FISH PASSAGE CENTER

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MEMORANDUM

TO: The Files

FROM: Jerry McCann

DATE: March 25, 2008 (update of memo from June 6, 2007)

RE: Methods for estimating a Population Index for juvenile salmon at Lower Granite Dam and Little Goose Dam from detection probability

Overview

In 2007 the Fish Passage Center first implemented the population index at Lower Granite Dam to better estimate the daily population passing the project based on collection in the SMP sample and the operations at the dam, such as flow and spill. In 2008 FPC has refined the method first developed for Lower Granite Dam and expanded that method to include daily population indices at Little Goose Dam as well. The original goal was to improve upon the passage index that was used for years to estimate daily passage numbers. The passage index expanded the collection at the powerhouse to include fish passing via spill. Fish were assumed to pass the spillway in equal proportion to the water spilled; a 1 to 1 ratio of fish to water.

The route of passage configuration has changed significantly at Lower Granite Dam since the installation and use of the Removable Spill Weir (RSW). This change in operations made it difficult to use the traditional passage index calculation within season for management application. The FPC explored the use of another metric called the "population index" (PI) at this project in 2007. Based on a request by NOAA fisheries the FPC has developed the index for both Lower Granite Dam and Little Goose Dam yearling chinook and steelhead.

Using PIT-tag detections at Little Goose Dam, it is possible to estimate daily detection probability (CE) at Lower Granite Dam. Then, using the daily estimates of detection probability a regression relationship was developed between CE and flow, spill and temperature, and then this regression was used to predict daily CE. Once daily detection efficiencies were predicted, a daily PI was calculated by dividing the daily collection (from SMP data) by the predicted CE for that date.

FPC estimated daily detection probabilities for hatchery yearling chinook and hatchery steelhead, for four years from 2003 to 2006 at Lower Granite Dam. Then predictive models were developed for estimating CE at the dam for each species. The regression model developed performed well when used to predict past years (2003-2006). However, when the regression model was applied to 2007 data there appeared to be some differences, especially for steelhead. The model overestimates detection probability for steelhead at the low flows experienced in 2007. Consequently, the predicted population index is low. The 2007 migration conditions are different from what existed in the years used to build the model. Flows in 2007 are relatively low, with regular spill occurring during the peak of migration. Due to this unique operation, the predicted values are outside the range of data from which the model was developed, so caution should be used in interpreting the results. The model will be repopulated with 2007 data after the season is completed, which should improve predictive capabilities under conditions similar to this year.

A similar method as described above was also used to estimate detection probability at Little Goose Dam. For those estimates subsequent detections at Lower Monumental Dam were used to calculate the daily detection probabilities in the same way the estimates were developed for Lower Granite.

Estimating Daily Detection probability at Lower Granite Dam

Sandford and Smith 2002, and others have employed a method of using downstream PIT-tag detections to estimate proportions of daily detections at upstream projects. The method uses the travel time distribution data for fish detected at both sites to reconstruct their prior passage timing at the upstream dam. Applying the same passage distribution to the fish only detected at the downstream dam, allows their passage at the upstream site to be reconstructed as well, assuming the fish undetected at the upstream dam, have the same travel time distribution as the fish detected at both sites.

For each date at Little Goose Dam, the downstream site, there are a number of fish that were previously detected at Lower Granite dam. The travel time for each fish can be calculated, so that for a given day at Little Goose, the number of fish detected, n_i , the average travel time $\bar{x}_i$, and the population variance σ_i^2 can be estimated. From these statistics, using the method of moments , parameters, gamma and lambda can be calculated, for estimating gamma distributions to describe the distribution of travel times (LGR to LGS)observed at Little Goose Dam for the ith day (Lee 1980). Using the gamma distribution probability density function for a given date at Little Goose, the observed number of detections can then be distributed back through time at Lower Granite Dam, by solving $P(X_{11})_i$ for days i to i minus 20 days. Since there are daily distributions for days 1 to n, where n is the last date for which adequate detections available, then the estimated number of fish passing detected X_{11} and undetected X_{01} at Lower Granite Dam on the jth date at Lower Granite is the trace sum $\hat{N}_{j X_{11}} = \sum_{i=1}^{n} \sum_{j=(I-n)}^{i} P(X_{11})_{ij}$ for fish detected at both sites, and similarly, $\hat{N}_{j X_{01}} = \sum_{i=1}^{n} \sum_{j=(I-n)}^{i} P(X_{01})_{ij}$ is the estimated number of undetected fish passing Lower Granite Dam on the same date.

Once the number detected and undetected is estimated for each date, an uncorrected estimate of detection probability can be calculated $\hat{N}_{X_{11}} \big/ (\hat{N}_{X_{01}} + \hat{N}_{X_{11}})$. However, this number must be corrected by the proportion of PIT-tagged fish that were removed on the jth date at Lower Granite Dam, Rj. These are fish that are either transported or removed for research. The final estimated detection probability for each date is calculated:

$$\hat{p}_j = \hat{N}_{X_{11}} \big/ (\hat{N}_{X_{01}} + ((1 - R_j) \bullet \hat{N}_{X_{11}})$$

Derivation of Data Predictive Model for CE

Fish Passage Center developed estimates of daily detection probability for yearling chinook and steelhead for the years 2003 to 2007. For each date at Lower Granite Dam, we paired the estimated detection probability with Flow, Spill and Date data. It was determined based upon analysis of operational data, that 3 distinct operations occurred at both Lower Granite and Little Goose dams (see Figure 1). There were periods when no spill occurred, and two distinct periods of spill operations. The first spill operation occurred at flows below hydraulic capacity (approximately 100 kcsf at LGR and 110 kcfs at LGS) such that standard RSW spill of approximately 19 kcfs occurred. At flows greater than 100 kcfs (110 kcfs at LGS) typically some level of uncontrolled spill occurred. Each of the different operations produced distinctly different patterns in spill, flow and spill proportion that in turn were each associated with unique functional relationships to detection probability. Therefore three different detection probability functions were developed under these three different operational scenarios.

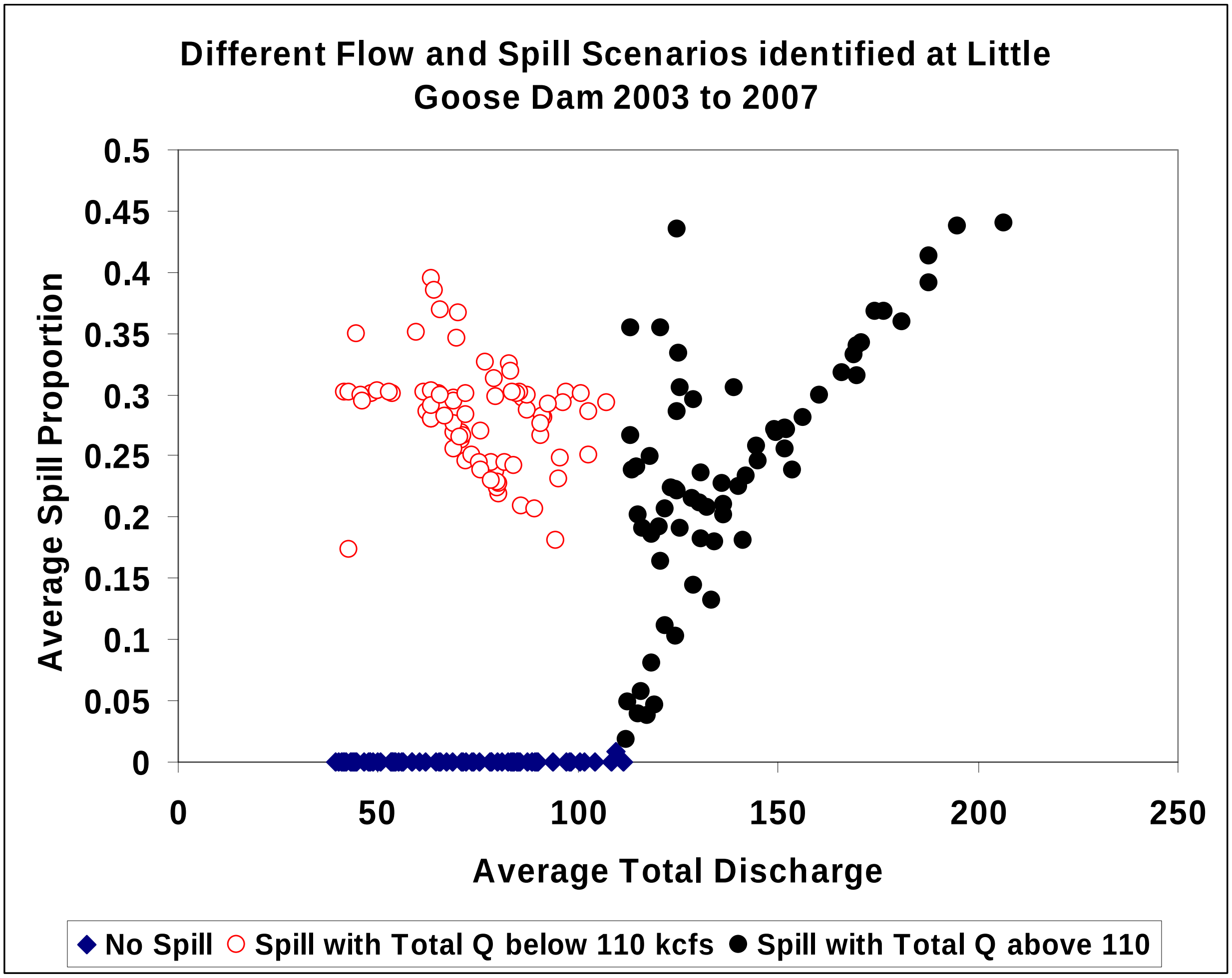

Figure 1. Plot showing the different flow and spill proportions under 3 distinct operational scenarios at Little Goose Dam during spring operations in April and May from 2003 to 2007. Separate functions were developed to predict detection probability for each different operational scenario.

Detection probability was transformed to a logistic function, and regressed against predictor variables. Multiple regression models, using combinations of the predictor variables were calculated. The predicted $\hat{p}$ were compared to those $\hat{p}_j$'s estimated for each year. Of the candidate models for *no spill* operations;

$$\ln\left(\frac{\hat{p}}{1-\hat{p}}\right) = \beta_0 + \beta_1 DaysAfterMarch1 + \beta_2 AvgQ + \varepsilon$$

was chosen as the best predictor of the daily $\hat{p}_j$'s for those years for both yearling chinook and steelhead data sets as well as at both dams. Of the candidate models for *spill discharge* operations;

$$\ln\left(\frac{\hat{p}}{1-\hat{p}}\right) = \beta_0 + \beta_1 DaysAfterMarch1 + \beta_2 AvgQ + \beta_3 AvSpillprop + \varepsilon$$

was chosen as the best predictor of the daily $\hat{p}_j$'s for both yearling chinook and steelhead data sets. Two separate functions were used, with differing coefficients i.e. $\beta_{0...}\beta_i$, for the low discharge spill and high discharge spill but with the same predictor variables (date, discharge and avg spill proportion). All models evaluated had similar predictive capability, but the use of flow, percent spill and date was deemed most comparable to the historic passage index, which used flow and spill to calculate the index. And, these data are readily available to anyone wishing to calculate the index.

Confidence Intervals

Once the model was chosen, the variance for the predicted daily detection probabilities, $V(\hat{p})$ were calculated based on the variance covariance matrix from the regression (Draper and Smith 1981) as follows;

$$V(\hat{p}) = \sigma^2 [X_0'(X'X)^{-1} X'_0]$$

Confidence intervals were then calculated as

$$\hat{p} \pm 1.96 \bullet \sqrt{V(\hat{p})}$$

Population Index

The daily population index PI_j was calculated by dividing the daily collection by the estimated collection efficiency (C_j); $PI_j = C_j / \hat{p}_j$.

Confidence intervals around the estimated population index were the daily collection divided by the upper and lower daily index limits. For cumulative plots, the daily upper and lower limits were summed to provide the upper and lower bounds for the cumulative estimate.

Literature Cited

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Lee, E.T. 1980. Statistical Methods for Survival Data Analysis. Belmont, CA: Lifetime Learning Publications.

Sandford, B. P., S. G. Smith. 2002. Estimation of smolt-to-adult return percentages for Snake River Basin anadromous salmonids, 1990-1997. Journal of Agricultural, Biological, and Environmental Statistics, 7:243-263.