Estimating Survival and Distribution of Juvenile Chinook Salmon Migrating through the Sacramento – San Joaquin River Delta

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Introduction

To recover endangered salmon populations in the Sacramento River Watershed, fishery and water managers need to understand the effects of water management actions on movement and survival rates of juvenile salmon migrating through the Delta. Yet the complex channel network of the Delta poses challenges for studying migration dynamics of salmon smolts (Figure 1). Researchers recently began using acoustic telemetry techniques to better understand movement and survival dynamics of juvenile salmon migrating through the Delta.

Goals

Our goal is to develop statistical models that can be used with telemetry data to:

1) Estimate survival of juvenile salmon for discrete reaches of the Delta.

2) Estimate smolt entrainment probabilities at important channel junctions: for example, the proportion of fish entrained into the Delta Cross Channel and Georgiana Slough on the mainstem Sacramento River.

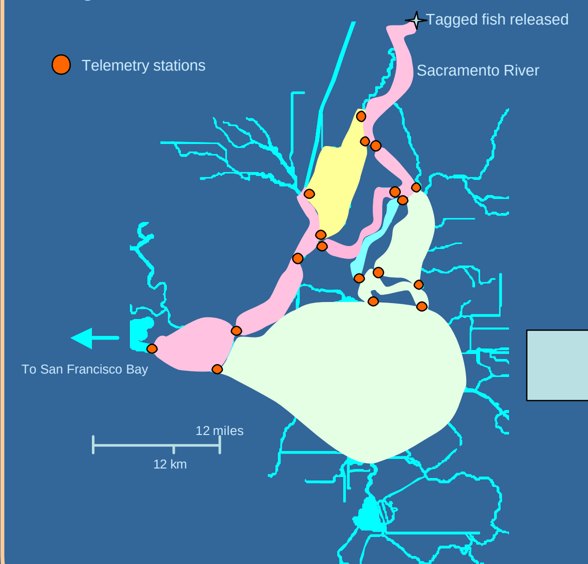

Figure 1. Map of the Sacramento-San Joaquin River Delta showing deployment of telemetry sites that can be used to estimate survival and entrainment probabilities of acoustically tagged juvenile salmon smolts. Colored areas on the map correspond to the schematic in Figure 2 to link river reaches with parameters that are estimated for each reach and telemetry site.

Methods

The detection pattern of each tagged fish can be used to estimate survival, entrainment, and detection probabilities (Figure 2). The modeling process is to:

1) Define the detection pattern of each fish in terms of the model parameters. For example, a fish detected at every telemetry station in the mainstem Sacramento R. survived through the Delta. The joint probability of this event is (following pink path in Figure 2):

$$p_i = S_1{*}(1\text{-}A){*}P_{b1}{*}S_{b1}{*}(1\text{-}D){*}B{*}P_{b2}{*}S_{b2}{*}P_{b3}{*}S_{ab1}{*}P_{b4}{*}S_{ab2}{*}P_{b5}{*}S_2{*}P_{b6}{*}l$$

2) Tally frequencies of fish with each detection pattern. These frequencies follow a multinomial distribution.

3) Estimate parameters by using a maximum likelihood function to fit the data to a multinomial model:

$$L(q \mid R, n_i) = \binom{R}{n_i} \prod_{i=1}^{k} p_i^{n_i}$$

where L is the likelihood function to be maximized, R is the number of fish released, n_i is the frequency of fish with each of k detection patterns and $\Sigma n_i = R$, and p_i is the probability of each detection pattern defined in terms of the parameters, q.

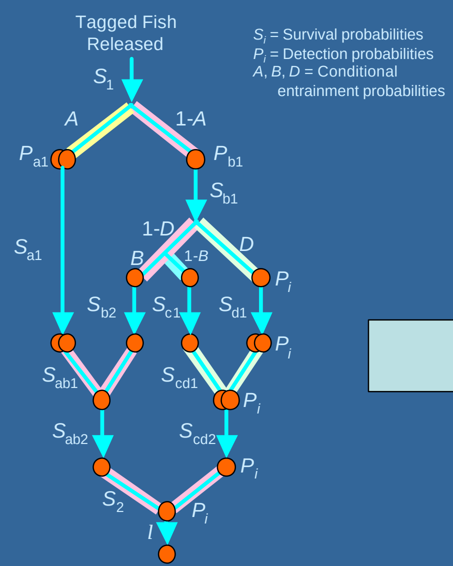

Figure 2. Schematic of multinomial model showing survival (*Si*), entrainment (*A*, *B*, and *D*), and detection (P_i) probabilities that can be estimated from the unique detection pattern of tagged fish migrating through the Delta. Colored branches of the schematic correspond to the map (Figure 1) to link parameters on the schematic to specific river reaches on the map.

Results

We applied these models to data collected during pilot telemetry studies conducted by USGS and USFWS during the winter of 2006/2007. In addition to estimating model parameters, we used functions of the parameters to estimate survival through larger regions, such as the North Delta (S_{nd}), South Delta (S_{sd}), and entire Delta (S_{delta}; Figure 3). The probability of entrainment into Steamboat and Sutter Slough (PR_{sutstm}) and Georgiana Slough (PR_{gg}) were also estimated as functions of the parameters *A*, *B*, and *D*. Given the small sample size, confidence intervals were narrow for the reaches in the North Delta. But only about 9% of fish entered the South Delta (PR_{cd}) leading to wide confidence intervals for this region. Overall, we estimated a survival probability of 0.49 through the entire Delta (Figure 3).

Next Steps

The first year of this three-year project was successful in developing and applying these models to data from telemetry studies in the Delta. In the future we plan to:

- Quantify effects of river discharge and the Delta Cross Channel on survival and entrainment probabilities.
- Examine finer spatial scales within the South Delta.
- Use larger sample sizes to improve precision

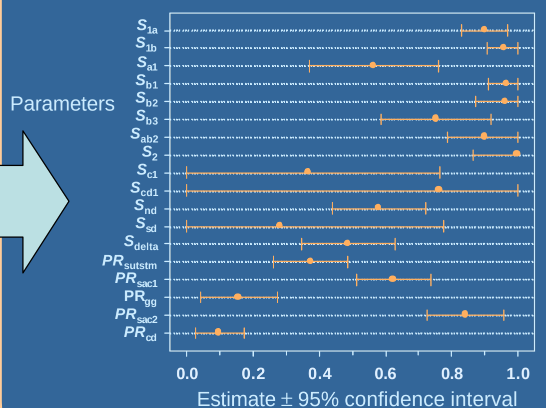

Figure 3. Survival and entrainment probabilities for 80 acoustically tagged late fall Chinook salmon in the San Joaquin – Sacramento River Delta. The model for this data differed slightly from that shown in Figures 1 and 2 due to differences in location of telemetry receivers and because the Delta Cross Channel was closed during the study period. Confidence Intervals and estimates were truncated an 0 and 1.

Many thanks to our collaborators: