United States Department of the Interior

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June 14, 1994

429

California Urban Water Agencies
c/o Randy Bailey
Bailey Environmental
3050 Meadow Creek Road
Lincoln, CA 95648

Dear Randy,

This letter is being written to summarize our meeting on Monday, April 11, 1994 and to identify our concerns regarding your draft document entitled "A review of the Salmon Smolt Survival Index As Proposed by the U.S. Environmental Protection Agency As Water Quality Standards For The San Francisco Bay Estuary".

I would like to applaud your desire to help us refine our understanding of the factors controlling salmon smolt survival in the Delta and look forward to working with you through the EPA and SWRCB standard setting processes. Although we have some minor differences in how the model should be used, we are in agreement that the Delta salmon resources specifically, and the Bay/Delta aquatic resources in general, do need additional habitat protection.

As we provide information to the State Water Resources Control Board and EPA it is my goal to convey to them the general issues of agreement. For instance, we both agree that salmon smolts in the Delta could benefit from reduced temperatures, lower exports, increased flows (especially on the San Joaquin River) and prevention of diversion into less desirable areas (as the central and south delta). We are also in agreement that protective standards addressing these issues need to be adopted quickly before additional degradation of the salmon resources occur.

My responses to your document will first focus on your summary of primary conclusions.

1. "The index as proposed is not a water quality standard." We believe, as EPA does, that the concept of a smolt survival index can be used to protect this beneficial use. However,

temperature. We believe if temperature is reduced these sublethal effects would decline as well and net survival would increase.

In addition, higher temperature mortality in reach 2 is likely due to the smolts increased exposure time as the distance needed to successfully reach the ocean is increased.

You also state that "Until all of the factors affecting survival are incorporated into the estimates of survival, the use of the equations to develop salmon survival indices is patently invalid." Any model has it limitations because by its very nature it attempts to simplify complex biological systems using relatively simple mathematical equations. You have stated some of the shortcomings of our salmon smolt survival model, but we do not agree that it is possible or even desirable to incorporate all the factors affecting survival into a model or that developing salmon survival indices from the model is invalid.

As stated earlier, essentially all salmon biologist agree that decreasing the negative effects of high temperature, exports, and diversion off the mainstem rivers, will aid in improving salmon smolt survival in the delta. It is on this basis that we and DFG recommended specific measures in the July, 1992 State Board hearings for D-1630. The model provides a means whereby we attempted to quantify the benefits of those actions. While the model is imperfect in nature that imperfection does not negate the need to improve smolt survival through measures that are well supported by our CWT experiments and our basic understanding of salmon biology.

5. "None of the experimental data used to develop the various regression equations was based on very high flow data. Most fishery biologists would agree that exports would have a minimal effect on salmon smolt migration at very high flow conditions."

The first statement above is untrue, as 1980, 1982, 1983 and 1986 were used in the development of the model and were all high or extremely high flow years.

It is true, that survival was greater in those high flow years. When flow at Freeport is greater than 25,000 cfs the cross channel gates are closed. Also in these high flow years, temperatures were generally low and exports were in the midrange (3700 to 5200 cfs). Thus in these wet years a smaller percentage of smolts are diverted into the Central Delta and their survival in the interior Delta is greater than for the greater percentage of smolts diverted in a dry year. Overall survival in these wet years would be relatively high and is reflected as such in the model.

However, the effect of high exports (greater than 6000 cfs) on smolt survival during periods of high flow has not been measured and is outside the range of parameters used to develop the model.

6. "Given reasonable operational and flow conditions in the spring, the standard on the Sacramento River will be violated in most years because of the lack of influence of outflow

change.

Page 7, 2. Indices of 100% have occurred using the trawl index of survival as well as the ocean index of survival in years where survival is high (wet years). We attribute this to variability in both indices for different reasons or to a bias in the wet years where it is advantageous for the smolts to be released in the North Delta versus Suisun Bay (Port Chicago or Benecia).

Page 8, 3. In our meeting we discussed the problems with biological data of obtaining meaningful confidence intervals and asked to receive some guidance from your statistician in what could or should be done in these cases.

"While this level of precision may be appropriate for management actions, the question of whether or not this level is acceptable for regulatory purposes needs to be examined." We believe that both management actions and regulatory measures should be based on the best available science.

Page 8, 4.1: An evaluation was done in 1984, by Don Stevens, Marty Kjelson and Pat Brandes. In that analyses, it was determined that although there may be some bias from the difference in temperature between the stocking truck and the receiving waters, there was no consistent bias noted that would invalidate the conclusions based on the smolt survival indices. In addition, the fact that smolt survival through the Delta using both the trawl index and ocean index of survival are significantly correlated to each other supports the conclusion that we are successful in indexing smolt survival through the Delta using either method.

Page 8-9, 4.2: All salmon smolts used in the generation of the Sacramento smolt model were from Feather River Hatchery origin. There were no mixing of stocks between years.

Page 9, 5: We do not assume predation is constant at all water temperatures. We believe predation is a function of water temperature and that if water temperature is decreased, predation will decrease as well. Predation is a natural component of the ecosystem, and given a healthy and viable smolt population, predation in of itself would not control the population. Considering there is fewer predators (sublegal Striped Bass) now than in the last 25 years, it is very unlikely they are responsible for the decline of the natural population of chinook salmon. There may be more warmwater predators now than historically, but if temperatures were reduced, the number and success of warmwater predators would also be reduced.

Page 9, 6: Wickwire and Stevens, 1971, evaluated the diurnal distribution of salmon smolts at Collinsville. They found that the smolts were more evenly distributed at night and more aggregated to the surface during the day. In our generation of smolt survival indices, we do not assume a random distribution throughout the water column, we assume a random horizontal distribution, with the vast majority of smolts near the surface during our day

To: PAT BRANDES

Appendix I

Sacramento River Salmon Smolt Survival Index

		Temperature (F)			Index				Standard
Year*	Type	April	May	June	April	May	June	Total	Met?
1962	BN	56.6	61.0	68.5	0.043	0.211	0.021	0.275	NO
1963	W	54.1	59.3	68.9	0.042	0.252	0.019	0.313	NO
1964	D	58.2	63.7	70.6	0.045	0.154	0.013	0.213	NO
1965	W	58.8	59.5	66.1	0.044	0.247	0.031	0.321	NO
1966	BN	57.6	65.9	68.0	0.045	0.114	0.022	0.181	NO
1967	W	49.8	58.1	60.9	0.045	0.273	0.059	0.377	NO
1968	BN	58.5	65.6	70.0	0.045	0.119	0.015	0.180	NO
1969	W	55.7	60.7	65.3	0.043	0.218	0.034	0.295	NO
1970	W	57.4	64.4	71.6	0.044	0.141	0.010	0.195	NO
1971	W	55.0	59.4	64.4	0.042	0.249	0.039	0.331	NO
1972	BN	58.1	65.6	69.6	0.045	0.119	0.017	0.181	NO
1973	AN	59.7	67.0	70.1	0.039	0.096	0.015	0.150	NO
1974	W	54.2	62.0	66.5	0.042	0.189	0.029	0.260	NO
1975	W	54.1	60.7	66.3	0.042	0.218	0.030	0.290	NO
1976	C	57.9	66.8	68.5	0.045	0.099	0.021	0.165	NO
1977	C	62.5	63.9	73.4	0.025	0.150	0.006	0.181	NO
1978	AN	57.1	63.0	70.0	0.044	0.168	0.015	0.227	NO
1979	BN	59.8	63.8	69.2	0.038	0.152	0.018	0.208	NO
1980	AN	57.1	63.6	66.9	0.044	0.156	0.027	0.227	NO
1981	D	61.5	66.7	71.9	0.030	0.101	0.010	0.140	NO
1982	W	54.0	61.1	66.0	0.042	0.209	0.031	0.282	NO
1983	W	55.0	60.1	69.2	0.042	0.232	0.018	0.293	NO
1984	W	59.7	66.5	68.4	0.039	0.104	0.021	0.164	NO
1985	D	62.5	65.1	70.9	0.025	0.128	0.012	0.165	NO
1986	W	59.8	65.8	71.6	0.038	0.116	0.010	0.164	NO
1987	D		70.7			0.047		0.047	N/A
1988	C	59.5	66.0	68.6	0.040	0.112	0.020	0.172	NO
1990	C	61.4	65.7	70.1	0.030	0.117	0.015	0.162	NO
1991	C	59.5	65.5	68.2	0.040	0.121	0.022	0.182	NO
1992	C	64.0	70.7	70.8	0.019	0.047	0.013	0.078	NO

Constants
P1= 0.7
P2= 0.3

Weighting	
April	0.17
May	0.65
June	0.18

Index Value	
AN	0.38
BN	0.36
C	0.29
D	0.32
W	0.45

Exports	
April	11000
May	6000
June	6000

*1989 missing due to insufficient data

Flow through the San Joaquin portion of the Delta appears extremely important to smolt survival of the San Joaquin basin stocks and should be incorporated in concert with export curtailments, temperature reduction where possible and prevention of diversion into Old or Middle River. In addition, flows of less than 2000 cfs at Jersey Point, appear to decrease the survival of marked smolts released at Jersey Point (see WRINT-7, 1992). Some positive net Delta Outflow at QWEST from both the Sacramento and San Joaquin Rivers would appear to increase smolt survival for all races.

We will refer you to NMFS for reviewing CVP and SWP operations for effects on Winter run, our Sacramento Endangered Species office on Delta Smelt and to California Department of Fish and Game for other listed species or other species of concern.

However, there are races of chinook salmon (San Joaquin fall run, Sacramento spring and late fall runs) that are of special concern that are being negatively impacted by CVP and SWP operations. We believe that these races (especially, spring and late fall) would benefit from protective measures, that limit exports and the percent diverted into the Central Delta, between November and January. Recent data from November 1993 (also referred to in our May 11, 1994 letter) indicates that diversion into the Delta, even when temperatures are low and the outmigrants are relatively large, causes substantial mortality. Protection during this time of year appears to be justified considering the low levels of abundance of these races. We refer you to California Department of Fish and Game for escapement numbers for these races in recent years.

We have no specific information on the effects of upstream water projects other than the CVP and SWP, but where they limit the amount of flow entering the Delta and increase salmon mortality due to predation and entrainment loss, they would be of concern.
During May, our office has completed the editing and standardization of our historical beach seining data (1976 - 1993). We have provided it to both California Department of Fish and Game, California Urban Water Users Association, California Department of Water Resources, and Metropolitan Water District for there use in the Splittail Biological Assessment. If this data can be of any value to you in this standard setting process, please notify us and we will send you a copy.

Additional Chipps Island and Sacramento trawl data will be forthcoming by the end of June and may also help you to assess the status and trends of various fishery resources in the Bay/Delta estuary.

During the May 16th hearing the Board asked about the definition of an "Ecosystem Approach" for the Bay/Delta process. Our Fish and Wildlife Service has defined what they believe to be an ecosystem approach and the initial documents are available via our Region 1 office or ourselves.

DRAFT

(In Process of Review)
Brandes 5/31/94

The Development of a refined San Joaquin Delta Salmon Smolt Model

A refinement of our model(s) to estimate salmon smolt survival through the San Joaquin Delta was needed to more accurately reflect the influence of various environmental conditions and management alternatives. Some of our past analyses (the without barrier model) was based on adult production indices and the direct link to smolt survival was assumed because the number of actual smolt survival indices were too limited to conduct meaningful multiple regression analyses. In the past few years several additional marked CWT releases have been made which have allowed us to better link smolt survival to factors influencing smolt survival in the different reaches of the San Joaquin Delta.

This version of our model is based solely on survival estimates of coded wire tagged smolts released at various locations in the San Joaquin basin and has the flexibility to model survival with or without a barrier at the head of Upper Old River. Our general approach was to use the available smolt survival data, model mortality in various reaches of the San Joaquin Delta, combine the reach equations to predict total San Joaquin Delta mortality and compare model estimates with observed values. This approach is similar to that used to develop the smolt mortality model in the Sacramento Delta (USFWS, 1989).

In deriving our survival model, the San Joaquin Delta was divided into four separate reaches. Reach 1 was on the mainstem San Joaquin River between Mossdale and its junction with Upper Old River. After the mortality in this reach was estimated, it was omitted from the model to estimate total mortality through the San Joaquin Delta as many of the estimates were negative (see later discussion for reach 1). Reach 2 was defined at the reach of Old River between its junction with the San Joaquin River and Chipps Island via the CVP and SWP salvage facilities. Reach 3 was between Dos Reis and Jersey Point via the main stem San Joaquin River and reach 4 was between Jersey Point and Chipps Island. Smolts would either travel through reach 1 and 2, or reaches 1,3 and 4 (Figure 1). (However, since reach 1 was omitted early on from the model, smolts would travel route 2 or routes 3 and 4.) The proportion of fish taking either route was based on the percent diverted into Upper Old River. If the Upper Old River barrier was in place this percent diverted was set to zero.

Adjusted mortality in reach 4 was used as the dependent variable in a backward stepping multiple regression analyses, with flow at QWEST, exports and temperature at release as independent variables. The best predictive variables identified from that analyses included flow at QWEST and temperature at release. This relationship is depicted by the equation $y = -4.006795 - 0.000105(x_1) + 0.069136 (x_2)$ where x_1 = flow at QWEST (5 day mean including release day) and x_2 = water temperature at release (adj $r^2 = 0.645$, $n = 6$ and $p = 0.098$).

However, modeling of fish released at Ryde has shown that smolt surival between Ryde and Chipps Island is only related to QWEST within a narrow range of flows: - 3000 to + 3000 cfs (as we had in 1989 - 1991) and that exports was also related to smolt survival in that reach of the river (Figure 2 and Appendix 1). Given that we wanted to model smolt survival over a broad range of conditions we felt using the similar relationship with exports would be better. But it should be acknowledged that reverse flows in dry years appear to have a negative affect o n smolt survival between Jersey Point and Chipps Island. Thus the equation defining survival in reach 4 on the San Joaquin River Delta was $-3.658670 + 0.000051 (x_1) + 0.058492 (x_2)$, (adj $r^2 = 0.588$, $n = 6$, $p = 0.120$) where x_1 = mean exports (5 day mean after release, including release day) and x_2 = temperature at release (at Jersey Point)(figure 3).

Although these relationships are not significant at the $p < 0.05$ level, presumably because of the small sample size, the general relationships in this model should help managers weigh the relative values of management actions and document changes in smolt survival in the San Joaquin Delta.

REACH 3

Mortality in reach 3, from Dos Reis to Jersey Point, was estimated in two ways. We used both methods because it was more accurate to use concurrent releases at both sites when possible and only estimate when necessary.

The first way of estimating mortality in reach 3, was used for data gathered in 1989 - 1991 (5 data points), where concurrent releases were made at both Jersey Point and Dos Reis. Thus to estimate mortality between Dos Reis and Jersey Point we subtracted the mortality experienced between Jersey Point and Chipps Island from that experienced by the group released at Dos Reis (table 2), as shown by the following equation: $m_3 = ((m_{34} - m_4)/(1-m_4))$, where m3 = mortality in reach 3 (Dos Reis to Jersey Point), m_{34} = mortality between Dos Reis to Chipps Island and m_4 = mortality between Jersey Point and Chipps Island.

The second way we estimated mortality in reach 3 (the remaining adjusted mortality was related to flow in Upper Old River in cfs. The resulting equation was $y = \cancel{1.00918} - 0.00003(x_1)$ (adj $r^2 = 0.653$, $n = 6$, $p = 0.032$), where x_1 = flow in Upper Old River. (Figure 5 & 6).

REACH 1

Reach 1 is defined as the reach of the San Joaquin River between Mossdale (or lower river releases) and the Upper Old River junction. Mortality in reach 1 was estimated by subtracting m_{234} from M_t to get M_1 with the following equation:

$$Mt - \{(P_2 * M_2) + (P_3 * M_{34})\} \text{ where } M_{34} = (m_3 + m_4) - (m_3 * m_4).$$

Estimates of M_t were from coded wire tag releases made at Mossdale in 1992 and 1993 and at Snelling in 1982, Lower Stanislaus in 1986, 1988 and 1989 and the Lower Tuolumne in 1987. The release made at Mossdale on 4/6/93 was not used since smolts from that release were significantly smaller than for the other release groups (table 4).

Many of the M_1's derived were negative and no relationship to flow at Vernalis (the most likely important environmental parameter in that reach) was apparent. Thus M_1 was removed from the model and we assumed mortality in m1 was negible. Although this assumption probably in error, as some releases were actually made upstream of Mossdale and there likely would be some mortality in the several miles they traveled before entering the Delta, we still should be able to use the model to understand the mortality factors for San Joaquin smolts in the Delta.

Total Mortality

Given that m_1 was not incorporated into our model, total San Joaquin Delta mortality was actually defined as the combined mortality in reach 2 and reaches 3 and 4. As mentioned above smolts would only travel routes 2 or 3 and 4.

Total estimated mortality between Mossdale and Chipps Island was estimated based on adding the mortality from each of the reaches together using the equation;

$$M_t = M_{234} = (P_2 * M_2) + (P_3 * M_{34}) \text{ where :}$$

P_2 = the percent of water diverted into Upper Old River,
P_3 = the percent of water remaining in the mainstem San Joaquin River below the Upper Old River junction,

$$M_2 = \underline{1.01045} - 0.00003(x_1)$$

between releases). The most conservative approach given this information would be to try to use Merced River Fish for all future CWT releases to model S.J. smolt survival through the Delta. Tagging enough smolts at Merced River Fish Facility for use in coded wire tag experiments has not been possible in reacent years because of the low number of spawners returning to the hatchery, specifically, and to the basin, in general.

Another general observation of how the model is pperforming is that it appears to underestimate Delta mortality with the barrier at the head of Upper Old River in place. Perhaps we have credited the barrier with obtaining better survival than has been actually been observed.

Given these observations and perhaps limitations of the model, we still believe the model can be useful to evaluate alternative management options to improve smolt survival and estimate the changes that have occurred to San Joaquin smolt survival over time.

Table 2: Survival, adjusted mortality for CWT smolts released at Dos Reis and Jersey Point and estimates of mortality in reach 3 (between Dos Reis and Jersey Point).
Flow at Vernalis and Stockton, temperature at release, percent diverted, and exports for those releases is also included. Flow and export levels are the 10 day mean after release in cfs.

release date	Hatchery Stock	Size of fish (mm)	Dos Reis survival		M34 adjusted Mortality	vernalis	exports	temp	stockton	% diverted	m4 mortality	m3	estimate of temp(F) @ Jersey P	exports	Date of Jersey Point release	Jersey Point survival	Jersey Point adjusted mortality
4/22 & 23/82	MR	67	0.7	@	0.611	19233	5598	65	7861	0.59	0.404	0.348	61 *	9608 **			
4/30/85	MR	79	0.59		0.672	2597	6311	70	513	0.80	0.443	0.412	65 *	5876 **			
5/29/86	MR	96	0.34		0.811	7215	5386	70	2514	0.65	0.539	0.590	67 *	5467 **			
4/27/87	MR	79	0.38	@@	0.789	2386	6093	70	471	0.80	0.300	0.698	63 *	5369 **			
4/20/89	FR	85	0.14		0.922	2274	10297	69	112	0.95	0.511	0.841	61	10142	04/24/89	0.88	0.511
5/2/89	MR	70	0.14		0.922	2289	2470	71	790	0.65	0.467	0.854	66	3394	05/05/89	0.96	0.467
4/16/90	FR	72	0.04		0.978	1290	9649	68	0	1.00	0.661	0.934	63	9579	04/18/90	0.61	0.661
5/2/90	FR	75	0.04		0.978	1665	2461	68	490	0.71	0.417	0.962	67	1890	05/04/90	1.05	0.417
4/15/91	FR	80	0.16		0.911	676	5153	60	60	0.91	0.050	0.906	59	4901	04/19/91	1.71	0.050
															05/13/91	1.69	

adjusted mortality = 1-(survival/1.8)
* temperature is at Chipps Island approximately 5 days after the release at Dos Reis
This temperature was used to determine mortality in m4 using equation for first 4 data point

** exports 5 day mean starting 5 days after release at Dos Reis (day 5-10)
This export level was used to determine mortality in m4 using equation for first 4 data points

M4 was either the observed values (1- (survival/1.8)) or estimated using the m4 equation:
$M4 = -3.658670 + 0.000051(x1) + 0.058492(x2)$
where x1 = exports and x2 = temperature at Jersey Point.
temperature at Jersey Point was unavailable thus estimates were obtained from our Chipps Island trawl records.

$M3 = ((M34-M4)/(1-M4))$

@ Original survival estimate modified (0.60) based on the ratio of recovery rates between the Dos Reis and Merced River release because sampling for the Merced River group did not cover the first week when the marked fish were likely to be passing by Chipps Island trawl.

@@ Original survival estimate modified (0.82) based on the ratio of recovery rates between Dos Reis and Upper Old River releases that year (see USFWS 1991 Annual Report).

file (dosreis.wk1)

Table 4: Survival, adjusted mortality, size and environmental conditions for fish released at Mossdale, Snelling, Lower Stanislaus and Tuolumne Snelling, Lower Tuolumne and Lower Stanislaus between 1982 and 1993.

year	site		Hatchery Stock	Mean size in (mm)	survival	Adjusted mortality	vernalis	exports	temp	channel depletion	stockton	%diverted	Qwest	
4/6/93	Mossdale		FR	59	0.038	0.979	3321	6997	63	800	695	0.79	2692	2.122232
4/28/93	Mossdale		FR	71	0.067	0.963	4630	1519	64	1400	1764	0.62	4953	0.331081
5/4/93	Mossdale		FR	72	0.072	0.960	4309	1512	61	1600	1626	0.62	4553	0.354846
5/12/93	Mossdale		FR	75	0.071	0.961	3111	3815	65	1800	898	0.71	1533	1.247956
4/7/92	Mossdale		FR	78	0.17	0.906	1538	2131	64	900	420	0.73	742	1.410324
4/13/92	Mossdale		FR	81	0.12	0.933	1270	1096	63	1000	406	0.68	1344	0.883871
4/20/82	Snelling	*	MR	68	0.62	0.656	27560	9426	65	1200	10594	0.62	31844	0.342465
4/29/86	L. Stan	*	MR	89	0.58	0.678	18400	5140	64	1100	7179	0.61	20320	0.27985
4/16/87	L.Tuol	*	MR	82	0.17	0.906	2870	7152	64	1200	484	0.83	199	2.523641
4/19/89	L.Stan	*	MR	76	0.21	0.883	2148	10189	65	1300	-115	1.05	-1792	4.8312
4/26/88	L.Stan	*	MR	79	0.09	0.950	2165	7180	66	1400	209	0.90	-1644	3.382007
4/24/92	Mossdale		FR	84	0.08	0.956	1455	1730	69	1300	417	0	790	1.221751
5/4/92	Mossdale		FR	84	0.01	0.994	1135	1736	71	1600	277	0	1443	1.597056
5/12/92	Mossdale		FR	86	0.02	0.989	868	1264	72	1800	207	0	409	1.552826

* Flow and export conditions are on day of release.
Flow and export conditions for releases not noted with an asterick are an average of 10 days after release

file (wobarr.wk1)

Legend
① Upper Old River
② Dos Rios
③ Jersey Point
④ Mossdale
⑤ mouth of Stanislaus River
⑥ mouth of Tuolumne River
⑦ Snelling - Merced River

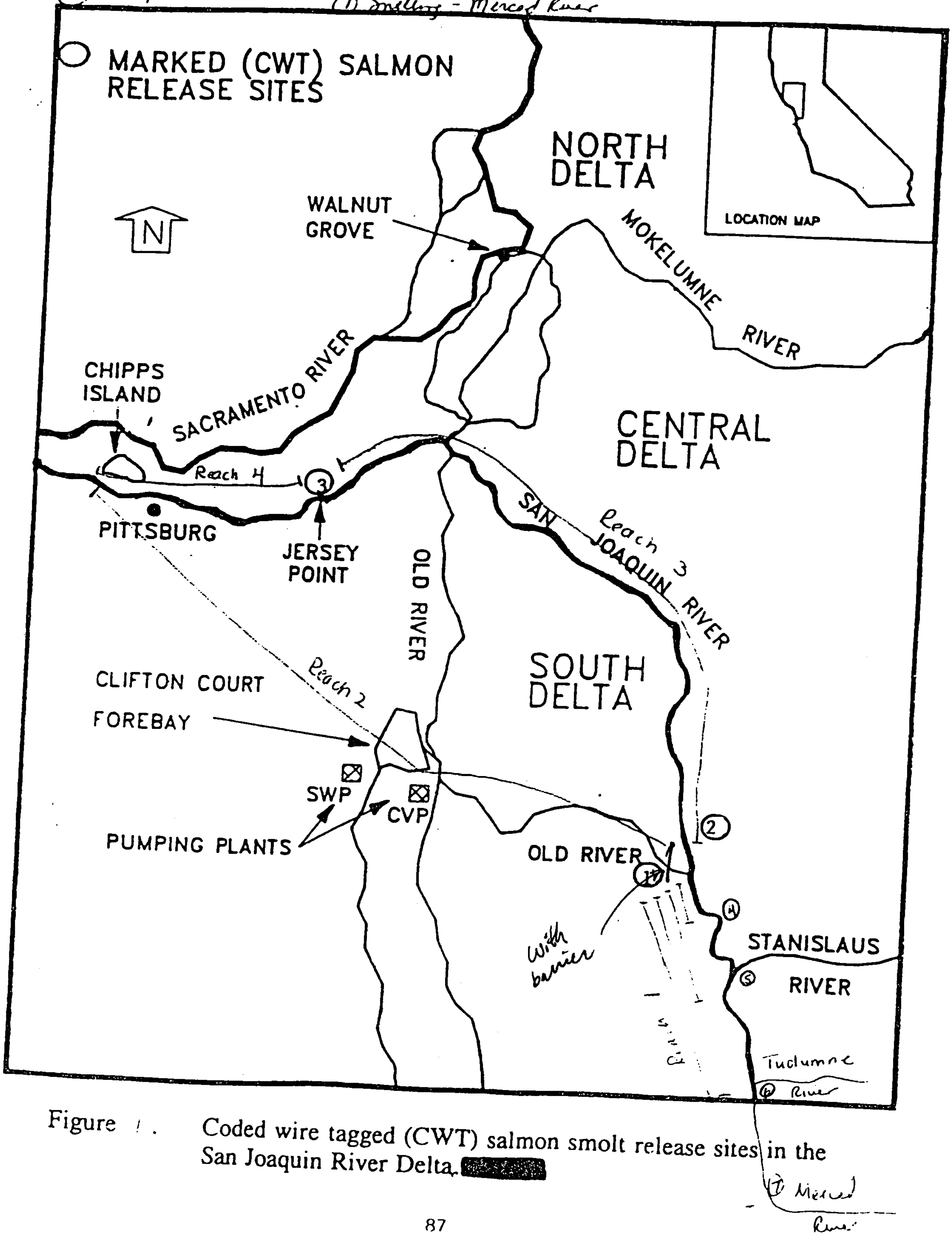


Figure 1. Coded wire tagged (CWT) salmon smolt release sites in the San Joaquin River Delta. [redacted]

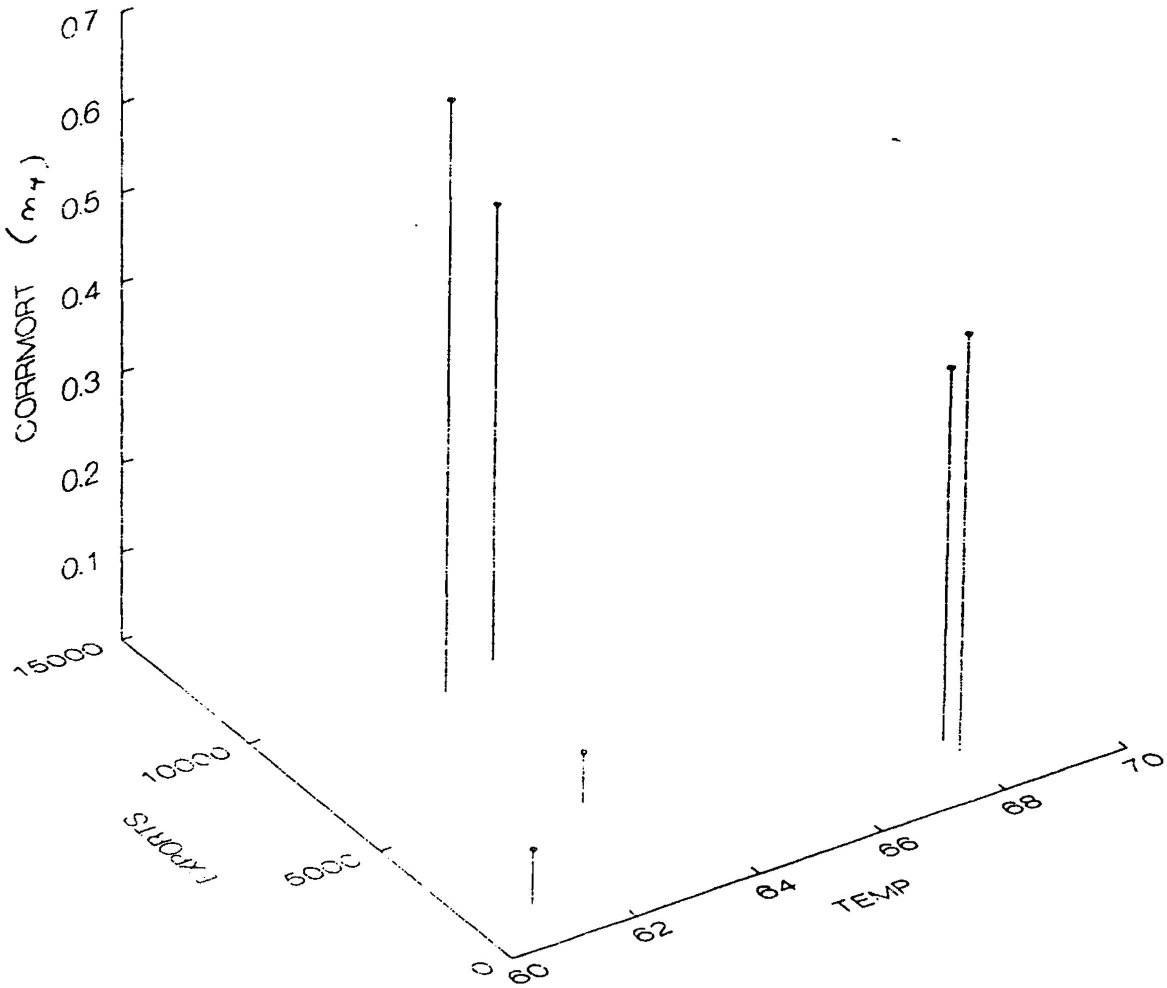


Figure 3: The relationship between adjusted mortality between Jersey Point and Chipps Island, temperature at release and CVP and SWP exports (in cfs).

Figure 3

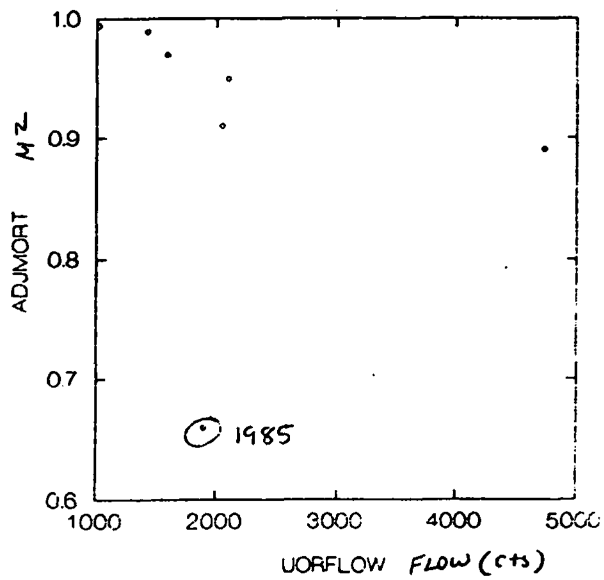
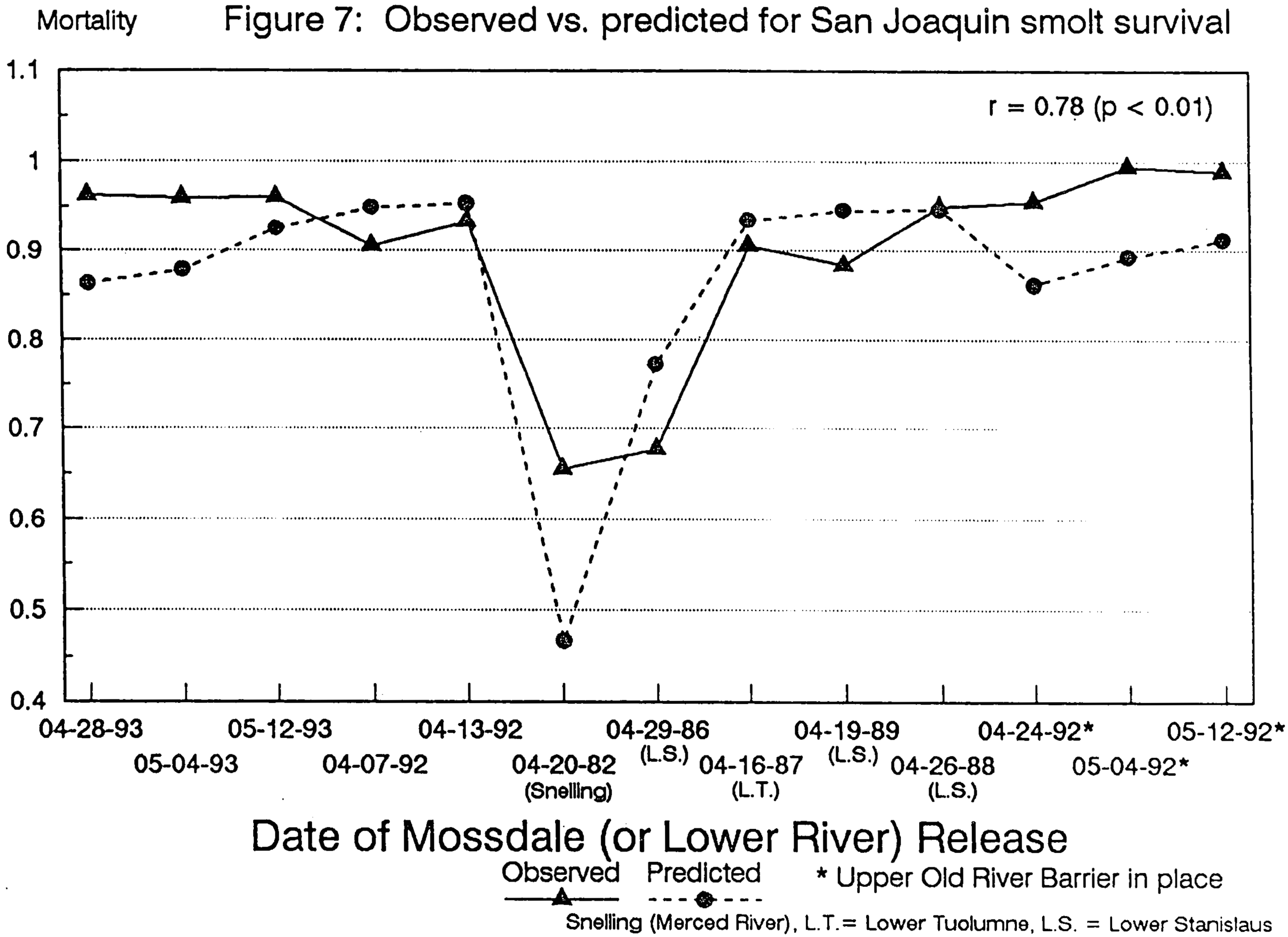


Figure 5: Relationship between adjusted mortality in Reach 2 and flow in Upper Old River (cfs) including data obtained in 1985.

Figure 5

Figure 7: Observed vs. predicted for San Joaquin smolt survival



Neither Sheila or I modified the raw survival indices in our modelling which accounts for the survival estimates of greater than 1 and less than 0 in our predictions.

Table A

Pat's Smolt survival model (REACH 3 - Q WEST)
Reflecting combined survival in reach 2 and reach 3

	BASE	ALT E	ALT H	ALT C	ALT B
FEB	.32	-1.9	.59	1.03	1.09
MAR	.56	-0.7	.59	.89	1.07
APR	.69	-0.9	.59	.91	1.04

Sheila's Smolt survival model (REACH 3 - TEMP AND EXPORTS)
Reflecting combined survival in reach 2 and reach 3

	BASE	ALT E	ALT C	ALT B	ALT H
FEB	.74	1.12	1.48	1.46	1.96
MAR	.74	1.27	1.37	1.48	1.85
APR	.94	1.07	1.25	1.28	1.72

Check with DAYFLOW

Antioch Flow * = 0.8 (1,000 + Vernalis + 0.13 (Freeport) - 0.667 (CD) - Exports)
When both Delta Cross Channel gates are closed.

San Joaquin River at Stockton = 0.42 (Vernalis) - 0.0873 (Exports). -100

Old & Middle River = 0.58 (Vernalis) - 0.913 (Exports)

The Old and Middle Rivers and the San Joaquin River at Stockton equations have been updated and will be used in preparing the Dispatcher's Daily Water Report in the near future. The updated equations are:

A

San Joaquin River at Stockton X_4 = 0.4184 (Vernalis) - 0.0186 (CD) - 0.0971 (Exports). X_4

Old & Middle Rivers Flow X_4 = 0.5816 (Vernalis) - 0.2703 (CD) - 0.9029 (Exports). X_4

Use the above equations when: Exports ÷ (Vernalis - 0.03 CD) ≤ 3.0.

B

San Joaquin River at Stockton = 0.3137 (Vernalis) - 0.0156 (CD) - 0.0625 (Exports).

Old & Middle Rivers Flow = 0.6862 (Vernalis) - 0.2733 (CD) - 0.9375 (Exports).

Use the above two equations when: 10.0 ≥ Exports ÷ (Vernalis - 0.03 (CD)) >3.0.

C

San Joaquin River at Stockton = 0.1114 (Vernalis) - 0.00950 (CD) - 0.0432 (Exports).

Old & Middle Rivers Flows = 0.8886 (Vernalis) - 0.2794 (CD) - 0.9568 (Exports).

Use when E/V-0.03(CD) >10.0

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*If the .8 factor in this equation is deleted, then the resultant flow approximates the flow in the San Joaquin River at Bradford Island above 3-Mile Slough.

	April	May
CD =	1053	1971