower flows difficult to detect.

We also evaluated the impact of Jersey Point flow on the Ryde raw survival indices, by comparing releases made at the same temperatures. We found an average of 39 percent increase in our raw survival index when Jersey Point (Q West) flows were greater (Table 5).

In addition, for fish released at Jersey Point between 1989 and 1991 we found that temperature corrected survival increased with an increase of flow at Jersey Point ($r=0.76$, $p<0.10$) (Figure 5).

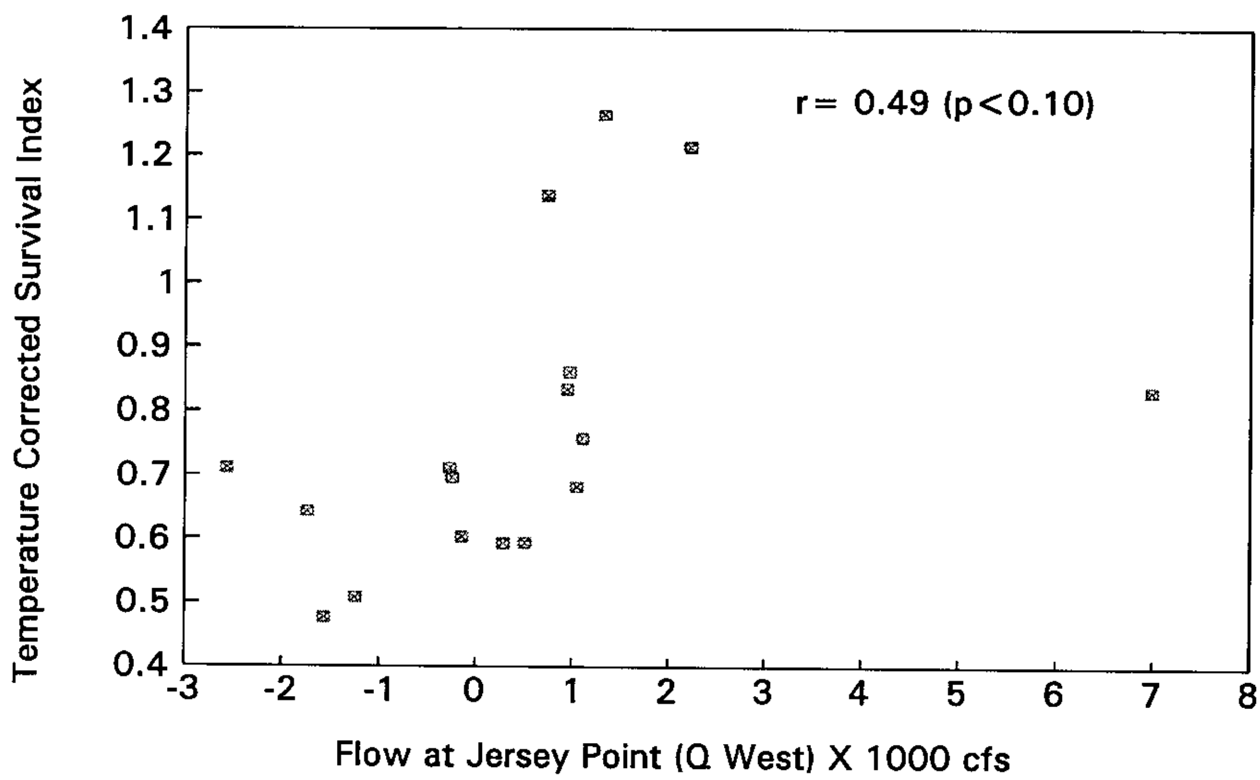

Figure 4: Temperature corrected survival for fish released at Ryde between 1984 and 1992 versus flow at Jersey Point on the San Joaquin River .

Table 5: Temperature, survival, temperature corrected survival (to 61 degrees F.), migration rate (miles per day) and flows (cfs) during the time the CWT salmon smolts were passing Chipps Island for fish released at Ryde from 1983 - 1990 and 1992.

Year	Temperature degrees F.	Raw survival index	Corrected mortality 1/	Temperature corrected mortality	Temperature corrected survival	miles per day	Rio Vista flow	Jersey Point flow	% increase in raw survival
83	61	1.33	0.2611	0.2611	0.7111	4.2	42989	35026	
88	61	1.28	0.2889	0.2889	0.7111	5.6	7322	-271	4
88	63	0.94	0.4778	0.4080	0.5920	7	6029	285	
92	63	2.15	-0.1944	-0.2642	1.2642	4.6	6683	1321	56
87	64	0.88	0.5111	0.4064	0.5936	7	5046	511	
92	64	1.36	0.2444	0.1398	0.8602	3.5	8072	972	35
84	66	1.05	0.4167	0.2422	0.7578	4	6395	1108	
85	66	0.77	0.5722	0.3978	0.6022	5.6	7051	-147	27
87	67	0.85	0.5278	0.3184	0.6816	7	6451	1046	
92	67	1.67	0.0722	-0.1371	1.1371	7	2181	736	
89	67	0.48	0.7333	0.5240	0.4760	9.3	7647	-1563	62
86	74	0.68	0.6222	0.1687	0.8313	7	6870	6984	
88	74	0.34	0.8111	0.3575	0.6425	14	5588	-1736	50
							Mean difference in %		39
88	75	0.4	0.7778	0.2893	0.7106	14	7357	-2569	
89	62	1.19	0.3389	0.304	0.696	5.6	4280	-247	
89	73	0.16	0.9111	0.4924	0.5076	9.3	7709	-1243	
90	69	1.62	0.1	-0.214	1.214	7	2536	2215	
90	65	1.25	0.3056	0.166	0.834	7	4955	945	

1/ Corrected mortality = 1- (survival / 1.8)

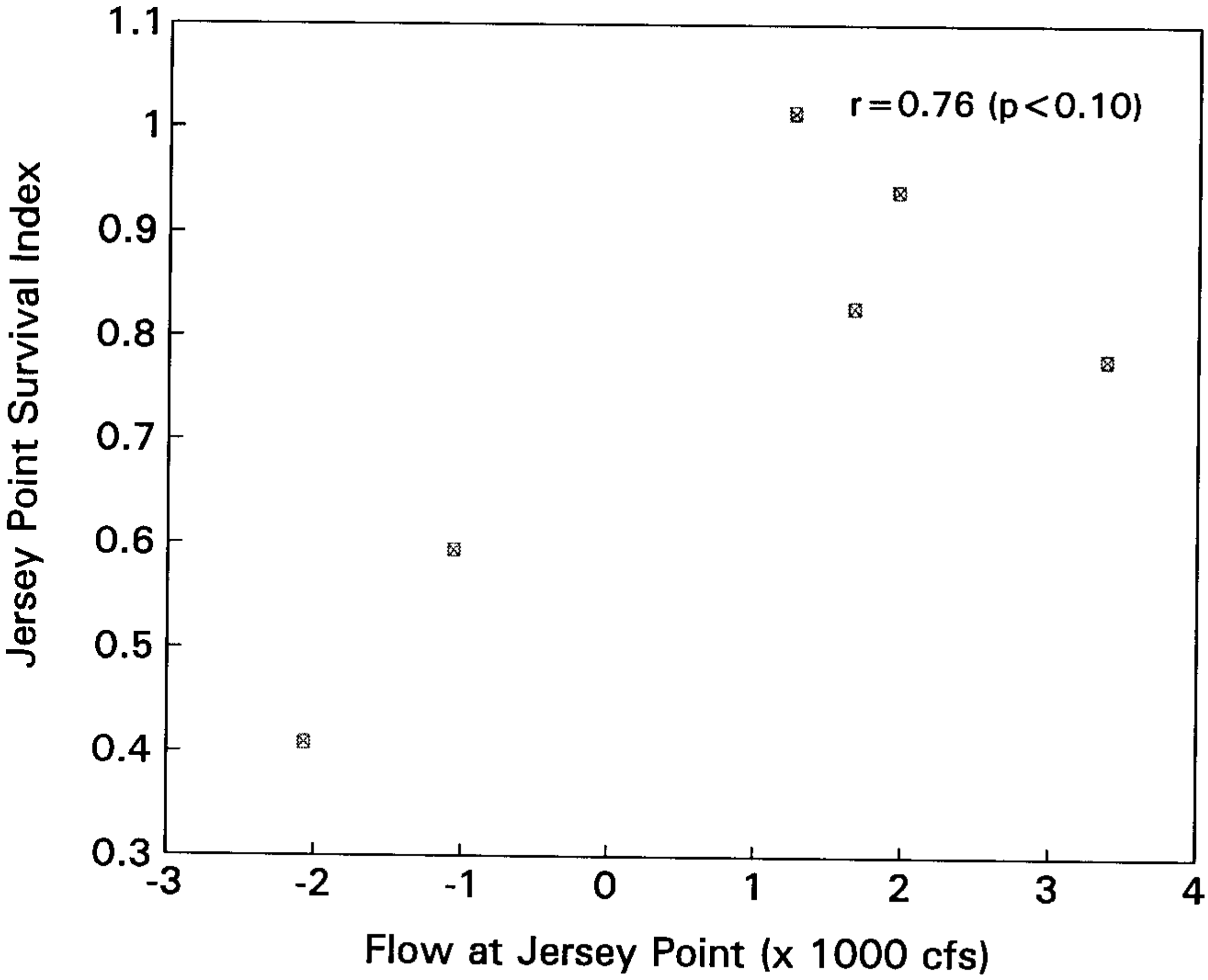

Figure 5: Temperature corrected (to 61 degrees F.) survival indices for CWT salmon smolts released at Jersey Point and recovered at Chipps Island between 1989 and 1991. Flow estimates were the 5 day mean starting on the release date.

The results of these relationships would support the fact that positive flows at Jersey Point may increase the survival of fish migrating down both the Sacramento and San Joaquin Rivers from Ryde and Jersey Point as well as for fish diverted into the Central Delta and moving to the San Joaquin via the Mokelumne River.

Additional discussion on the potential impact of reverse flows on smolts migrating through the Central Delta is given in the section on the San Joaquin portion of the Delta.

Potential Solutions: Reducing exports to minimal levels to reduce entrainment from the pumps and eliminate reverse flows during critical salmon migration periods on the Sacramento River would increase the survival of Sacramento smolts diverted into the interior Delta.

Problem 3: High Temperatures

Issue: Temperature in the Sacramento Delta especially in late May and June of drier years can cause significant mortality for salmon smolts emigrating to the ocean. Reducing those temperatures by even a few degrees in certain years could have benefits to Sacramento Delta salmon production.

Description of Problem: Temperatures acutely lethal to chinook salmon determined by laboratory studies are about 76 degrees fahrenheit, although temperatures over about 65-66 degrees fahrenheit are considered undesirable and stressful. As temperature increases from the low 60's, mortality increases most likely due to the sublethal effects of temperature on fish. Such sublethal effects include increased physiological stress due to increased food needs and metabolic rate, and greater predation.

We have found that temperature is negatively correlated to survival of marked salmon smolts migrating through the Sacramento River Delta (Figure 6). We also have found similar relationships between unmarked salmon smolts migrating from the North Delta (Sacramento) to Chipps Island and water temperature in the Delta (Figures 7 and 8) (WQCP-USFWS-2).

When analyzing our trawl data (1978 to 1989) using multiple regression analyses to develop our smolt survival model for the Sacramento Delta, we found that temperature explains a high degree of the variability in survival in all parts of the Sacramento River Delta (WQCP-USFWS-1).

In 1992, releases made at Ryde and into Georgiana Slough, showed preliminarily that the greatest difference in survival between the two groups was at the higher temperatures (67° F), where mortality was 2 1/2 times greater than at temperatures of 63° F and 64° F (Table 3). This infers that being diverted into the

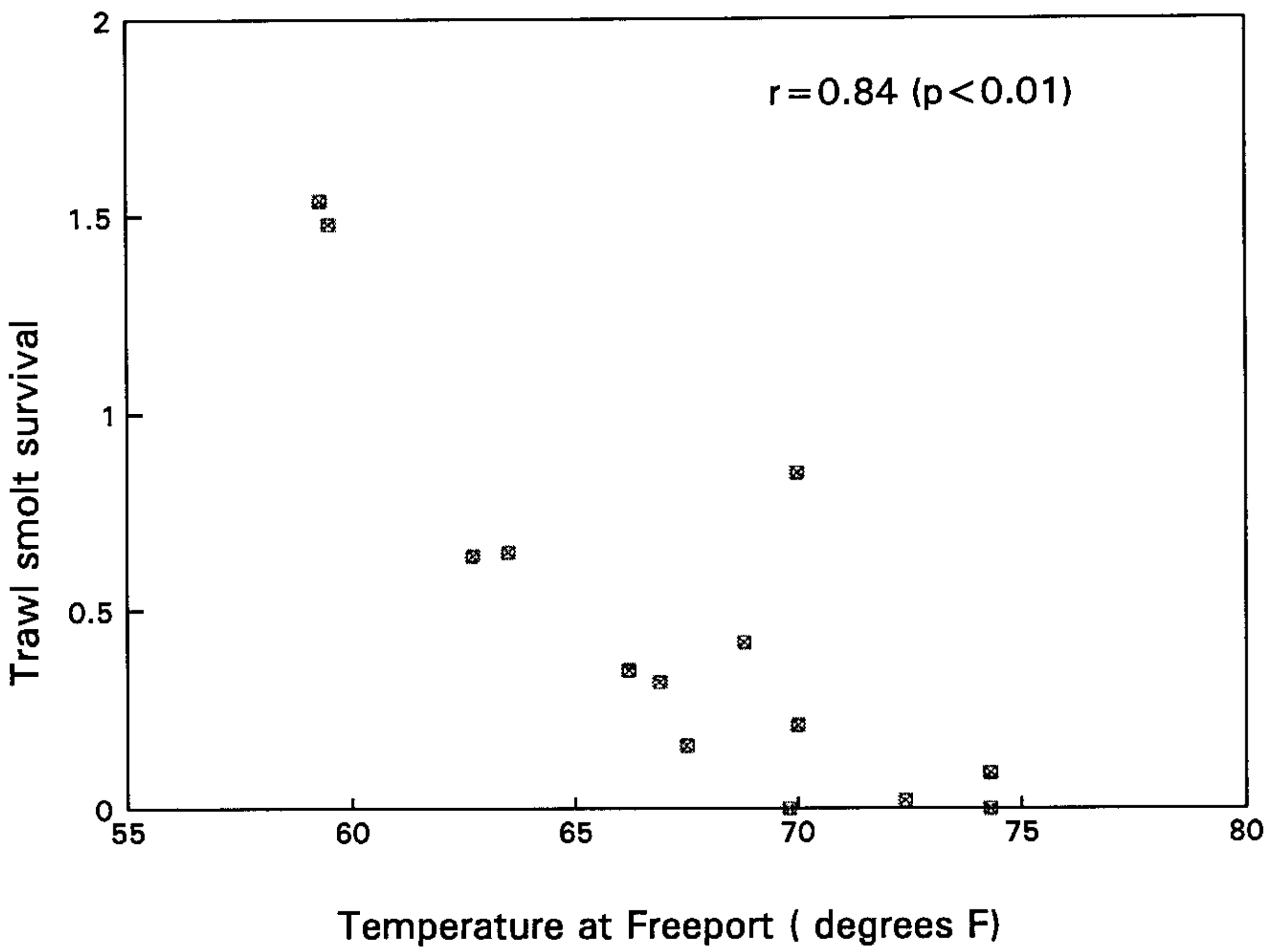

Figure 6: Raw Chinook salmon smolt survival for CWT fish released at Sacramento and recovered via midwater trawl at Chipps Island from 1978 to 1990 versus Sacramento River water temperature at Freeport.

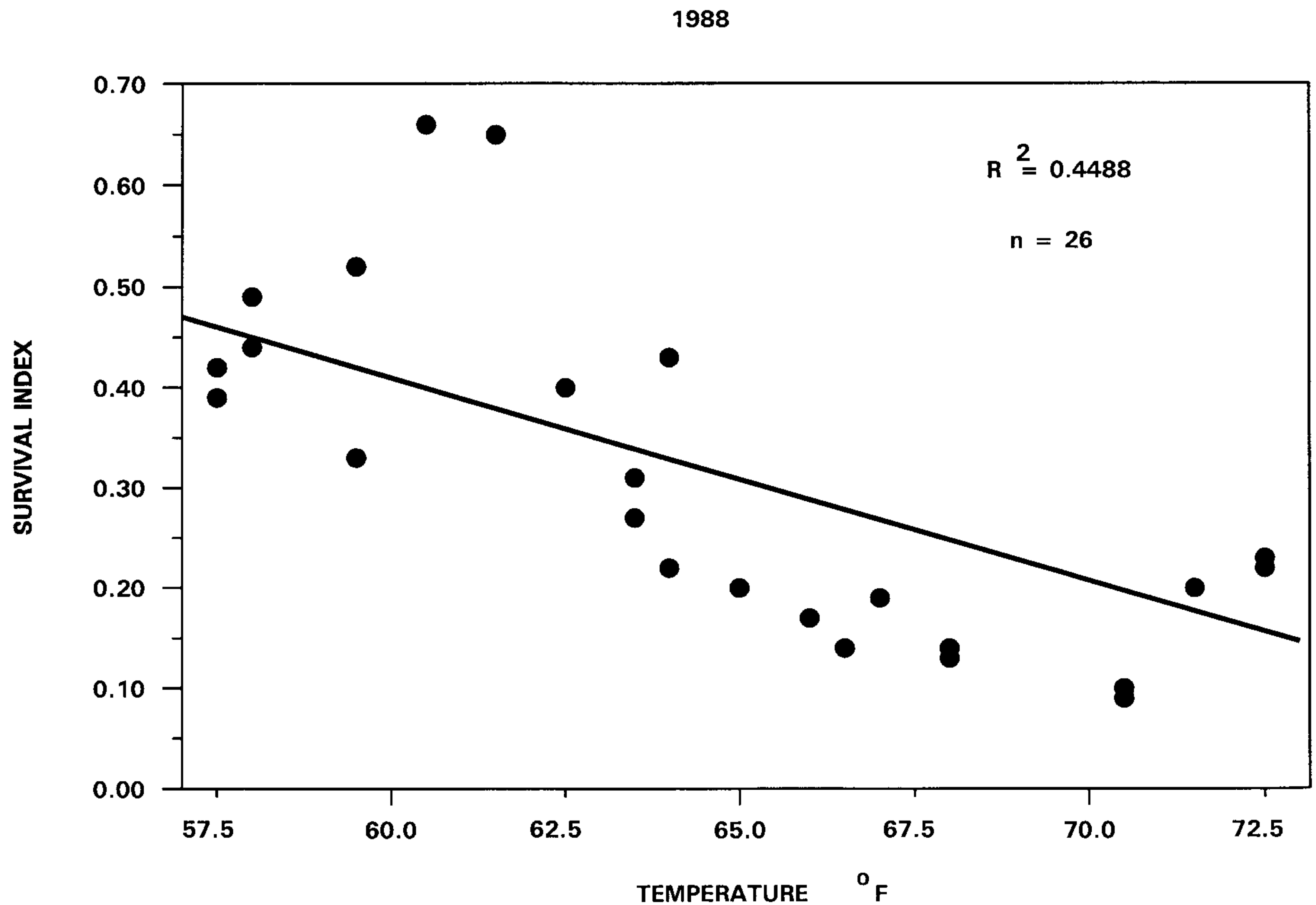

Figure 7. Relationship between unmarked, natural smolt survival and temperature through the Sacramento River delta in April, May and June 1988.

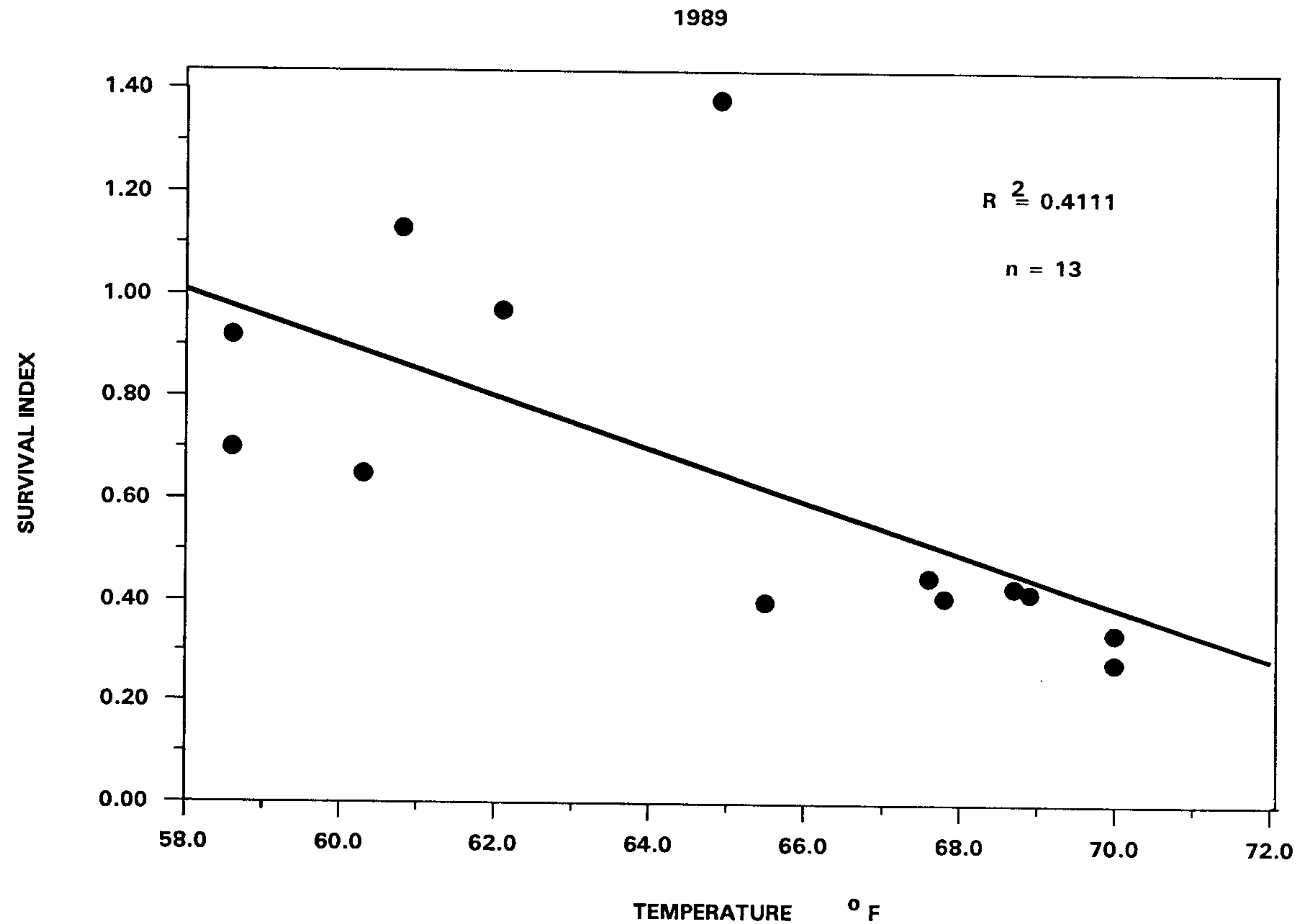

Figure 8. Relationship between unmarked, natural smolt survival and temperature through the Sacramento River Delta in April, May and June 1989.

Central Delta especially during times of relatively high temperatures causes high mortality to migrating smolts (Table 3).

Although we have occasionally found survival relatively high at high temperatures and acknowledge some uncertainty in the exact response of salmon smolts to water temperature, we believe that high temperatures in the Delta can be a significant mortality factor to outmigrating smolts in the Sacramento River Delta and reductions in temperature would be beneficial to salmon production.

Potential Solution: Releases of water from the upstream reservoirs or other possible means (increases in riparian vegetation and reduction in agricultural drain water) have been shown to have some potential to reduce temperatures in the Delta.

Problem 4: Low Flows

Issue: Low flow through the Delta may decrease the migration rate of smolts migrating through the Sacramento River, thus increasing their exposure time to varied mortality factors such as high temperatures. In addition, low flows could increase the concentration of toxic constituents present in Delta, increase water clarity which would be expected to increase predation losses and increase the percentage of fish diverted from the Sacramento River at Walnut Grove.

Description of Problem: With the onset of reservoirs and the pumping plants, flow in the Delta has been regulated such that flows are generally reduced in the spring and early summer whereas in the late summer and fall they are generally higher than they were historically. In USFWS Exhibit 31 (Figures 4-1 and 4-2), it is documented how salmon smolt survival through the Sacramento River decreases with decreased flow. Since 1987, we have gathered additional experimental data and have determined that the most probable mechanisms for the flow survival relationship were temperature and the percent of water diverted at Walnut Grove (WQCP-USFWS-1). Although temperature and the percent diverted have been documented to be of major importance in the survival of salmon smolts, flow may still be an important variable.

Recent data, from both wild and hatchery fish migrating from the North Delta (Sacramento and Courtland) to Chipps Island (1988 to 1991) provided limited evidence that increased flow in the Delta may increase the migration rate through the Delta (Figure 9 and WRINT-USFWS-9). This may be compounded by the fact that increased flows between Sacramento and Chipps Island would decrease the percent diverted at Walnut Grove.

We did not find for CWT fish released at Ryde that migration rate was related to Rio Vista flow (Figure 10). However, we did find

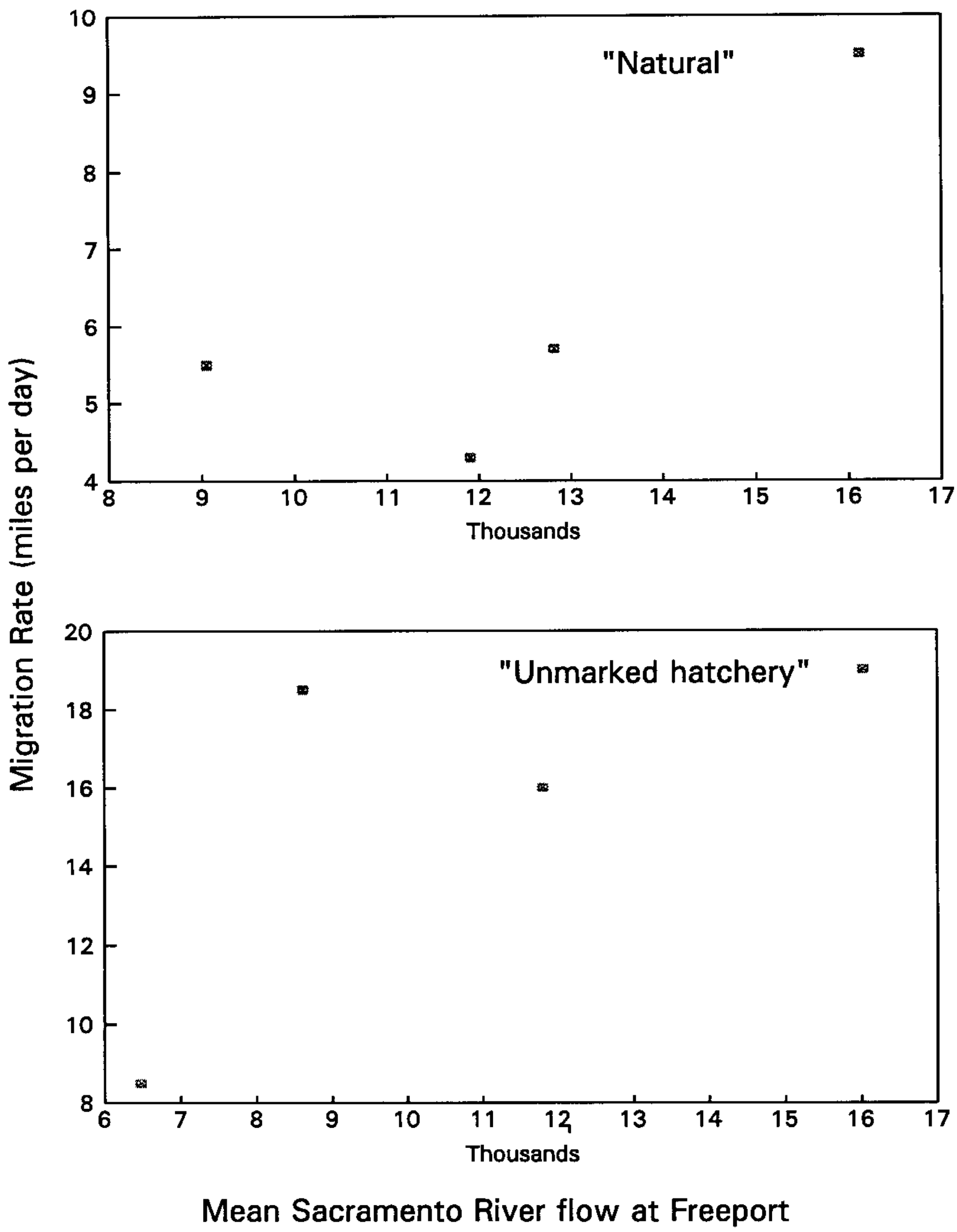

Figure 9. Migration rate for "natural" and "unmarked hatchery" fish determined by peak recoveries at Sacramento and Chipps Island versus Sacramento River flow at Freeport during the migration period (WRINT-USFWS-9), for years 1988 to 1991.

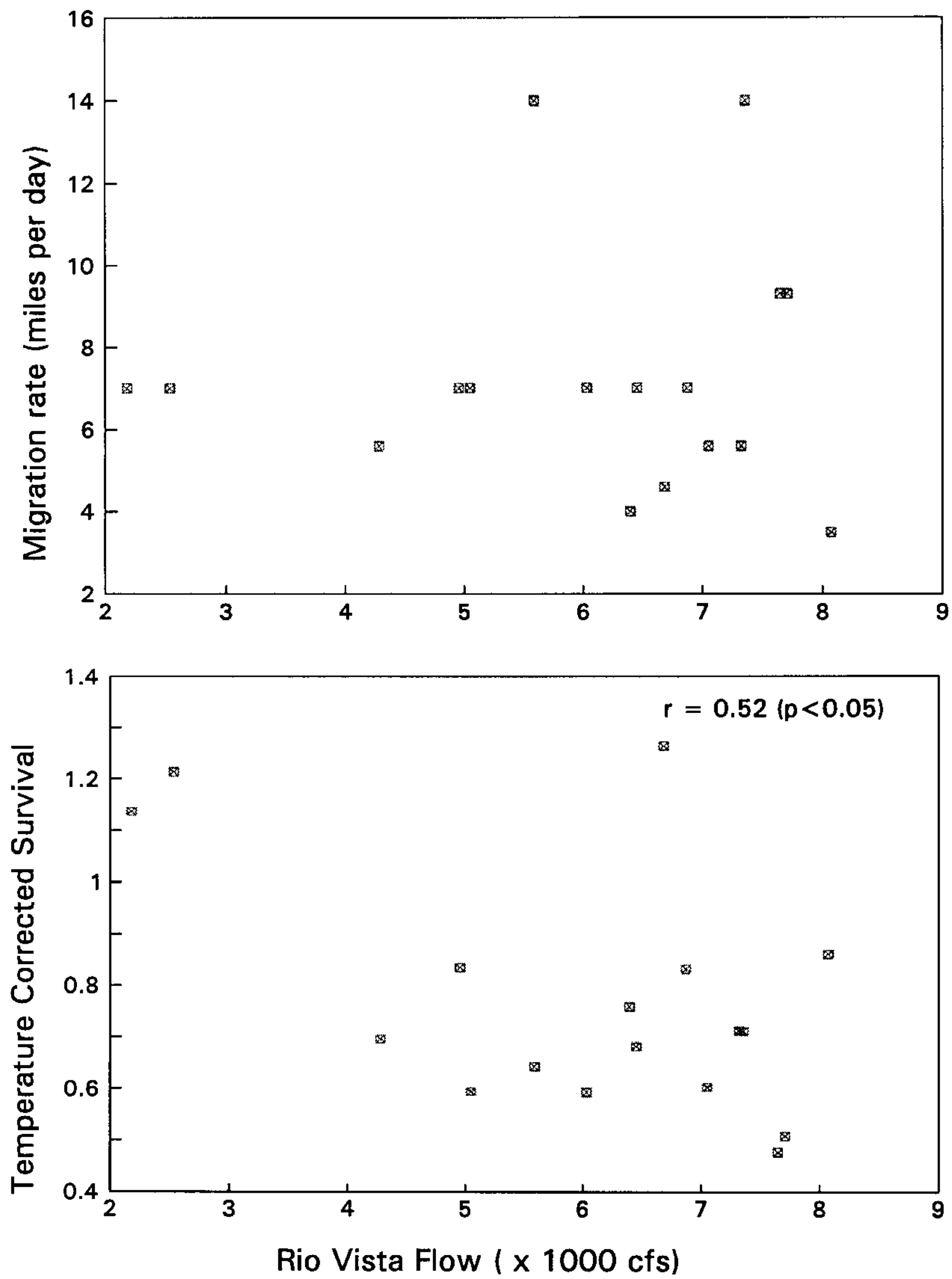

Figure 10: Migration rate and temperature corrected survival (to 61 °F) for CWT smolt salmon released at Ryde versus Rio Vista flows during the time the fish were migrating, 1983 to 1990 and 1992.

that temperature-corrected (to 61° F) Ryde survival was negatively related to Rio Vista flow, which is counter to our hypothesis that increasing flows would increase the migration rate and resulting survival. Additional analyses is needed to thoroughly evaluate the mechanism for this relationship, since it is not intuitive.

Although we have not been able to correlate migration rate to survival rate, our opinion is that the faster smolts can move through the Delta the less exposure they will have to mortality factors and thus have improved survival.

Potential Solutions: Increasing flow to potentially decrease temperatures and reduce the percent diverted at Walnut Grove could be done by releasing water out of reservoirs.

San Joaquin Delta Problem Identification

Problem 5: Smolt diversions off the San Joaquin River into Upper Old River

Issue: Salmon migrating down the San Joaquin River have a better survival rate if they are not diverted into Upper Old River. Reducing the number of salmon diverted towards the pumping plants at this junction could increase the survival of smolts migrating through the San Joaquin Delta.

Description of Problem: The survival of chinook salmon smolts migrating through the San Joaquin Delta (Vernalis to Chipps Island) from nursery areas in the San Joaquin River drainage is much lower than the survival of fall-run smolts emigrating from the Sacramento River drainage (USFWS Exhibit WRINT-9). The relatively low Delta survival of San Joaquin smolts is apparently caused by unfavorable conditions encountered upstream of Jersey Point and in the southern Delta as CWT data indicated smolts released at Jersey Point survive better than those released at Dos Reis Park on the San Joaquin River near the head of Old River (Table 6 and Table 7).

Survival estimates to Chipps Island show that in 7 out of 8 groups of CWT releases, fish released in the San Joaquin river at Dos Reis Park survived about two times better than those released into Upper Old River, under varied environmental and pumping conditions (Table 6). It is assumed that many smolts do go into Upper Old River because a large percentage (at times > 100%) of the water at the junction is diverted into Upper Old River. Smolts diverted into Upper Old River are on a direct path to the State and Federal pumping plants where they suffer direct mortality. Additional indirect mortality occurs in the south Delta channels most likely due to high temperature, predation and

Table 6. CWT smolt survival indices for smolts released at Dos Reis on the main San Joaquin River and in Upper Old River between 1985-1987 and 1989 to 1991. Ocean recovery rates are in parenthesis.

Upper Old River Release Date	Survived to Chipps Island	Ocean Index Dos Reis/ Upper Old River	Trawl Index Dos Reis/ Upper Old River
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	1.5
5-03-89 (Low Export)	.05 (0.00044)	2.2	2.8
4-17-90 (High Export)	.02		2.0
5-13-90 (Low Export)	.01		4.0
Mean	.16	1.8	

Dos Reis		Flow at Stockton[1/]	CVP & SWP Export[1/]	Temperature on Release Day °F
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, flow and exports in cfs.

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

** Original survival estimate (.82) modified based on the ratio of recovery rates between the Dos Reis and Upper Old River releases.

92TAB6.006

Table 7. Survival estimates for CWT smolts released at Jersey Point in the San Joaquin River Delta in 1989-1991.

	1989	1990	1991 April	1991 May
Low Export (no reverse flows)	0.96	1.05	1.70	1.69
High Export (reverse flows)	0.88	0.60		
percent increase	9	75		

92TAB7.007

lengthy exposures to mortality factors due to high hydraulic residence time.

Tagged fish released in Upper Old River have shown that in some years as low as 1 to 3 percent of the release is salvaged at the State and Federal Fish Facilities (Table 8). This may indicate that conditions in Upper Old River are so poor that few survive to be salvaged. If survival was high in Upper Old River, we would expect to see a large percentage of fish at the facilities as we did in 1986 (74%) when flows were high in all South Delta channels (EIRSP-USFWS-4).

Although percentages of fish recovered from CWT groups released at Dos Reis on the San Joaquin River, also are low (Table 8), we would expect to see less of these fish at the facilities because their migration path to the ocean does not expose them directly to the pumping plant intakes as is the case for the Upper Old River release groups.

During 1992, a total of 800,000 coded wire tagged smolts were released at three sites in the Delta. More than half (500,000) were released in 100,000 lots at Mossdale, one group per week for 5 weeks (April 7 to May 12). Preliminary data on the recoveries (unexpanded recoveries multiplied by an expansion rate of 6) for these groups indicated that less than 2 percent of these groups were recovered at the facilities themselves (Table 8). As we have observed in past dry years (when survival was low), it appears that most of the fish in 1992 did not survive to be salvaged at the fish facilities. We will finalize these findings at a later date.

The 1992 study was designed to evaluate the effects of a full barrier at the head of Upper Old River on the survival of smolts migrating down the San Joaquin River. The barrier was installed on April 23, 1992, with two and three groups of marked fish, released before and after the barrier was installed, respectively.

Preliminary survival indices for the groups released at Mossdale ranged between .17 and .01 with the greater survival estimates obtained for the groups of fish released in early April when temperatures were lower (64 and 63 degrees) and the barrier was not in place (Table 9). This was contrary to past data that inferred a barrier would be beneficial.

In order to separate out the influence of temperature from that of the barrier, we standardized our survival estimates to a constant temperature (63 degrees) as we have done in previous analyses (USFWS-WRINT-Exhibit 9). Average survival after being corrected for temperature without the barrier was 0.10 while that with the barrier was 0.29. This would reflect a three fold benefit with the barrier which is similar to the doubling we saw

Table 8. Percentage of the expanded number of CWT Chinook Smolts released that were recovered at the State and Federal Fish Facilities (1985-1987 and 1989-1992).

Year	Upper Old River	Dos Reis	Jersey Point	Mossdale
1985	20	3	NR	NR
1986	74	3	NR	NR
1987	27	8	NR	NR
1989 (High Export)	6.9	5	0.2	NR
1989 (Low Export)	2	0.6	1.6	NR
1990 (High Export)	2.5	1.7	0.2	NR
1990 (Low Export)	1.3	0.1	0.1	NR
1991 April	NR	8	0.5	NR
1991 May	NR	NR	0.01	NR
1992*				2.0

* This estimate is preliminary and based on multiplying the total raw number of marked fish recovered at the two Fish Facilities during April and May, by 6. This is based on the average sampling time of 10 minutes every 2 hours. A more refined estimate will be provided in our 1992 USFWS Annual Report.

92TAB8.008

with our Upper Old River and Dos Reis data. Average exports during the time the marked fish were released were similar before and after the barrier was installed (Table 9).

Preventing salmon from being diverted into Upper Old River would appear to increase the survival of smolts migrating through the San Joaquin Delta.

Potential Solutions: Any measure that would reduce the number of salmon diverted into Upper Old River should be beneficial to San Joaquin salmon. Both decreased export pumping and increasing the inflow would decrease the percent of water and fish diverted to Upper Old River. In addition, a full barrier at the head of Upper Old River would prevent salmon from migrating down Upper Old River. Each of these measures have the potential to increase the survival of smolts through the San Joaquin Delta, although all three used in combination is expected to yield the greatest survival benefit. There is a definite need to evaluate the potential benefit of the barrier to smolt survival under a range of exports and flows.

Problem 6: Low Inflow in the San Joaquin Delta
Issue: Low inflow, especially when combined with high exports, is most likely causing a major part of the extremely high smolt mortality rates observed in the San Joaquin Delta. Low flow has been shown to decrease the migration rate of smolts migrating through the San Joaquin Delta (EIRSP-USFWS-4).

It also has been documented that smolt survival down the San Joaquin and adult recruitment 2 1/2 years later is directly related to the spring outflow at Stockton and Vernalis respectively (USFWS-WRINT-9 and DFG 1987, Exhibit 15).

Description of Problem: Other than in wet water years, very little flow is released into the San Joaquin tributaries and mainstem during the spring months coinciding with salmon smolt outmigration. As in the Sacramento River, most of the natural runoff and snow melt is captured in the many reservoirs on the system, and prevented from flowing down the rivers as it did historically. Especially in dry and critical years, spring flows into the Delta from the San Joaquin River and tributaries is very low (1000 to 2000 cfs at Vernalis).

Migration time to Chipps Island of CWT fish released into the San Joaquin River at Dos Reis Park was longer in the dry years of 1985, 1987, 1989 and 1990 (about 8 to 13 days) than it was in 1986 (about 4 days) when inflows were high (7000 cfs at Vernalis) (Table 10). The South Delta has a myraid of potential mortality factors that reduce survival for San Joaquin salmon smolts and the longer the fish are in the Southern Delta and exposed to them the worse their survival is likely to be. Moving the fish

Table 9. Estimated preliminary survival of five groups of coded wire tagged fish (approximately 100,000 per group) released at Mossdale on the San Joaquin River, with and without the presence of a barrier at the head of Old River in April and May of 1992. Survival was standardized to a temperature of 63° F using the relationship of temperature to survival between Ryde and Chipps Island (WQCP-USFWS-1).

	Release Date	Release Temperature	Uncorrected Survival Index	Temperature Standardized survival	CVP+SWP Exports	Vernalis Flow
Without Barrier	4/07	64	.17	.13	--	--
Without Barrier	4/13	63	.12	.07	--	--
Without Barrier	--	--	--	$\bar{X}$ = .10	1979 cfs[1]	1409[1]
With Barrier	4/24	69	.08	.25	--	--
With Barrier	5/04	71	.01	.28	--	--
With Barrier	5/12	72	.02	.32	--	--
With Barrier	--	--	--	$\bar{X}$ = .29	1665 cfs[2]	1258[2]

[1] Mean daily flow and exports between 4/7 and 4/23 in cfs.

[2] Mean daily flow and exports between 4/24 and 5/15 in cfs.

92TAB9.009

Table 10. Days between release and peak recovery for CWT smolts released in the San Joaquin River at Dos Reis Park and recovered at Chipps Island, 1985-1987 and 1989-1991, and average San Joaquin River flow at Jersey Point (Q west).

San Joaquin River (at Dos Reis)

Release Date	Day to Peak Recovery	Average Jersey Point Flow (cfs)[1/]
4-30-85	10	+ 587
5-29-86	4	+ 7798
4-27-87	10	+ 57
4-20-89 (High export)	8	- 2129
5-2-89 (Low export)	8	+ 470[2/]
4-16-90 (High export)	13	- 1924[3/]
5-2-90 (Low export)	13	+ 1383[3/]
4-15-91	10	- 1952

[1/] Ten days after release date

[2/] Average 20 days after release date.

[3/] Flow at Antioch.

92TAB10.013

through the San Joaquin Delta as quickly as possible should be beneficial and increase their survival rates.

In addition, we have been able to demonstrate with CWT fish released at Dos Reis (1982, 1986-1987, 1989-1991) that survival through the San Joaquin River Delta is significantly related to flow at Stockton although data at high flows is especially limited (Figure 11). The data from 1985 was considered an outlier and not used in the regression calculation. Modification of the 1982 and 1986 raw survival data was done based on the ratio of ocean recovery rates between two sites in the same year and appear to reflect more accurate indices (Table 6).

In DFG's 1987 Exhibit 15, they showed several examples of how adult recruitment in the San Joaquin was directly correlated to spring outflow 2 1/2 years earlier. The high flow would not only be beneficial for migration through the Delta, but also should also improve conditions in upstream areas (see testimony for this proceedings by DFG on salmon in the San Joaquin basin). Increased flow specifically in the San Joaquin Delta would not only increase migration rates but potentially decrease temperatures and increase turbidity which in turn would decrease predation, and create net downstream flow all of which should increase smolt survival through the Delta.

Recent experimental data from the San Joaquin Basin indicates that short-term "flushing flows" (i.e., increased flow releases from reservoirs on the Stanislaus and/or Tuolumne) resulted in an increased trawl catch of smolts at Mossdale in both 1991 and 1992 (DFG Region 4, William Loudermilk, personal communication).

Potential solutions: Releasing water from the upstream reservoirs could increase the survival rate of smolts migrating through the San Joaquin Delta via the several mechanisms discussed above.

Problem 7: Reverse Flows in Lower Old, and Middle Rivers, Turner Cut, and Western San Joaquin River

Issue: The low amount of inflow into the San Joaquin Delta in conjunction with the high amount of exports at the Federal and State Pumping plants causes reverse flows in many southern Delta channels. Such reverse flows impede the ability of the salmon smolts to migrate to the ocean in a timely manner and in doing so increases their exposure time to the many mortality factors present in the south Delta. Reducing or eliminating these reverse flows would enable the outmigrating smolts to more readily find their way out to the ocean and increase their survival.

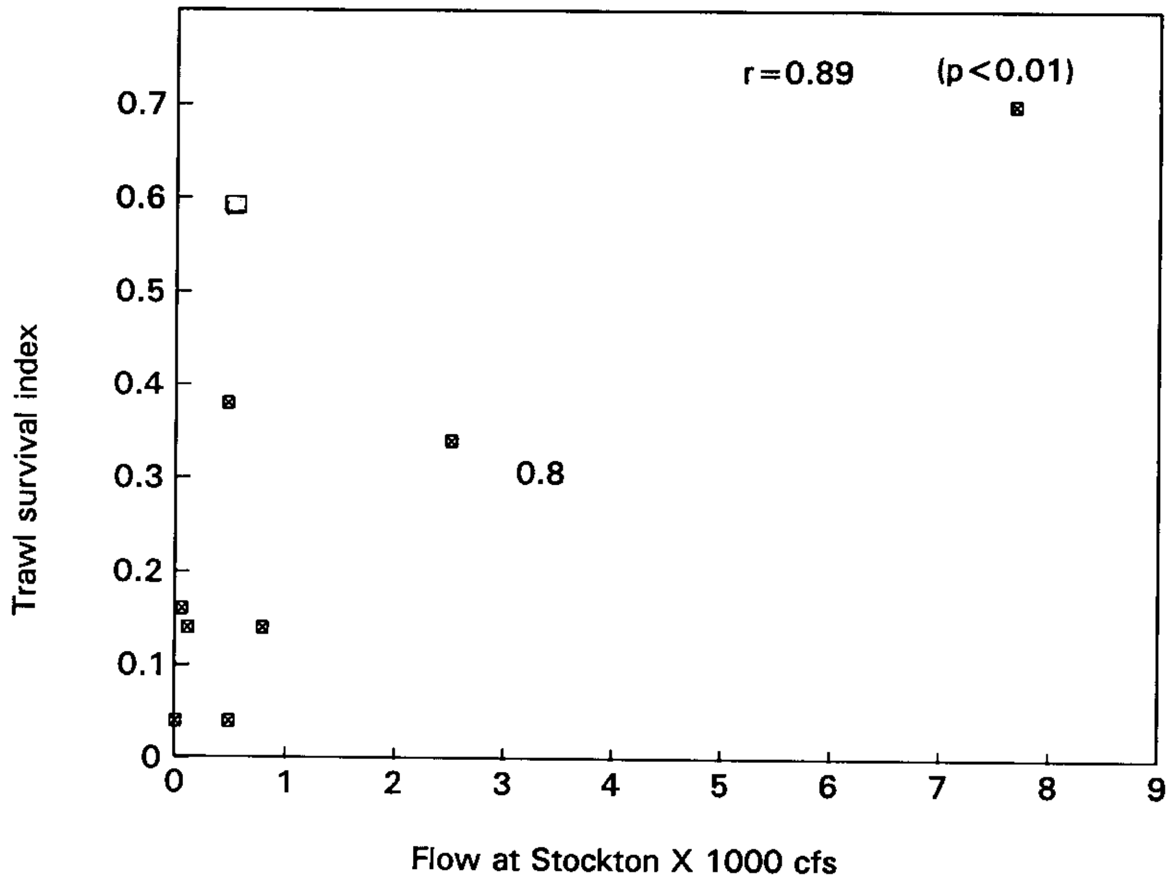

Figure 11: Flow at Stockton versus smolt survival in the San Joaquin Delta as indexed by midwater trawl recovery of CWT smolts. □ Indicates an outlier not used in the regression. y= 0.12257 + .000076 (flow at Stockton)

Description of problem: During the time the fish are migrating out of the San Joaquin Delta, inflow is normally low (<2000 cfs).

During this same time period, especially in April, the pumping plants are exporting at high levels (in the range of about 5,000 to 10,600 cfs). This disparity between inflow and pumping rates cause reverse flows in the main San Joaquin River downstream of the Upper Old River junction as well as in lower Old and Middle Rivers and at Turner Cut. With essentially no net downstream flow in the mainstem San Joaquin past Stockton or Antioch, successful migration to the ocean is delayed and extremely difficult. Based on our estimates of the survival of San Joaquin smolts to Chipps Island, most are not successful and succumb to one of the many mortality factors present in the southern Delta.

Recovery data from several groups of experimental fish released in the San Joaquin Delta have indicated that reverse flows throughout the Delta are affecting the survival of smolts emigrating from the San Joaquin basin. Tagged fish released at Jersey Point in 1989 and 1990 have shown that survival was greater by 9% to 75% respectively for fish released at Jersey Point during periods of no reverse flow (Table 7). Data from 1991, representing no reverse flow, yielded the highest survivals although low temperatures also were present at the time of CWT smolt release. As mentioned previously, temperature standardized survival for marked fish released at Ryde decreased as reverse flows at Jersey Point increased (Figure 5).

Based on the timing and magnitude of CWT recoveries at the State and Federal Fish Facilities, we found that reverse flows probably carried some of the Dos Reis release group in 1990 and 1991, upstream to the pumps via Upper Old River (EIRSP-USFWS-4 and WRINT-USFWS-9). In this case, reverse flows downstream of Upper Old River prevented fish released at Dos Reis Park from migrating down the mainstem San Joaquin to the ocean.

Data in both April and May for 1991 CWT releases along the San Joaquin River from Dos Reis Park to Jersey Point indicates that the survival rate/mile was lowest between Stockton and the mouth of the Mokelumne, the region where smolts are exposed to the greatest number of channels that carry water via net reverse flows to the CVP/SWP pumps (Figure 12).

We believe reducing reverse flows in the southern Delta channels and the western San Joaquin River would benefit smolts and increase their survival rate through the San Joaquin Delta.

Potential Solutions: Increased flow combined with decreased exports, or possibly other measures, would reduce or eliminate reverse flows in the southern Delta. Alone or in combination, these measures would increase the survival of San Joaquin smolts migrating through the Delta.

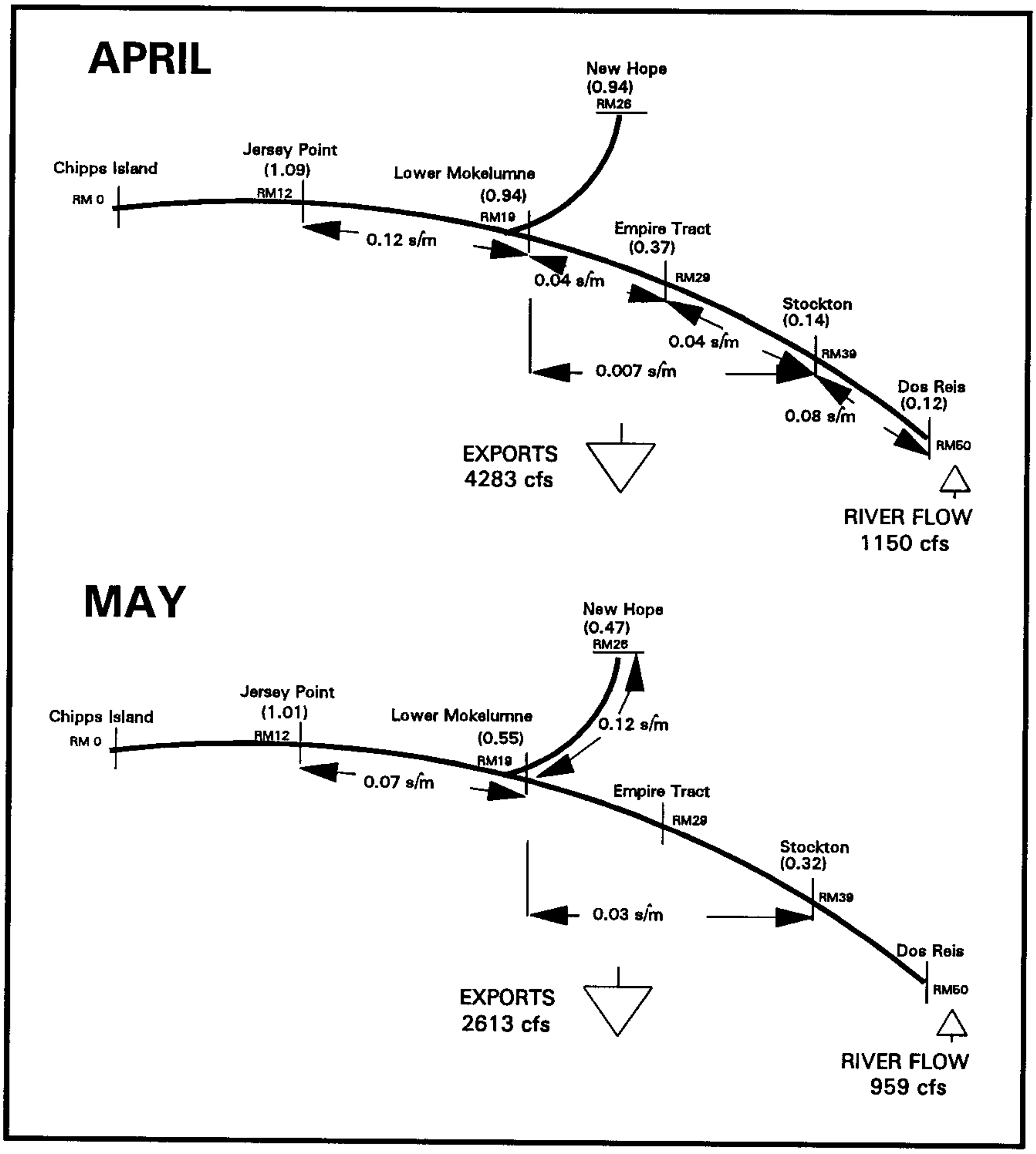

Figure 12: Diagrammatical representation of the San Joaquin River Delta area reflecting data from CWT smolt experiments in April and May of 1991. Temperature corrected (to 59 °F) survival (in parentheses) per release group to Chipps Island and survival per mile (Ŝ/m) provided between release locations. April exports and river flow encompasses the 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 is measured at Vernalis.

Problem 8: High Exports

Issue: Salmon smolts migrating through the San Joaquin Delta are exposed to high exports especially in the month of April. Not only do high exports increase the direct mortality of salmon lost to the pumps, but they also aggravate many of the problems discussed above such as increases in reverse flows and decreases in net downstream flow. Reducing exports alone or in conjunction with other actions has the potential to increase salmon survival in the San Joaquin Delta.

Description of Problem: Exports in April are typically high with combined levels of about 10,000 cfs for both the State and Federal Facilities. Salmon outmigration in the San Joaquin Delta occurs earlier in the spring than outmigration in the Sacramento with a large percentage (a mean of 44% from 1988 to 1990) of fish migrating out of the tributaries by May 1 (Table 11). Thus, many San Joaquin smolts are exposed to degraded conditions in the South Delta caused directly or indirectly by the high project exports. With all of the San Joaquin inflow going to the pumps and reverse flows increased, migration is delayed and survival is extremely low in most dry years. Although pumping is reduced during May per D1485, temperatures increase during the month and likely cause increased mortality.

In 1989 and 1990 with extremely low inflow, exports were reduced from about 10,000 in April to 2500 cfs in May. The raw survival indices did not appear to change due to the change in export rates. However, when the corresponding release made into Upper Old River was used as a control (denominator), we found about a 2 fold increase in survival at the lower exports (Table 6). Also, with less export, a smaller percent of water is diverted into Upper Old River (and likely less fish) where survival was shown to be less. This in itself would be a benefit to migrating salmon at lower exports.

Additional CWT smolt data from 1991, however, indicated that survival between Stockton and the Lower Mokelumne junction, when standardized for temperature, was lower in April when exports were greater than in May (Figure 12). Adult escapement in the San Joaquin River between 1969-1978 and 1980-1986 is significantly related to inflow at Vernalis and combined exports at the SWP and CVP (WRINT-USFWS-Exhibit 9). Other things being equal, variation in adult escapement should be related to smolt survival, thus export reductions either alone or in combination with increased flows past Stockton have the potential to increase smolt survival through the San Joaquin Delta.

Potential Solutions: Export reductions or curtailments during the critical migration period of San Joaquin smolts in conjunction with flow increases could substantially increase smolt survival through the San Joaquin Delta.

Table 11: Salmon smolt catches at Mossdale in April and May of 1988-1990 (source, DFG, Region 4, and IFD).

				% Migration
1988	April	1st 3 weeks	2.9 x 3 = 8.7/tow	16
		last week	22.3/tow	41
	May	first week	9.6/tow	18
		last 3 weeks	4.4 x 3 = 13.2/tow	24
			53.8/tow	
1989	April	1st 3 weeks	8.57 x 3 = 25.7/tow	37
		last week	8.13/tow	12
	May	first week	10.81/tow	16
		last 3 weeks	8.17 x 3 = 24.5/tow	35
			69.1/tow	
1990	April	1st 3 weeks	0.76 x 3 = 2.28/tow	13
		last week	2.6/tow	15
	May	first week	3.8/tow	22
		last 3 weeks	2.9 x 3 = 8.7/tow	50
			17.38	
$\bar{X}$ (88-90)	April	1st 3 weeks		22
		last week		22
				44
	May	first week		19
		last 3 weeks		36
				55

92TAB11.014

Problem 9: High Temperatures in the South Delta

Issue: High temperatures in the south Delta, often seen as early as late April and early May, are a problem for San Joaquin smolts emigrating to the ocean. Reducing those temperatures could increase the survival of these smolts.

Description of Problem: Temperatures in the south Delta are typically higher than other parts of the Delta during the spring (USFWS, 1987, Exhibit 31), which may account, in part, for the much lower smolt survival rates that we see in the San Joaquin Delta versus those obtained in the Sacramento Delta. Higher temperatures seen in the south Delta are likely due to the combination of low inflow and reverse flows resulting in high water mass "residence time". In addition, much of the inflow is comprised of agriculture drain water which is typically warmer.

Although we have very little data showing the response to temperature by smolts migrating through the San Joaquin Delta, we believe the same general relationships found on the Sacramento are applicable. Raw survival indices from 1992 (Table 9) shows a decrease in survival as temperatures rose between April and May.

Reducing temperatures by even a few degrees if possible would appear to be beneficial to these smolts. Reducing temperatures in conjunction with improving other conditions would seem the most comprehensive method for improving survival through the San Joaquin Delta.

Potential Solutions: Increasing flow from upstream reservoirs may decrease the temperature in the south Delta. Also, increases in riparian habitat (for shade) and reductions of agricultural drain water could decrease the temperature in these channels, and flushing flows used early in the migration period may enable a portion of the smolt population to migrate sooner, thus avoiding higher temperatures.

Potential Salmon Protective Measures

Based on the above knowledge of the problems for salmon in the Delta and measures needed to correct them, a list of potential measures that could improve salmon protection was developed (Table 12). A general ranking, primarily by fishery biologists on the Delta team, as to the relative feasibility and likelihood of success and comments on each measure also is included in Table 12.

Goals for Levels of Protection

Protection-level goals were established for fall-run smolt survival relative to the hydraulic conditions present for

Table 12. Potential measures to improve salmon protection in the Delta with emphasis on smolt life stage, including rank relative to feasibility/likelihood of success and team comments.

	Measure	Problem(s) Addressed	Rank	Comments
Sacramento Delta				
1.	Increase Sac. R. Inflow	D,R,MR?	M to L	Biologists sense more flow helps, available data not conclusive. Potential to overcome predation via greater turbidity, lower temperature and toxic effects. Most value when X-channel and Georgiana gates closed.
2.	Close Delta Cross Channel	D	H	Strong agreement of major benefit.
3.	Close Georgiana Sl.	D	H	Strong agreement, cost ~$10M (DWR?) Boat locks needed.
4.	New Hope Screen/Gate	D	H	Strong agreement, New Intake to replace X-channel and Georgiana Sl. diversions which would be closed to water diversion. High cost facility.
5.	Curtail CVP/SWP Exports	D,R	M to L	Greatest benefit if inflows remain constant, indirect impacts appear greater than direct as Sacramento smolt numbers not high at Salvage facilities.
6.	Remove Predators Clifton Court Forebay	R	L to NC	Uncertainty as to feasibility/success and benefit to Sacramento salmon.
7.	Screen Georgiana Sl.	D	U	Rejected, too many uncertainties, R & D not worthwhile, tidal problems and space limitations make ineffective.
8.	Screen Cross Channel	D	U	Same as above
9.	Fish and/or flow diverters - Steamboat Sl. -Sutter Sl. -Cross Channel -Georgiana Sl.	D,R	U	Rejected, great uncertainties, R & D not worth while, tidal complexities, major navigation, predation issues.
10.	Trap/Truck or Barge in Sacramento R. and/or Cross Channel and/or Georgiana Sl.	D,R	U	Rejected, High R and D, Problems with effectiveness, trapping of other spp., handling losses, Columbia R. still poor success with ideal facilities.

Table 12. (cont)

	Measure	Problem(s) Addressed	Rank	Comments
	San Joaquin River			
11.	Increase San Joaquin R. inflow.	D,R,MR	H	Benefit depends on export level and presence of Upper Old R. barrier. Greatest value when inflow/export > 3 to 5 without barrier; possible less ratio with barrier in.
12.	Block Western Flow into upper Old River.	D	H	Strong agreement of benefit if exports cut and inflow is sufficient. Uncertainty as to Inflow/Export need.
13.	Curtail CVP/SWP Export	D,R	H	Benefit depends on inflow at Vernalis, best with Inflow/Export >3 to 5 (preferred). Low inflow and low export w/o UOR Barrier shown to be of little benefit based on recent data (1988-1990).
14.	Block San Joaquin R flow below head Old R.	R	U,NC	Rejected, designed to direct fish to CVP/SWP salvage facilities. Impacts to Water Quality above Stockton likely.
15.	Remove Predators CCFB	R	M to L	Continued uncertainty, if successful could help San Joaquin juvenile more than Sacramento.
16.	Screen Upper Old R.	D	L to NC, Neg	Of value if bypass flow sufficient, tidal problems similar to Walnut Grove. Potential harm to adult migration.
17.	Trap/Truck or Barge	D,R	L to U	A lot of R and D, more feasible than Sac. R. but uncertainty remains and handling loss/straying still an issue.
18.	Improve CVP (Tracy) Fish Salvage Facility	R	L	Improvement possible, benefit relative to other measures low.
19.	Eliminate Reverse flows in south Delta and San Joaquin R.	D,R,MR	H	Strong agreement, some data support linked to export and inflow levels.

Key:

Ranking
H = high feasibility/success
M = medium " "
L = low " "
NC= no change in protection
Neg=negative impact to salmon
U = deemed unfeasible

Problem Addressed
D = diversion
MR= increase migration rate
R = lessen mortality in a specific region

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specific historical time periods. This approach assumed conditions in the Delta for salmon smolt survival have degraded over time. We utilized five different goals of protection in our analyses. They are provided in Table 13. Another goal was initially considered, that of doubling smolt survival relative to "base" (existing) conditions as stipulated in State Senate Bill 2261. It may be of value to the Board to consider this goal in their decision process. Additional historical time periods could have been used but the five chosen provide a broad range of environmental conditions and should help the Board and participants by providing sufficient information with which to chose a goal of protection. Shorter historical periods (fewer years) result in fewer numbers of each water year type of which to average resulting in greater variability and at times no estimate.

Average smolt survival indices for each water year type for each goal were estimated using smolt survival models (see next section) for the San Joaquin and Sacramento River portions of the Delta (Table 13). A mean survival index for the five water year (i.e., n=5) was used for all goals.

Considerable change has occurred in the Delta in the past 50 years that is reflected in the decrease in smolt survival estimates in Table 13. Through the period 1950 to the present, the Delta Cross Channel was built and increasing exports occurred from the South Delta via the CVP and SWP. Inflow and outflow volumes and timing and the direction of net channel flows also have changed. All resulted in greater numbers of salmon being diverted off their mainstream migration routes toward the south and Central Delta and a likely general increase in residence time, thus, slowing their migration rate. Both changes caused an overall decrease in survival in the Delta. In addition, there has likely been a rise in water temperature since water development projects have decreased spring time river snow melt flows, at least in the wetter years. Limited comparisons between two "wet" years showed higher temperatures in April through June of 1986, than were present in 1927 (Heidi Bratovich, State Water Resources Control Board, personal communication).

The choice of a "base case" representing present conditions in the estuary, with which to compare with previous periods, is an elusive concept. We believe the 1995 level of Development Operation Study with 1989 demand is an appropriate base to use as a tool to estimate the benefits of any proposed action. This operational study assumes 1995 level of development with 1989 level of demand for the 70 years of hydrology and reflects the greater exports and lower smolt survival over the entire period of record.

Methods Used to Estimate Salmon Smolt Survival by Goal and Alternatives

Table 13. Predicted smolt survival indices for the Sacramento and San Joaquin River portions of the Delta for specified goals under varied water year types.

Sacramento Delta Smolt Survival Indices

	W	AN	BN	D	C	MEAN OF FIVE YEAR TYPES
GOAL						
1940 Level of Development	.76	.81	.77	.63	.44	.68
1956-70 Historical	.56	.45*	.35	.26	.20*	.36
1960-88 Historical	.44	.43	.31	.25	.19	.32
1978-90 Historical	.39	.32*	.28*	.22	.16	.27
1995 Level of Development**	.37	.26	.22	.18	.17	.24

SAN JOAQUIN

	W	AN	BN	D	C	MEAN OF FIVE YEAR TYPES
GOAL						
1940 Level of Development	.58	.50	.52	.47	.39	.49
1956-70 Historical	.61	.25*	.18	.17	.15*	.27
1960-88 Historical	.43	.12	.17	.13	.12	.19
1978-90 Historical	.48	.15*	.09*	.06	.07	.17
1995 Level of Development**	.18	.08	.06	.06	.12	.10

* = Interpolated
** = At 1989 level of demand

Our basic approach was to use a variety of models that are designed to represent the factors influencing survival of fall-run smolts through the Delta. Factors used for input values in these models were San Joaquin River flow at Vernalis and Stockton, combined CVP/SWP Delta exports, water temperature at Freeport, the percent of water diverted off the Sacramento River at Walnut Grove via the Delta Cross Channel and Georgiana Slough, and the use or non-use of a full barrier at the head of Old River.

Flow and export data were provided by DWR's DAYFLOW records or operations studies. The percent diverted at Walnut Grove was calculated using DWR equations and appropriate flow and Delta cross channel gate operations (see USFWS Exhibit 31, 1987).

Water temperatures were from U.S. Geological Survey (USGS) records at Freeport (1960-1990) or from the Sacramento Water Treatment Plant (1939 to 1959).

The smolt survivals used for historic (goal) survival estimates were weighted by the percent migration by month as follows: Sacramento Delta - April 17%, May 65%, June 18%; San Joaquin Delta - April 45% and May 55%.

Water year types for all goals with the exception of the 1995 LOD and Alternatives A-E were based on the Sacramento River four Basin index (per D1485). The 1995 LOD and Alternatives A-E were based on the 40-30-30 water year classification system for the Sacramento Basin and the 60-20-20 for the San Joaquin Basin.

Some of the shorter time periods, 1956-1970 and 1978-1990 did not have all water year types represented. Survival levels were obtained for these year types by interpolation. Model survival levels that were over 1.0 were set at 1.0 for averaging by year type. Negative estimates of survival were set equal to 0.0.

Smolt survival for the Sacramento River Delta is based on the model described in Kjelson, et. al. 1989 (WQCP-USFWS-1) which uses the percent diverted at Walnut Grove, Freeport water temperature, and CVP/SWP Delta exports as variables. The model is based on coded wire tagged (CWT) smolt recovery data from tagged smolt releases between 1978 and 1989. A recent evaluation of the Sacramento model adding data for 1990 and 1991 changed the model equations in only minor ways with the three key factors remaining the same. Hence, we utilized the 1989 version.

Smolt survival for the San Joaquin Delta was based on three regression models using relationships between San Joaquin River inflow at Vernalis, San Joaquin River flow at Stockton and combined CVP/SWP exports. Due to the lack of CWT data for a variety of flow and export conditions from the San Joaquin River side of the Delta we relied in part on relationships between adult fall-run salmon escapement to the San Joaquin basin and spring time Vernalis inflow and CVP/SWP exports 2½ years earlier.

By assuming that smolt survival was related to inflow or the combination of inflow and export in the same way as they are to escapement we arrived at a means to predict smolt survival through the Delta for historic periods without a full barrier at the head of Upper Old River.

The relationship for predicting smolt survival at the 1940 level of protection goal relied on only inflow as the independent variable (Figure 13). It represents conditions when no barrier is at the head of Old River. The relationship is defined as: $y = 0.1943+.0000304$ where y = smolt survival and x = San Joaquin River flow at Vernalis, $r^2 = 0.59$ $r =.77$ ($n=6$, $p< 0.10$).

This smolt survival flow relationship was based on the original relationship between escapement (in the Tuolumne river) and Tuolumne City flow for the escapement years 1938-1940, 1942, 1944 and 1945 (Figure 14). We replaced escapement values on the Y-axis with smolt survival values with a range of 0 to 100% survival corresponding to the range of 1 to maximum escapement (140,000).

The relationship used to predict smolt survival for all other levels of protection goals without a barrier at the head of Old River was based on a multiple regression between adult production index (W. Loudermilk, personal communication, DFG, Fresno, CA, 1988 draft report), from years 1969 to 1987 (excluding 1981) and both Vernalis inflow and combined CVP/SWP export 2½ years earlier (Figure 15). Again, we replaced escapement values with percent survival number in the same manner as above. This relationship (Figure 16) is defined as : $y = (4.90106+.000286(x_1)-.000774(x_2))/12$ where y = smolt survival, x_1 = Vernalis flow and x_2 = CVP+SWP exports.

The relationship we used to predict smolt survival when a full barrier was present at the head of Old River was based on survival data from our CWT smolt releases made at Dos Reis Park on the San Joaquin River just downstream of the junction with Upper Old River from 1982, 1985-1987 and 1989-1990 (Table 6). Regression analysis indicated that there was a significant relationship between San Joaquin River flow at Stockton and smolt survival. Flow at Dos Reis was obtained by subtracting the flow diverted into Old river using DWR equations from flow at Vernalis. The relationship is defined as: $y = 0.191271+.000067x$ where, y = smolt survival, x = San Joaquin flow at Stockton ($r=0.68$, $n=8$, $p< 0.10$).

Our regression analysis did not indicate that adding CVP and SWP exports to the equation would improve it. However, it is our

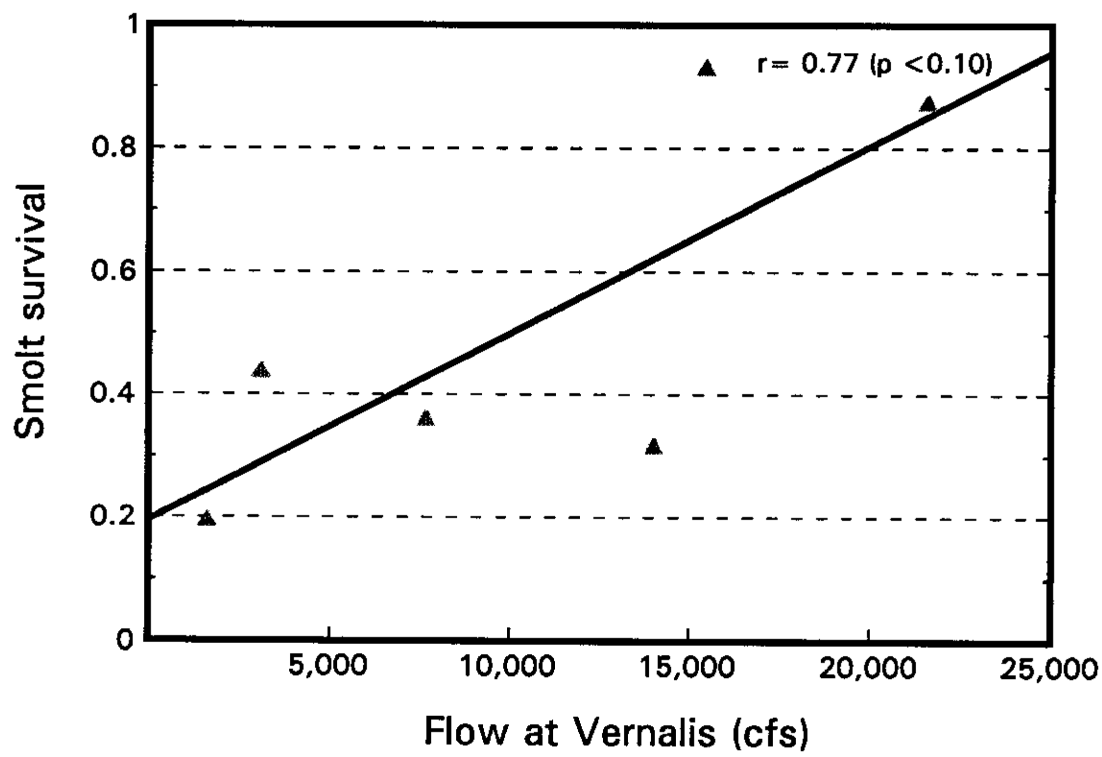

Figure 13: Relationship between smolt survival through the San Joaquin Delta and flow at Vernalis based upon a relationship between fall run escapement and flow in the Tuolumne River, 1938 to 1940, 1942, 1944 and 1945.

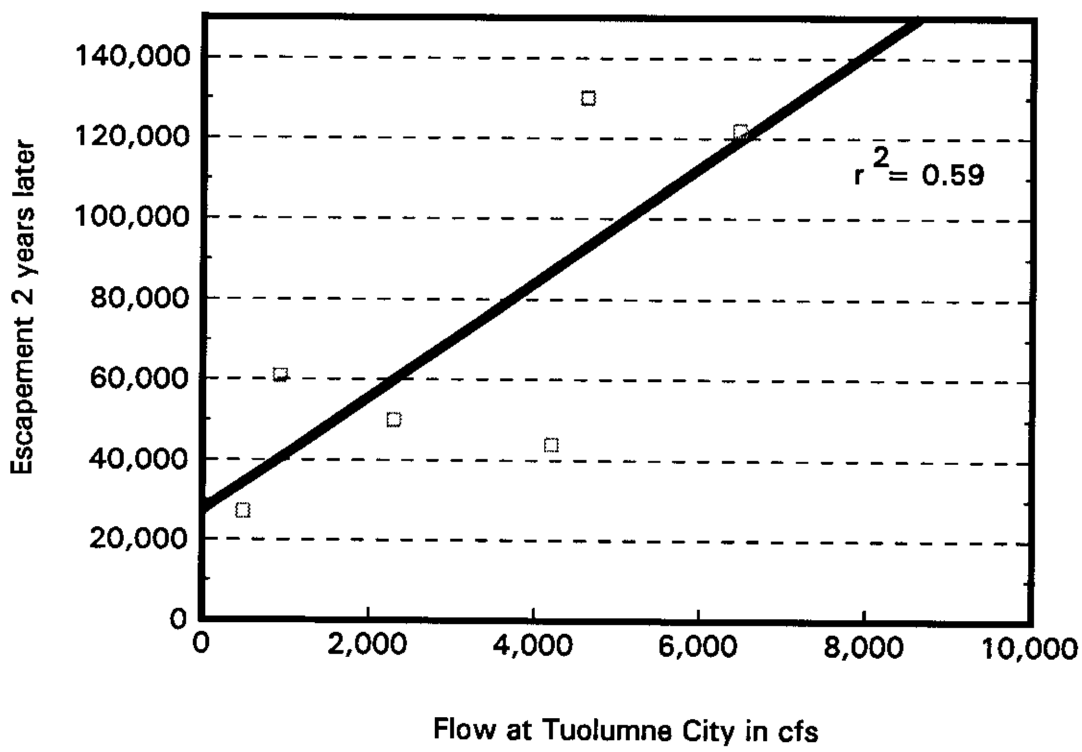

Figure 14: Relationship between fall run salmon escapement and flow in the Tuolumne River, 1938-1940, 1942,1944 and 1945.

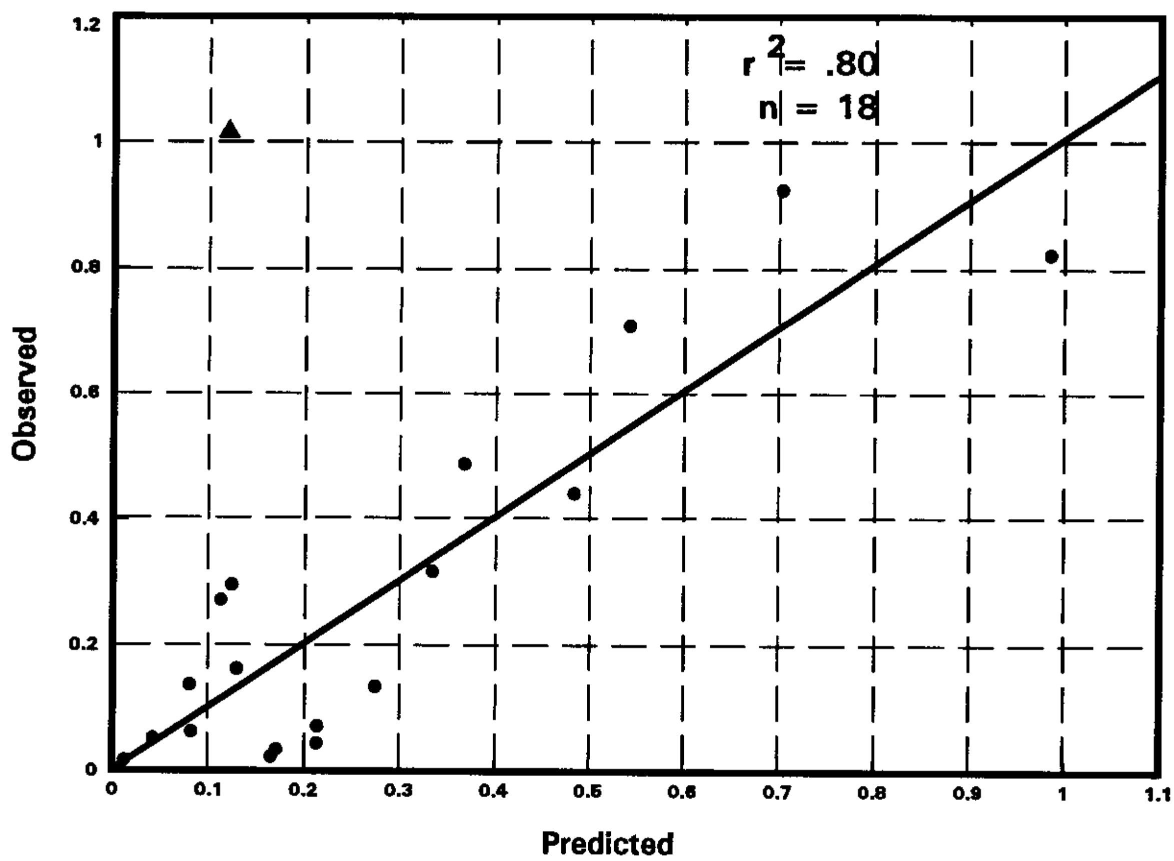

Figure 15: Observed and predicted smolt survival through the San Joaquin Delta from 1967 to 1985. ▲ Indicates outlier (1979) (not used in regression).

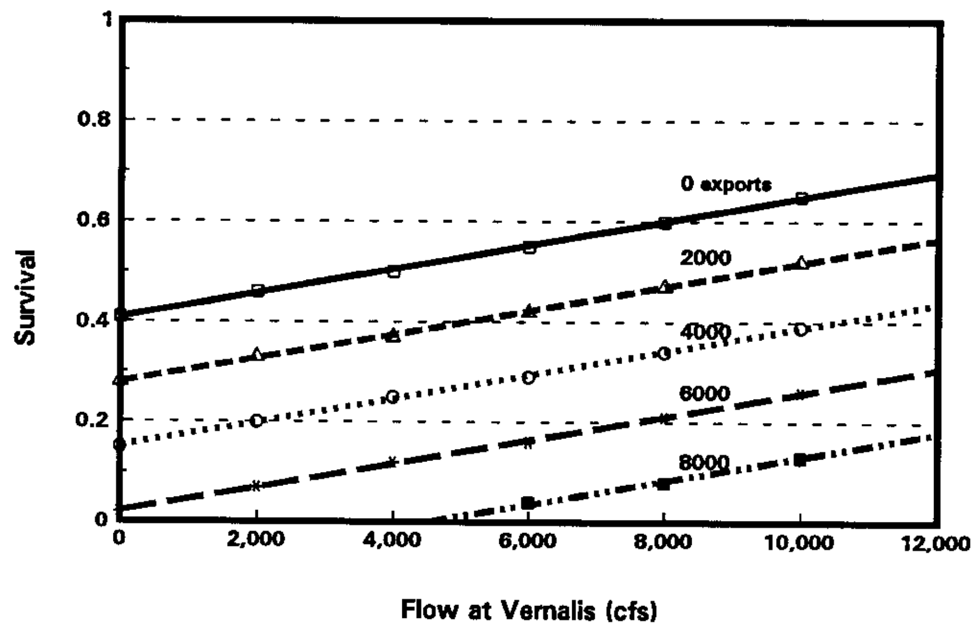

Figure 16. Relationship between smolt survival through the San Joaquin Delta, flow at Vernalis and exports at the CVP and SWP pumping plants without a barrier at the head of Upper Old River.

opinion that even with a barrier in the head of Old River that smolts migrating down the San Joaquin River would be exposed to negative impacts associated with the draft of water to the export facilities. We believe that the mortality would increase slightly less than without a barrier as exports increased. Hence, we developed a compressed family of lines to depict the change in survival as both flow and exports vary. Our initial relationship (Figure 16) represented an average total CVP and SWP export of about 6000 cfs where lines were separated by 0.10 units of survival. Compressing our original pattern of regression lines by about 1/2 (.05) both above and below the initial line depicting 6000 cfs we generated Figure 17. This was used to predict survival when a barrier was in Old River and is defined by the equation $y= (.341271 - 0.000025\ (X_1) + 0.000067\ (X_2))/1.8)$, where X_1 is CVP + SWP exports and X_2 is reverse flow at Stockton in cfs. Survival indices obtained using our Chipps Island index (as in the with barrier relationship) were divided by 1.8 as was done in the development of our Sacramento model (Kjelson et. al., 1989). (See WRINT-USFWS-9 for additional explanation.)

We continue to have the most reservation with our relationship that depicts survival with a barrier at the head of Old River due to the relatively high survival it provides at very low flow.

Selecting Alternative Protective Measures

Salmon protective measures were largely chosen to lessen or stop the diversion of salmon off the mainstem migration route and to increase migration rate through the Delta, or in some cases, to lessen salmon mortality once the fish have been diverted into high mortality regions. The potential solutions to these problems are fairly straightforward conceptually, but vary greatly in their relative benefits to salmon and their impacts (i.e., costs) to other beneficial uses.

Several characteristics further define the measures we have chosen: 1) measures that improved protection for both Sacramento and San Joaquin stocks with limited, if any, trade offs (i.e. protection for one stock or life stage at expense of other), 2) alternatives which could protect all life stages, although we have emphasized alternatives for fall-run, 3) measures that were feasible, could be implemented quickly, and with a high likelihood of success, 4) a mix of both operational and structural measures, 5) combinations of measures that had a minimum of complexity to lessen problems in implementation and compliance.

Our choice of actual measures to use was quite limited with survival primarily influenced by what the length of time given

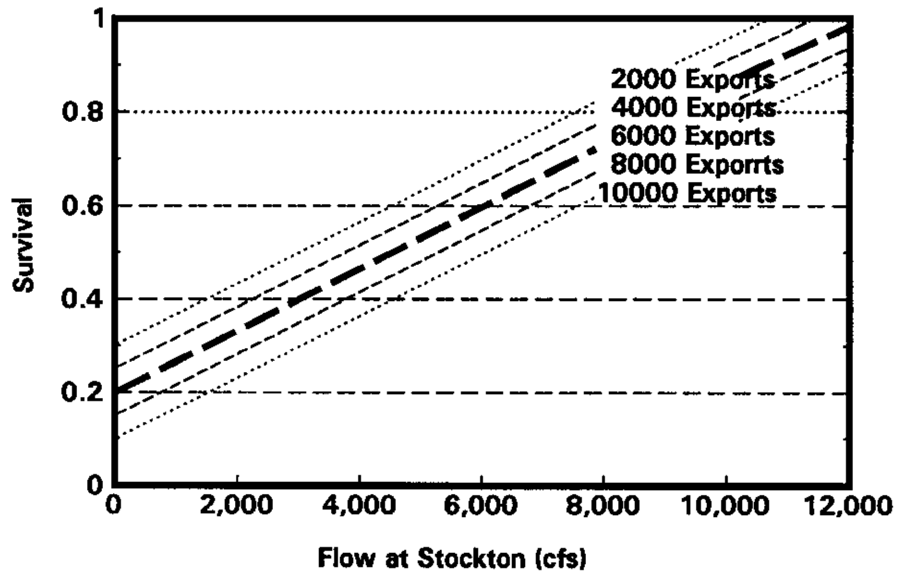

Figure 17: Relationship between smolt survival in the San Joaquin Delta, flow at Stockton and combined exports at the CVP and SWP pumping plants with a barrier at the head of Upper Old River.

measures were implemented. Changes in both inflow and export and a barrier at the head of Old River were used for the San Joaquin smolts protection. Delta cross channel and Georgiana Slough closures and export limits to protect smolts were used in the Sacramento portion of the Delta.

It is important to emphasize that, while we have used modelling (with its inherent limitations) to quantify the benefits of combined sets of protective measures, the primary basis for selecting given measures and their schedule of implementation is from a combination of basic experimental and monitoring data and professional judgment by a team of fishery biologists representing the five agencies and interested parties.

Estimated Smolt Survival Indices by Historical Period

Estimated smolt survival for the various historical periods are provided in Table 13.

As expected, the results indicate that fall-run smolt survival has decreased over time with the greatest change in survival between the 1940 level of Development and the 1956 to 1970 Historic period, with continued degradation to present day. Survival also decreased between the wet and critical water year types.

Alternative Measures to meet Salmon Protection Level Goals

The benefits, measured in smolt survival, to be obtained from any of the following protective alternatives (identified in Table 14), were derived by superimposing new flow, export and diversion conditions on the 1995 LOD operation study (1989 demands) and then using these output environmental conditions as input variables to our salmon models. Through this process, we developed five sets of alternatives (protective measures) that gave a range of smolt survivals which included all protection-level goals except the 1940 level of development. (The 1940 level of protection was unattainable because of the lower temperatures measured between 1939-1948 and 1951-1959.) The five alternatives are provided in Table 14 and, in general, reflect similar alternatives developed in the summer of 1991 for the scoping phase. The alternatives reflect protective measures for fall run salmon alone with some overlap for other runs in Alternatives D and E. They do not address, directly, protection for other fish species such as striped bass. However, the requirement of no net reverse flow at Jersey Point, when either the Delta Cross Channel or Georgiana Slough are closed, should help protect other species.

TABLE 14. Fall-run Salmon Protective Alternatives for Delta. [4]

Alter.	Year Type	Close Delta Cross Channel[1]	Close Georgiana Slough	Max Total CVP/SWP Exports[2]	Full Barrier Upper Old River	Minimum Flow Vernalis[2]	Minimum Flow Jersey Point[2]	Minimum Flow Rio Vista[2]	Fall-Run Smolt Survival Index[3] Sac .24	SJ .10 1995 LOD (Base X̄)
A	W AN BN D C	5/1-31 5/1-31 5/1-31 2 wks May 2 wks May	—	--	4/1 to 5/31 and 9/1 to 11/30 all year types	--	0 cfs during time cross channel gates closed	4/1 to 6/30 2500 cfs all water year types	.39 .30 .27 .21 .19 X̄=.29	.38 .19 .16 .16 .16 X̄= .23
B	W AN BN D C	5/1 to 5/31 all year types	--	May and June 5000 cfs all year types	4/1 to 5/31 and 9/1 to 11/30 all year types	3500 cfs 4/1-5/31 3000 cfs " 2500 cfs " 2000 cfs " 1500 cfs "	500 cfs during time cross channel gates closed	4/1 to 6/30 2500 cfs all water year types	.40 .31 .27 .23 .21 X̄=.30	.39 .21 .19 .17 .16 X̄= .24
C	W AN BN D C	4/15 to 6/15 all year types	--	6000 cfs 4/23-5/6 5000 cfs " 4000 cfs " 3000 cfs " 2000 cfs "	4/1 to 5/31 and 9/1 to 11/30 all year types	10000 cfs 4/23-5/6 8000 cfs " 6000 cfs " 4000 cfs " 2000 cfs "	4/15-4/22 and 5/7-6/15 — 4/23-5/6 1000 cfs — 3000 cfs 1000 cfs — 2500 cfs 1000 cfs — 2000 cfs 1000 cfs — 1500 cfs 1000 cfs — 1000 cfs	4/1 to 6/30 2500 cfs all water year types	.40 .32 .30 .26 .24 X̄=.31	.42 .25 .21 .19 .18 X̄=.27
D	W AN BN D C	4/1 to 6/30 all year types	4/15 to 6/15 all year type	6000 cfs 4/15-5/15 5000 cfs " 4000 cfs " 3000 cfs " 2000 cfs "	4/1 to 5/31 and 9/1 to 11/30 all year types	10000 cfs 4/15-5/15 8000 cfs " 6000 cfs " 4000 cfs " 2000 cfs "	4/1-4/14 and 5/16-6/30 — 4/15-5/15 1000 cfs — 3000 cfs 1000 cfs — 2500 cfs 1000 cfs — 2000 cfs 1000 cfs — 1500 cfs 1000 cfs — 1000 cfs	4/1 to 6/30 4000 cfs all year types	.48 .39 .37 .32 .29 X̄=.38	.46 .30 .26 .23 .20 X̄=.31
E	W AN BN D C	2/1 to 6/30 all year types	2/1 to 6/30 all year types	4/1 to 6/30 zero export all year types	2/1 to 6/30 and 9/1 to 11/30 all year types	10000 cfs 4/1-6/30 8000 cfs " 6000 cfs " 4000 cfs " 2000 cfs "	3000 cfs 4/1-6/30 2500 cfs " 2000 cfs " 1500 cfs " 1000 cfs "	2/1 to 10/30 6000 cfs all year types	.49 .40 .38 .33 .30 X̄=.39	.62 .49 .41 .34 .26 X̄= .44

1/ During time periods when no cross channel closure, export level or Rio Vista is specified then those standards required under D-1485 are to be implemented. SWRCB 1991 WQCP for Delta also is to be implemented.

2/ Flows and exports are mean daily averages

3/ Average survival ($\bar{x}$) indices are based on the average of the 5 water year type estimates (n=5).

4/ Estimates of survival for all the alternatives were derived from superimposing the new flow, export, and diversion conditions on the 1995 LOD operation study (1989 demands) and then using the survival models to estimate survival as described in the text.

The measures for the April-June period best reflect fall-run salmon smolt needs and are the result of the analysis process described previously. As noted earlier, protective measures for other races in other months assume that our knowledge on the factors influencing fall-run survival are generally applicable for smolt and/or yearlings of other races and steelhead trout.

We assume that these measures also provide some protection for any fry that are rearing in the Delta. We assumed that closing the Delta cross channel and or Georgiana Slough will not hinder the migration of adult Sacramento basin salmon through the Delta. Use of the Head of Old River barrier in the fall is a protective measure for San Joaquin spawner migration.

Long Term Goals to Protect Chinook Salmon

There are several potential methods whereby long term protection goals may be defined. Two have been mentioned earlier, they are: 1) that of keeping outmigrant salmon in their mainstem migration routes and 2) increasing their rate of migration through the estuary (this appears most necessary on the San Joaquin where typical mainstem flow levels and direction appear to slow migration greatly). Smolt migration rate has been regularly estimated in the Interagency program using mark/ recaptive methods on tagged smolts as well as the use of peaks in catch at Sacramento and Chipps Island for unmarked fish (WQCP-USFWS-2). Another method is that of 3) achieving a minimum smolt survival index for their Delta migration. Smolt survival has been measured since 1978 by the Interagency Estuarine Salmon Program through the use of coded wire nose tagged (CWT) smolts releases at various sites in the Delta with tag recoveries by trawl at Chipps Island and in the ocean salmon fishery (see USFWS Exhibit 31, 1987). Although characterized by sample variability typical of any fishery monitoring/recovery effort, measurement of CWT smolt survival could be used to see if long term survival goals are being met.

We have also utilized the ratio of unmarked fall-run salmon smolt catches at Sacramento and Chipps Island as another measure of smolt survival with some success, although it has more complicated assumptions (see WQCP-USFWS-2 through 4 and EIRSP-USFWS-4).

Finally, there is some potential for measuring smolt survival by using an index of abundance of Coleman Hatchery fall-run smolts that are sampled at Chipps Island following their release in mass (from 10-12 million smolts annually) in the upper Sacramento River. Since that release process began some years ago, we have consistently been able to observe their passage via trawl sampling at both Sacramento and Chipps Island. While we have not assessed this method fully, it would appear that for the time these hatchery fish are in the Delta, we could obtain a measure of their survival through the Delta, using the ratio of some measure of Chipps Island and Sacramento catch to the number of smolts released up river.

Meeting a variety of well defined habitat conditions as to those specified in our table of alternative salmon protection measures constitutes a 4th) method of defining a long term goal. An example would be that of closing Georgiana Slough for a shorter period of time under the interim (5 year) protection plan while a long term goal would be to close the slough for some lengthier period. Other examples come to mind relative to flow levels and length of "flushing flows", the length and degree of CVP/SWP export curtailments, and prevention of net reverse flow. All are easily seen in our table of alternatives that reflect a gradient of protection relative to smolt survival.

We are not recommending that a basic abundance index of smolts/tow at Chipps Island be used as a method to monitor achievement of long term goals due to the variety of upstream and Delta factors that influence the number of smolt.

It should be noted that small incremental changes in abundance and survival will be difficult to detect with any of the above sampling regimes due to sample variability.

Appendix 1. Midwater trawl catches at Chipps Island and Montezuma Slough expanded for time and channel size and % fish diverted into Montezuma Slough for 1987 and 1992.

1987				
Date	Chipps Island Expanded Catches	Montezuma Slough Expanded Catches	Total Expanded Catches	% Fish Diverted to Montezuma Slough
4/06 4/07	658 --	-- 0	658	0.00
4/08 4/09	1711 --	-- 0	1711	0.00
4/14 4/15	-- 6974	40 --	7014	0.57
4/16 4/18	-- 8158	60 --	8218	0.73
4/21	10658	100	10758	0.93
4/23	25658	60	25718	0.23
4/28	24342	100	24442	0.41
4/29	22632	260	22892	1.14
4/30	43289	560	43849	1.28
5/01	30132	400	30532	1.31
5/02	46316	460	46776	0.98
5/03	67895	260	68155	0.38
5/04	38947	300	39247	0.76
5/05	47632	260	47892	0.54
5/06	45526	660	46186	1.43
5/07	58816	340	59156	0.57
5/08	55526	140	55666	0.25
5/09	27368	440	27808	1.58
5/10	59474	100	59574	0.17
5/11	35789	0	35789	0.00
5/12	30526	240	30766	0.78
5/13	43421	360	43781	0.82
5/14	20921	260	21181	1.22
5/15	15132	140	15272	0.92
5/19	35789	0	35789	0.00
5/21	19474	340	19814	1.72
5/26	4342	60	4402	1.36
5/28	5000	140	5140	2.72
				MEAN ($\bar{X}$) = .81

Appendix 1 (Continued)

1992				
Date	Chipps Island Expanded Catches	Montezuma Slough Expanded Catches	Total Expanded catches	% Fish diverted to Montezuma Slough
4/20	104737	200	104937	0.19
4/21	146974	620	147594	0.42
4/22	215789	720	216509	0.33
4/23	155263	1560	156823	0.99
4/24	123553	620	124173	0.50
4/27	77105	1220	78325	1.56
4/29	83684	1100	84784	1.30
4/30	68816	360	69176	0.52
5/01	95395	960	96355	1.00
				MEAN ($\bar{X}$) = .76

92APP1.015