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

EXHIBIT SJRGA-42

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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.

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 1930'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 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 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.

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

Table 1. Comparisons of the survival indici (S_T) for CWT chinook smolts released in the Sacr ito River above and below the opened and closed De Cross Channel and Georgiana Slough diversion chan s between 1983 and 1989.

	Year	Above[1/]	elow[2/]	Below/Above
Cross Channel Open	1984	0.61	.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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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

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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

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).

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	% incre in raw surviva
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	
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	5
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	3
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	-1:7	2
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	6
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	5
							Mean difference in %		3
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)

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

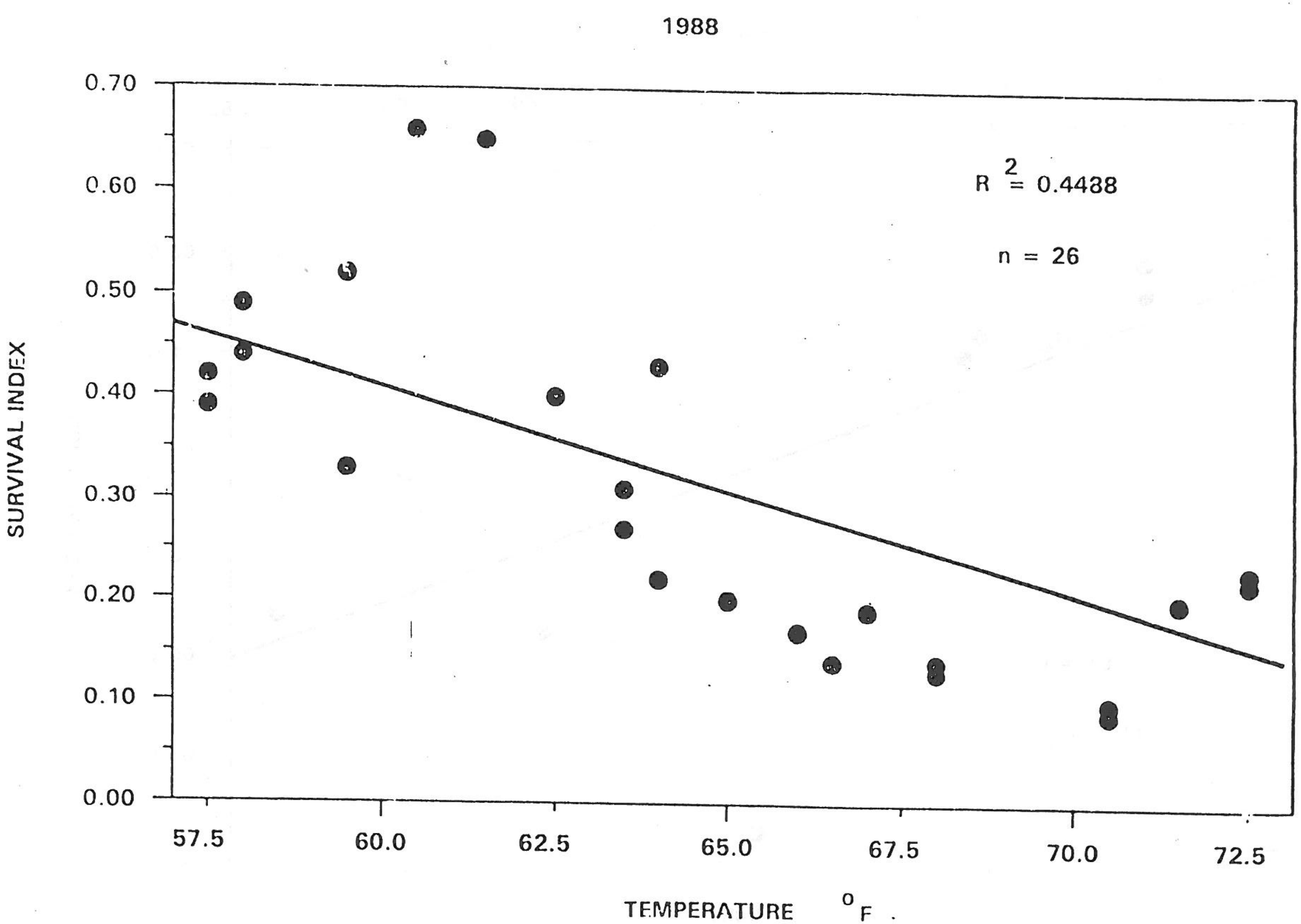

Figure 7. Relationship between unmarked, natural smolt survival and temperature through the Sacramento River delta in April, May and June 1988.

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

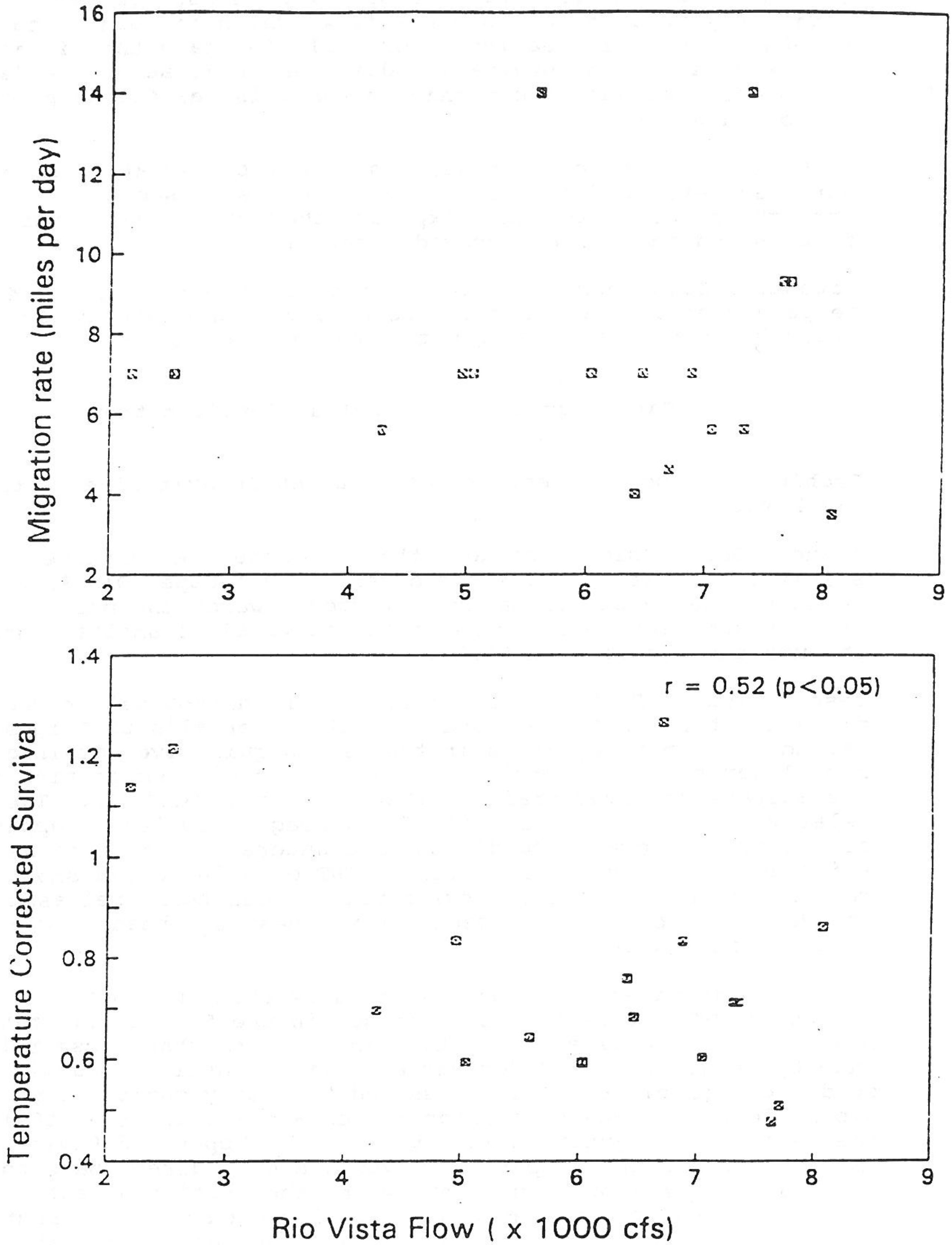

Figure 10: Migration rate and temperature corrected survival (to 61 °F) for CWT smolt salmon released at Ryde versus Rio Vista flows during the time the fish were migrating, 1983 to 1990 and 1992.

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
5-15-90 (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	**.33 (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.

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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 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 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.

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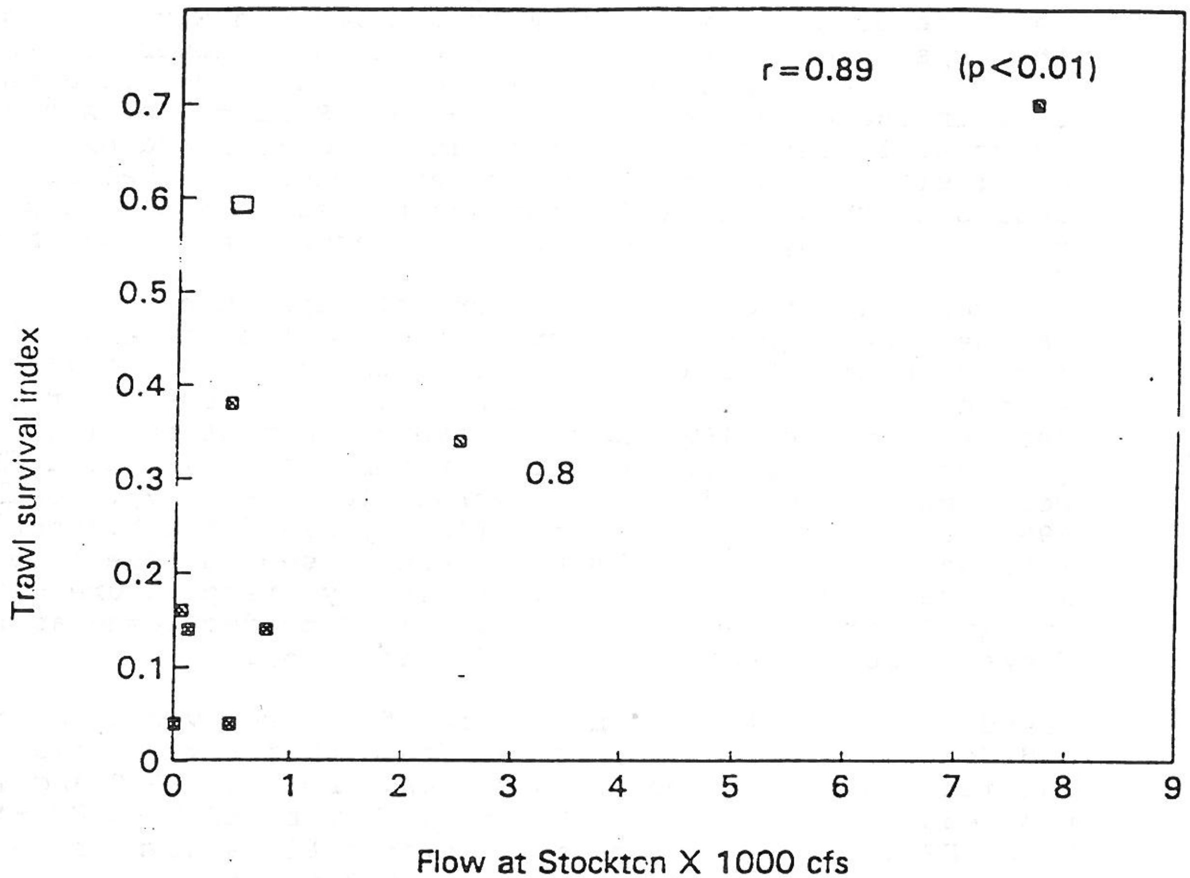

Figure 11: Flow at Stockton versus smolt survival in the San Joaquin Delta as indexed by midwater trawl recovery of CWT smolts.

□ Indicates an outlier not used in the regression.

y= 0.12257 + .000076 (flow at Stockton)

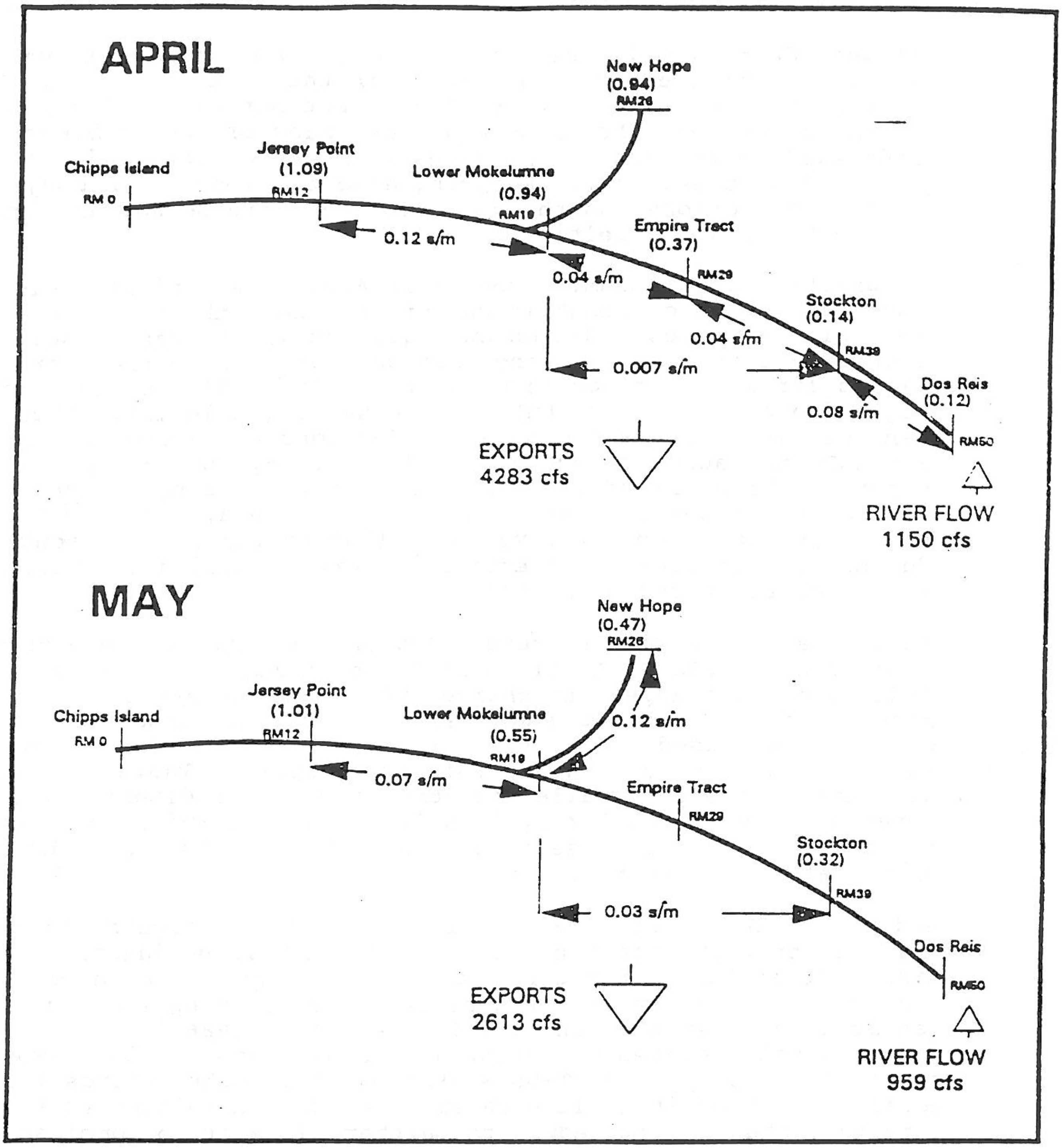

Figure 12: Diagrammatical representation of the San Joaquin River Delta area reflecting data from CWT smolt experiments in April and May of 1991. Temperature corrected (to 59 °F) survival (in parentheses) per release group to Chipps Island and survival per mile ($\hat{S}$/m) provided between release 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.

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	
$\overline{X}$ (88-90)	April	1st 3 weeks		22
		last week		22
				44
	May	first week		19
		last 3 weeks		36
				55

92TAB11.014

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 [illegible] conclusive. Potential to overcome predation via grea[illegible] turbidity, lower temperature and toxic effects. Most va[illegible] 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 need[illegible]
4.	New Hope Screen/Gate	D	H	Strong agreement, New Intake to replace X-channel [illegible] Georgiana Sl. diversions which would be closed to wa[illegible] diversion. High cost facility.
5.	Curtail CVP/SWP Exports	D,R	M to L	Greatest benefit if inflows remain constant, indir[illegible] impacts appear greater than direct as Sacramento sm[illegible] numbers not high at Salvage facilities.
6.	Remove Predators Clifton Court Forebay	R	L to NC	Uncertainty as to feasibility/success and benefit [illegible] Sacramento salmon.
7.	Screen Georgiana Sl.	D	U	Rejected, too many uncertainties, R & D not worthwhi[illegible] tidal problems and space limitations make ineffecti[illegible]
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, ti[illegible] 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 effectivene[illegible] trapping of other spp., handling losses, Columbia R. st[illegible] poor success with ideal facilities.

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

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

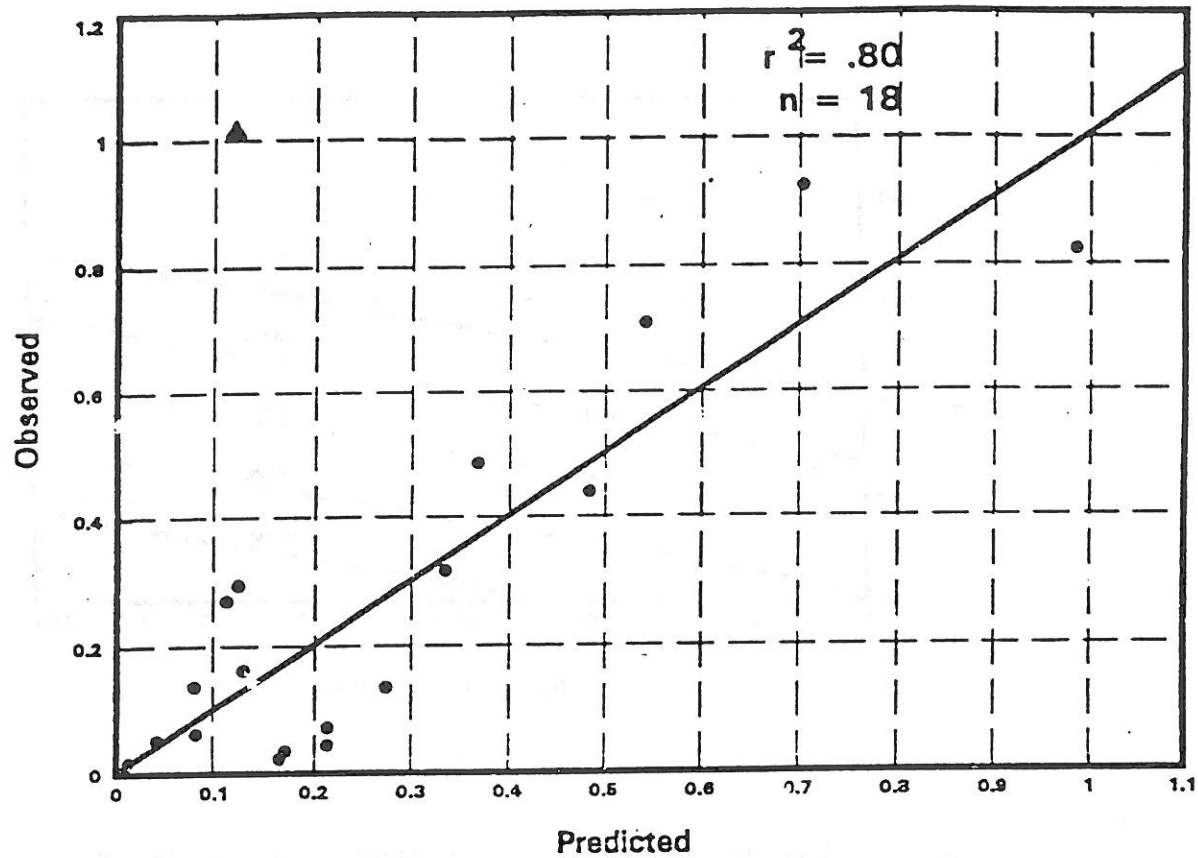

Figure 15: Observed and predicted smolt survival through the San Joaquin Delta from 1967 to 1985. ▲ Indicates outlier (1979) (not used in regression).

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 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 cros 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.

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

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