A MODEL FOR ESTIMATING MORTALITY AND SURVIVAL OF FALL-RUN CHINOOK SALMON SMOLTS IN THE SACRAMENTO RIVER DELTA BETWEEN SACRAMENTO AND CHIPPS ISLAND

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ABSTRACT

A multiple regression model is described that predicts fall-run chinook salmon smolt survival through the Sacramento River Delta between Sacramento and Chipps Island (near Pittsburg, CA). The model uses water temperature at Freeport, CA, the fraction of water diverted from the Sacramento River at Walnut Grove, CA, and total exports of the State Water and Central Valley Projects in the south delta. Each of these three factors is negatively related to smolt survival. Survival indices were based on coded wire tagged (CWT) smolts released at several delta sites and subsequently recovered at Chipps Island. CWT smolts were released under various environmental conditions. Correlation and regression analyses were used to choose those factors that explained a significant part ($p=0.95$) of the variation in smolt mortality. The model predicts the survival of smolts migrating from Sacramento to Chipps Island via the Sacramento River, and through the central delta via the Mokelumne and lower San Joaquin River systems. The greatest mortality was observed for smolts diverted into the central delta, indicating that keeping smolts out of that region would be highly beneficial to salmon production. Simulations of survival under varying temperature, fractions diverted and exports are provided to quantify the benfits of alternative salmon protective measures.

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by M. Kjelson, S. Greene and P. Brandes

INTRODUCTION

During Phase I of the California State Water Resources Control Board (CSWRCB) Bay/Delta Proceedings of 1987, the United States Fish and Wildlife Service (USFWS) presented testimony which described the relationships between survival of salmon smolts and streamflow, diversions and water temperature as smolts migrate downstream from Sacramento to Chipps Island (Figure 1). The relationship between survival and flow was used to represent the response of smolts to changes in flow, water temperature and diversion.

The USFWS noted that they had been unable to separate the independent effects of these three factors, but noted that smolt survival increased with increased river flows, decreases in the fraction diverted off the Sacramento River at Walnut Grove, and decreased water temperatures.

The inability to separate the effects of these physical factors was due to the fact that experimental coded wire tagged (CWT) smolts had most frequently been released at high water temperatures, high diversion fractions and low flows, or at low water temperatures, low diversion fractions and high flows. These two sets of conditions reflect how the State Water Project (SWP) and Central Valley Project (CVP) have operated in recent years, and the fact

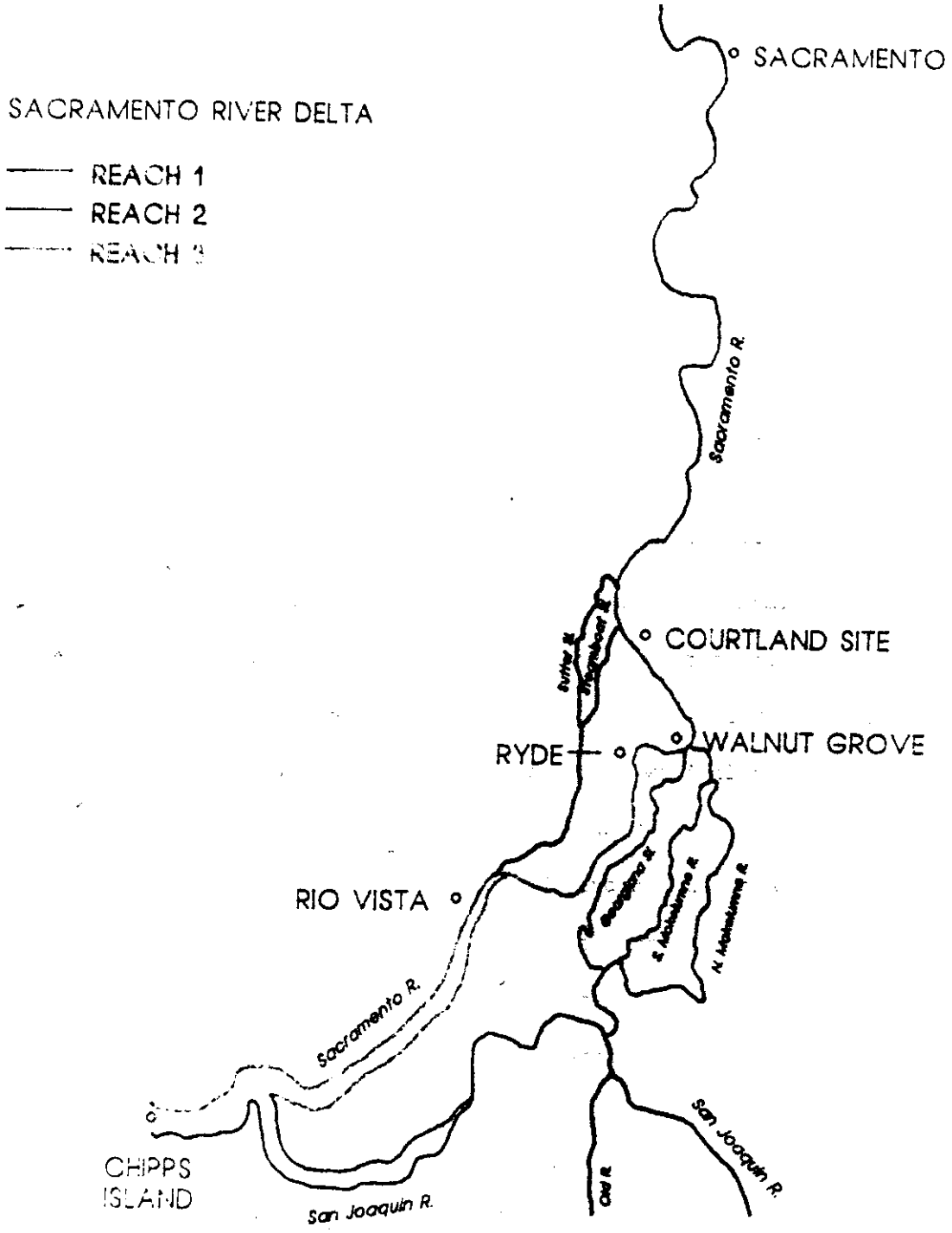

Figure 1 Reach diagram for Delta Survival Model.

that water temperatures naturally increase as flows decrease as the spring progresses. Survival was not measured when both flows and temperatures were low, when lower temperatures could have increased survival. The above conditions resulted in the three physical factors being intercorrelated (termed colinearity). Hence, as noted in our 1987 testimony, survival may have been underestimated during cooler, low flow periods using the flow:survival relationship.

During the spring of 1988 and 1989, management of the delta and upstream reservoir system allowed us to estimate the effects of the three factors independently. In these years CWT smolts were released in early May at relatively low flows and low temperatures and in June at low flows and higher temperatures. Diversion fractions were both high and low during both the May and June releases in 1988. These additional data enabled us to better separate the effects of flow, diversion and water temperature, and to develop a model that quantifies the smolt survival response to changes in several environmental parameters in the Sacramento River Delta.

The data used to develop the model has some limitations. (1) Survival measurements were not made over a broad range of conditions, (2) sample variability or potential error is present in both sample and environmental measurements, (3) some colinearity remains between factors, (4) there is a lack of survival measurements for specific reaches in the delta.

We have developed a multiple regression model that relies on the use of those environmental variables that account for a statistically significant fraction of the variation in survival. The model is conservative in that the environmental variables chosen were individually significant in each equation at the 95% level, and each regression equation was significant at 95%. This

Table 6. Stepwise multiple linear regression between estimated mortality using CWT chinook salmon smolts released at "Courtland" site and recovered at Chipps Island for Reach 2, Walnut Grove to Chipps Island via the central delta, (M_2) and average daily water temperature at Freeport on the day of release, daily State Water Project plus Central Valley Project exports during the period smolts passed from release point to Chipps Island.

Variable	Regression Coefficient	Standard Error	T-Statistic	Partial Correlation	Cumulative Percent Variation Explained
Intercept	-0.5808532	0.3343113	-1.737462	----	----
Average Daily Water Temp °F @ Freeport on Release Day	0.0179269	0.0047439	3.778932	0.77	48.71
SWP plus CVP Exports	0.0000418	0.0000184	2.279014	0.58	66.43

R-Squared = 0.6589
F-test = 9.658
Standard error of regression = 0.07834

Table 9. Linear regression between estimaetd mortality using CWT chinook salmon smolts released at Sacramento and recovered at Chipps Island for Reach 1, Sacramento To Walnut Grove, (M_1) and the average daily water temperature at the Freeport on release day.

Variable	Regression Coefficient	Standard Error	T-Statistic	Partial Correlation	Percent Variation Explained
Intercept	-2.858	1.211	-2.355	----	----
Average Daily Water Temp °F @ Freeport on Release Day	0.04851	0.01798	2.698	0.63	39.8

R-Squared = 0.3982
F-test: F ratio = 7.280
Standard error of regression = 0.3123