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MEMORANDUM

TO: Fish Passage Advisory Committee

FROM: Fish Passage Center

DATE: 3/21/2018

SUBJECT: Spring/Summer Chinook Travel Time between Ice Harbor and Lower Granite Dams, and Its Implication on Passage Assessment (updated on 3/21/2018)

Fishery and project operation management have raised concerns regarding the upstream passage of adult spring/summer Chinooks being disrupted by the tailrace hydraulic conditions, especially at Little Goose Dam (LGS). The management team therefore sought technical advice to develop a method that would identify expected adult salmon passage rates. By expressed interests, Fish Passage Center (FPC) began to develop an assessment method in continuation of our past analyses (see FPC, 2009; FPC, 2011a; FPC, 2011b; FPC, 2017). In particular, we developed a model based on the dynamics between fish travel time and its biological processes and environmental conditions. Here we summarized methods for developing the travel time models for passage assessment, model results, and examples of adult salmon passage prediction.

- Our model indicated that seasonality, flow, water temperature, and distance to tagging site/origin were important variables that could influence travel time of adult spring/summer Chinooks.
- In general, adult spring/summer Chinooks traveled faster later in the season and/or if they had longer distance to travel to the tagging sites.
- In general, adult spring/summer Chinooks traveled slower with higher water temperature and/or with a history of juvenile transport.
- There was suggestive, but inconclusive evidence for slower travel time on average for spring/summer Chinooks with increase in flow.
- Compared to dam counts alone, the travel time model provides a more realistic and accurate assessment of adult salmon passage progress. However, when viewed as lines of evidence, in combination they may provide better resolution on passage progress.

Background

Management action agencies have been using historical dam counts to assess adult salmon passage. While dam counts have important values in monitoring passage, fishery managers have also supplemented their assessment with PIT-tags information. Through PIT-tag data, analysts have access to detailed records that allow them to filter repeated dam passages and associate biological and environmental variables to individual fish. Furthermore, PIT-tag detection records a time stamp for individual fish, which enables analysts to diagnose passage progress by reviewing fish travel time.

Understanding the relationship between upstream migration success and the time spent in the Lower Snake River may inform operational adjustments affecting multiple species and life stages. For example, recent analysis by FPC has found no evidence that time spent in the Ice Harbor (IHR) to Lower Granite (GRA) river reach affected the probability of adult spring Chinooks arriving at the upstream point of origin, except for wild spring Chinooks that exceeding a 20-day residence time in the IHR to GRA river reach (FPC, 2018b). According to these results, assessment of adult salmon passage based on dam counts alone may be misleading because it does not account for fish travel time.

Previously, FPC staff conducted an analysis using historical dam counts to assess the relationship between project operations and spring Chinook adult passage at LGS (FPC, 2018a). In order to incorporate travel time to our assessment on the adult salmon passage issue, we extended our research using PIT-tag records between IHR and GRA Dams. Although our focus was on LGS passage, limiting our PIT-tag records between Lower Monumental (LMN) and LGS Dams would only allow us four years of data, which we deemed insufficient in this case.

Methods

Data

We included in our dataset the time and dates of PIT-tag detection at both IHR and GRA during April, May, and June, between years 2005 to 2017. The data comprised adult Chinooks that were PIT-tagged above GRA as juveniles, and excluded uncertain origins[1] such as the ones that were tagged at Clearwater Trap, Grande Ronde River Trap, Imnaha Trap, and Snake Trap.

For each fish, we summarized environmental and biological information such as Julian date of detection at IHR, flow (Kcfs) at IHR (upon detection), tailrace temperature (°C) at IHR (upon detection), distance (km) to tagging site (from GRA), and juvenile transport history. Migration year 2011 was excluded from our analysis due to an unusual spill operation during that year.

Travel Time Model

We fitted a generalized linear mixed effects model to assess the relationship between fish travel time and its biological and environmental conditions. For the model, the response variable was fish travel time (FTT, in days) between IHR and GRA Dams. The fixed effects explanatory

[1] Fish tagged at these traps originate from areas located far above the traps. Therefore, distance to origin is unknown for these fish.

variables were Julian date, flow, tailrace temperature, distance to tagging site, and juvenile transport history. The random effects explanatory variable was migration year. We used an inverse Gaussian (IG) distribution for the response, and an identity link function for the covariates/explanatory variables. The model was specified as follows:

$FTT_i \sim IG(\mu_i, \sigma^2)$, where i is individual PIT-tagged fish,
$\mu_i = \alpha + \beta_{Jday} \cdot JulianDate_i + \beta_{Flow} \cdot Flow_i + \beta_{km} \cdot Distance_i + \beta_{Temp} \cdot Temperature_i + \beta_{MigHis} \cdot Transport_i + \gamma_{yr[i]}$, where $Transport_i$ is an indicator variable,
and $\gamma_{yr} \sim N(0, \sigma_{yr}^2)$, where yr represents migration years 2005 to 2017.

To improve model fit, we standardized all continuous variables in the model. We fitted the model using `glmer()` function in the *lme4* package (Bates et al. 2015) in R.

Results

Relationship between Travel Time and Biological/Environmenal Conditions

Our model strongly indicated that, on average, adult spring/summer Chinook traveled faster in later season and/or if they had longer distance to travel to the tagging sites ($p < 0.001$; Table 1). And they traveled slower with higher water temperatures and/or if they were transported as juveniles ($p < 0.001$, $p = 0.012$, respectively). There was suggestive, but inconclusive evidence that adult spring/summer Chinook traveled slower on average with increase in flow ($p = 0.093$).

Table 1: Coefficient estimates for the travel time model.

	Estimate	Std. Error	*t* value	Pr(>|*z*|)
(Intercept)	6.514	0.436	14.934	< 0.001
Julian Day	-0.441	0.052	-8.522	< 0.001
Flow	0.046	0.027	1.682	0.093
Distance	-0.14	0.02	-7.08	< 0.001
Temperature	0.554	0.047	11.768	< 0.001
Transport	0.113	0.045	2.498	0.012

Model Prediction of Fish Travel Time

The main implication of this model was that it could be used to predict fish travel time and passage rates. That is, when a fish is detected at IHR, we can predict how long it would take to arrive at GRA given observed biological and environmental conditions (e.g. flow, temperature, detection date, distance to tagging site, and juvenile transport history). We may extend our prediction for all PIT-tagged spring/summer Chinooks detected at IHR within a particular period, and derive a predicted conversion at GRA. After summarizing how many of these fish actually arrived at GRA for the same period, we can compare the observed and predicted conversions and evaluate whether the fish are migrating within an expected time frame.

Figure 1 illustrated two examples evaluating travel time with our model prediction. In each example, we fitted the model using data without the respective year, and simulated travel time prediction based on observed data for all IHR detection on each day from May 15th to June 30th. In the end, we plotted the observed versus the predicted conversions for the same time period. It is worth noting that travel time model did not account for apparent mortality; therefore, model prediction without adjusting for mortality would tend to overestimate the conversion. To mitigate overprediction, we first estimated the mean conversion (0.96) between IHR and GRA with a logistic regression model using the same PIT-tag dataset, then adjusted our conversion prediction accordingly.

In 2016, the observed conversion line was always above the predicted range, indicating the actual conversion was higher than expected throughout the season. In 2017, the observed conversion line sometimes fell below the predicted range (around 5/15 and between 6/1 and 6/15), suggesting slower than expected travel time at these periods.

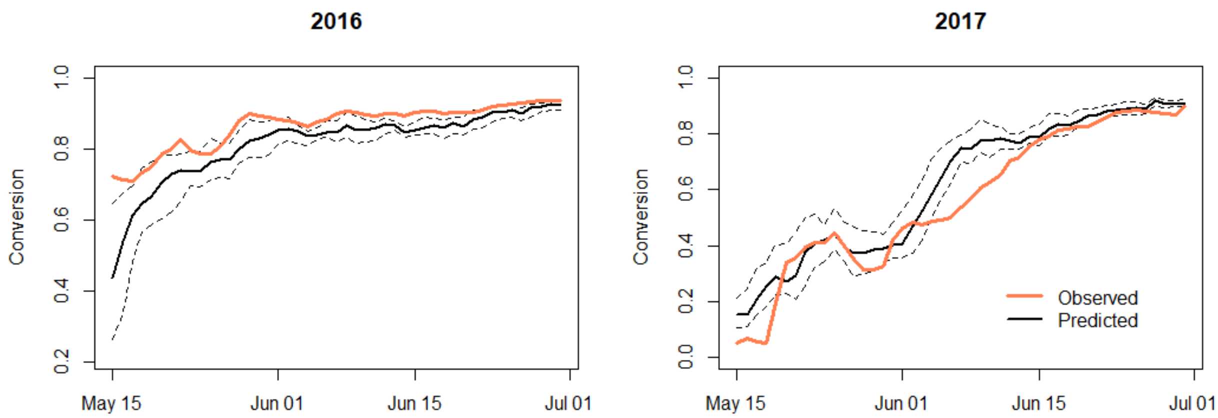

Figure 1: Comparisons of observed and predicted conversions with our travel time model for 2016 and 2017. Predicted conversion is in black with range of uncertainty in dash lines. Observed conversion is in orange.

Conclusion

Here we demonstrated examples of using travel time model to monitor passage progress. Because our PIT-tag detection were recorded at IHR and GRA Dams, any potential passage issues occurred between LMN and LGS might not be apparent at GRA until few days later. Further, because our PIT-tag detection spanned from IHR to GRA, any perceived passage issue would be hard to pinpoint. Therefore, it would be most beneficial to combine dam counts and PIT-tag information while assessing adult salmon passage. If one noticed a pattern in dam counts at LMN and LGS that might be perceived as a passage issue, the same pattern should be confirmed using PIT-tag data between IHR and GRA, and vice versa. Most importantly, any assessment methods, regardless of survey type, should account for the complexity of biological process and environmental conditions.

Reference

Bates, D., M. Maechler, B. Bolker, and S. Walker. 2015. Fitting Linear Mixed-Effects Models Using lme4. Journal of Statistical Software, 67(1):1-48. doi:10.18637/jss.v067.i01.

Fish Passage Center. 2009. Greater than 30% spill at Little Goose Dam and adult travel times and conversion rates (November 6, 2009). http://www.fpc.org/documents/memos/173-09.pdf.

Fish Passage Center. 2011a. 2011 Little Goose Dam spill operations and adult travel times and conversion rates (December 9, 2011). http://www.fpc.org/documents/memos/177-11.pdf.

Fish Passage Center. 2011b. Clarification of December 9, 2011 memo regarding Little Goose spill operations and adult Chinook conversion rates and travel times (December 14, 2011). http://www.fpc.org/documents/memos/179-11.pdf.

Fish Passage Center. 2017. Review of NOAA evaluation of 2017 Little Goose spill for fish passage manipulations (August 16, 2017). http://www.fpc.org/documents/memos/40-17.pdf.

Fish Passage Center. 2018a. Relationship between Project Operations and Spring Chinook Adult Passage at Little Goose Dam (February 5, 2018). http://www.fpc.org/documents/memos/4-18.pdf.

Fish Passage Center. 2018b. Incorporation of FPAC comments and recommendations: Upstream survival of hatchery and wild spring Chinook, response to variability in travel times in the Lower Snake River (March 6, 2018). http://www.fpc.org/documents/memos/10-18.pdf.