FISH PASSAGE CENTER

847 NE 19th Avenue, #250, Portland, OR 97232
Phone: (503) 833-3900 Fax: (503) 232-1259
www.fpc.org/
e-mail us at fpcstaff@fpc.org

MEMORANDUM

TO: Bill Tweit, Dan Rawding, WDFW
Ed Bowles, Tucker Jones, ODFW
Jim Fredricks, Lance Hebdon, IDFG
Ritchie Graves, NOAA Fisheries
Mike Matylewich, Zack Penney, CRITFC
Christina Wang, Janine Castro, USFWS
FPAC

FROM: Michele DeHart

DATE: June 22, 2018

SUBJECT: Response to IDFG technical comments on FPC March 6, 2018 and June 1, 2018 analyses.

The Fish Passage Center has developed the following response to Idaho Department of Fish and Game (IDFG) verbal comments from the June 12, 2018 Fish Passage Advisory Committee (FPC) meeting and written comments received at the FPC on June 15, 2018. The FPC has reviewed, considered and responded to the IDFG verbal and written comments, including additional analyses. These responses and additional analyses are provided below as separate memoranda and appendices. After carefully considering and analyzing the IDFG comments we have concluded that:

- The original analyses and conclusions of the March 6, 2018 analyses and the June 1, 2018 analyses used the appropriate methodologies, used established and appropriate analytical techniques and reached valid conclusions.
- Review and response to comments and additional analyses isolating the Little Goose special operation from river flow reaffirms the original conclusion from the June 1 analysis that the special operation at LGS resulted in an increase in powerhouse passage (PITPH) of juvenile migrants at LGS and LMN.

- Review of and response to IDFG comments regarding the March 6 analysis of travel time and upstream survival reaffirms the original conclusions of the upstream migration analyses. Wild Snake River spring Chinook showed an impact on survival to the upper most detection, when time in the Ice Harbor – Lower Granite river reach exceeded 20 days. All other groups analyzed showed no affect.

The FPC provided a suite of analytical products to FPAC to support consideration of operations at Little Goose Dam in which a balance of effects on multiple life stages must be considered. All of these analyses are valid and relevant to fish passage managers when considering operational decisions that balance risk of operations on multiple life stages of salmon and steelhead where an operation to benefit one life stage can have an adverse impact on another life stage. The managers are charged with the responsibility of making these types of difficult decisions. The objective of the FPC is to provide the best analytical products possible to the managers so they have knowledge of the full range of potential impacts. The suite of analyses presented to FPAC identified variables affecting adult passage including the relationship between travel time and survival. When balancing risk among life stages, it is important to consider all of the analytical results that have been presented and the risk to each life stage. These have all been presented to FPAC, and include:

- Adult salmon and steelhead that were subject to the smolt transportation program have slower upstream migration, have lower upstream migration success, and higher dam re-ascension rates, all contributing to delay.
- When considering adjusting operations to aid adult passage, consideration must also be given to downstream passage of juvenile salmonids. Each juvenile powerhouse encounter reduces subsequent SAR by a relative 9-13% (Chapter 7, McCann et al. 2016)
- Water temperatures, fishway temperatures, TSW operation, seasonality, distance to point of origin, specific project operations and flow all affect upstream migration rates. In particular, the operation of the TSW appears to negatively affect adult passage.
- Little evidence of negative effects on adult upstream survival has been found for Snake River spring Chinook relative to the time spent in the Ice Harbor to Lower Granite reach or the Lower Monumental to Little Goose reach.

It is important to recognize and identify risk to each life stage when considering operations that could benefit one life stage while having an impact on other life stages.

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MEMORANDUM

TO: Fish Passage Advisory Committee

FROM: Michele DeHart

DATE: June 22, 2018

SUBJECT: Response to IDFG concerns with June 1, 2018 memos to FPAC.

At the June 12, 2018 Fish Passage Advisory Committee (FPAC) conference call, the Idaho Department of Fish and Game (IDFG) representative expressed concerns over the Fish Passage Center (FPC) memo that was sent to FPAC on June 1, 2018 (FPC 2018b). In addition, IDFG voiced several concerns over a March 6, 2018 FPC memo that was sent to FPAC regarding upstream survival of hatchery and wild spring Chinook and travel time in the Lower Snake River (FPC 2018a). On June 15, 2019, IDFG followed-up with written comments regarding the June 1st memo (attached). The FPC has reviewed the recording of the IDFG verbal comments from the FPAC meeting on June 12th (01:48:25) (http://www.fpc.org/documents/fpac_minutes/fpac_min_2018/06-12_GTM.mp4) and the written comments and offers the following responses.

First, we will address both the written and verbal comments regarding the June 1, 2018 FPC memo (FPC 2018b). The original IDFG comments are provided below (numbered), followed by the FPC response (in blue). Many of our responses are summaries of additional analyses that the FPC staff prepared in response to these comments. These additional analyses are provided as appendices at the end of this memo.

1. As the subject line of the memo suggests, the review was, at least in part, requested to provide an analysis of whether the operation improved adult passage as intended. The memo addresses possible impacts to downstream migrating juveniles, but didn't address benefits to upstream passage. We request the memo include an assessment of the effectiveness of the special operation on improving adult passage.

It is important to provide context for the purpose of the June 1, 2018 memo to FPAC. The June 1 memo was provided to inform the FPAC discussion that was planned for later that morning regarding adult passage at LGS and whether to extend the LGS special operation beyond its original 3-day period. As the FPC has noted several times, when considering issues with adult delay at LGS, it is important for fisheries and operations managers to minimize interruptions during adult upstream passage. At the same time, it is just as important from the salmon life cycle perspective to consider the potential harmful effects of a spill reduction that can direct more juvenile migrants through the powerhouse of a project. Managers should keep these things in mind when balancing operational changes that may benefit one life-stage while harming a different life-stage.

The statement that IDFG makes about the June 1 memo not addressing benefits to adult passage is not accurate. The third bullet clearly references the increases in adult counts at LGS. The memo clearly states the FPC recommendation that the special operation at LGS should not be extended beyond the originally planned 3-day period, given the recent improvements in adult returns and the projected decreases in flows.

Finally, while the IDFG comments critique the June 1 memo for not accounting for the declining hydrographs effect on spill proportions and juvenile passage, they fail to recognize that the declining hydrograph would likely have resulted in an increase in adult counts at LGS as well. By the early morning of June 3, 2018, flows had decreased to a point where spill to the 115%/120% spill cap resulted in spill proportions of 0.30 and lower. The FPC will respond to the IDFG request for a full analysis of adult passage in a subsequent analysis when the adult migration is complete. Our assessment will include an assessment of travel times and adult success observed in 2018 and will address concerns IDFG noted in the June 12 FPAC meeting regarding fish missing from lack or slow response from FPAC to initiate the special operation.

2. The memo concludes the special operation decreased daily average spill proportions and increased juvenile powerhouse passage, stating: *Reductions in spill proportions, and total discharge, at LGS and LMN during the first two days of the special operation resulted in increases in daily average PITPH at LGS and, to a lesser degree, at LMN, compared to previous two days (Table 1, Figure 1). Furthermore, because spill proportions did not increase at LGS during the 1600-0400 period, PITPH did not improve during this period to make up for increases in PITPH during 0400-1200 period (Figure 1).* This statement implies the reduction in spill proportions were a function of the operation, when in actuality, the spill proportions were affected by the following factors that were unrelated to the operation:

   In response to these IDFG comments, the FPC staff has re-analyzed the data from the June 1, 2018 memo. In this re-analysis, we include data from Lower Granite Dam (LGR), as well as extending the analysis to two days after the special operation was ended. Also in response to the IDFG comments, we estimated spill proportion and PITPH at LGS, LMN, and IHR without the special operation (i.e., isolating the effects of the special operation). As a result of this most recent analysis, we stand by our original conclusion: the special operation at LGS resulted in decreases in spill proportions and increases in PITPH at LGS and LMN. Details from this re-analysis are provided in Appendix A.

- During the four days in Table 1 (May 28-31), the three uppermost LSR dams were in involuntary spill operations during a period of declining inflow. During the same four day period, LGR (with its higher powerhouse capacity) experienced a similar decline in daily spill proportions; 0.34, 0.32, 0.31, and 0.28.

  The special operation at LGS is was not expected to affect operations at LGR. As IDFG points out, average flows, spill volumes, and spill proportions at LGR did decline from May 28th to June 4th (Table A.1). As a result, average PITPH at LGR increased for both yearling Chinook and steelhead. However, our re-analysis (which isolated the effect of the special operation) still indicates that the special operation at LGS resulted in decreased spill proportions and increased PITPH and both LGS and LMN beyond the effects of the declining hydrograph.

- On May 29th LGO staff performed screen cleaning operations that include shutting off turbines which resulted in spill proportions of over 0.6 for several hours of the day and a daytime average of 0.50 as shown in Table 1.

  Although May 29th was included in Table 1 of the June 1 memo, it was not used in developing our conclusion. Comparisons to estimates from May 28th show that operations on May 30th and May 31st resulted in increased PITPH for yearling Chinook and steelhead by 4-8 percentage points (Table 1 of June 1 memo).

3. We found the following statement confusing and counterintuitive: *During the special operation, a greater proportion of detections occurred during night time hours. This change is likely due to increased powerhouse passage proportions after ponding/spill reduction caused more fish to be entrained in powerhouse flows*.

   It is our understanding that a greater proportion of detections occurring during night time hours with this operation would *reduce* daily powerhouse passage, not increase it as the memo suggests. Our interpretation of Figure 2 of this memo, when combined with hourly flow/spill data from the TMT website is that the special operation likely *benefited* juveniles.

   We disagree with IDFG regarding the use of powerhouse detections to characterize total dam passage. The powerhouse passage timing of PIT-tagged subyearling Chinook we provided in the June 1 memo, is likely unrelated to spillway passage timing (see Appendix B for an updated version of this analysis). There is evidence to suggest that hourly powerhouse passage is not representative of all fish passage timing at the project. Based on a radio telemetry study at Little Goose Dam in 2009, arrival timing of subyearling Chinook was spread throughout the 24-hour period; passage was not greater during night-time, and did not show a pronounced increase at dusk as PIT-tag data indicated (see Figure 1.1 below which is figure 28 from Beeman et al. 2009). Beeman et al. (2009) also saw longer delay for powerhouse passed fish compared to spillway passed fish (Figure 1.2). Beeman et al. (2009) found much shorter residence times in the forebay for fish that entered the bypass at night than those that passed the bypass during the daytime. The pattern we observed, of increased PIT-tag detections in the bypass at dusk, and during night-time, was consistent with results from Beeman et al. (2009) and consistent with increased PITPH during ponding operations, when spill was reduced. Fish arriving in the forebay during daylight hours, likely delay then pass into the bypass more rapidly at night, leading to the skewed distribution observed in the PIT-tag data. We interpret the more pronounced passage at dusk and into the night as further indication of powerhouse passage delay during ponding operations.

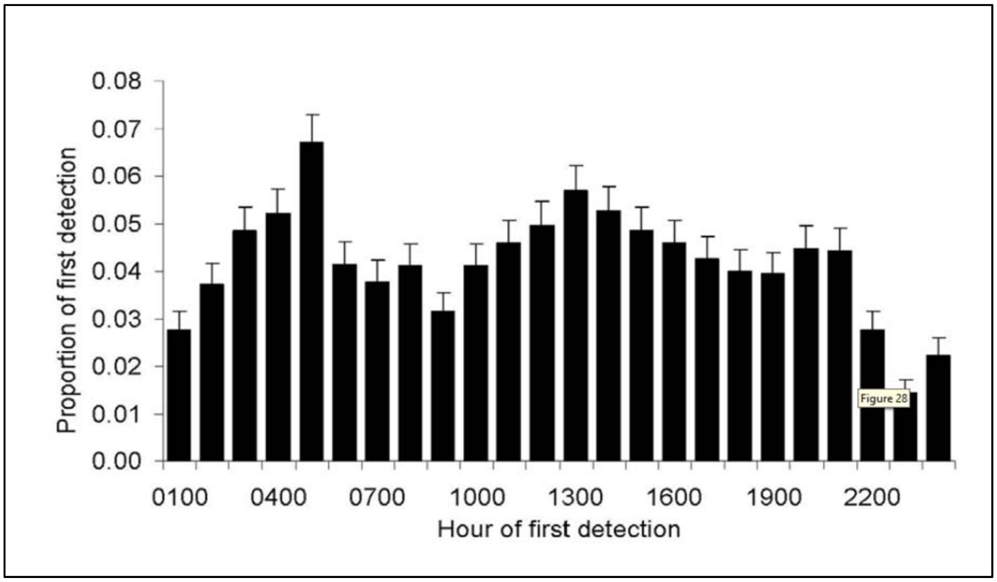

Figure 1.1. Arrival timing distribution of radio-tagged subyearling Chinook to the forebay of Little Goose Dam (taken from Figure 28 from Beeman et al. 2009).

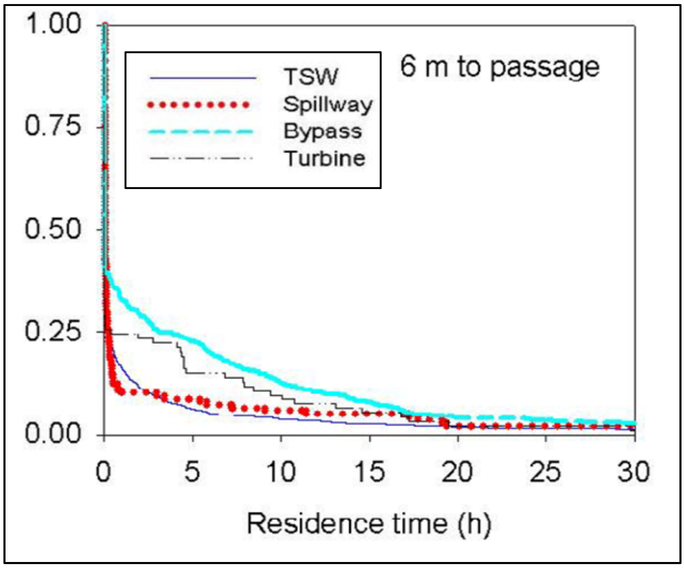

Figure 1.2. Proportion of subyearling Chinook delayed at forebay by route of passage at LGS dam (taken from Figure 31 from Beeman et al. 2009).

If we assume spill proportions would have averaged 0.385 during the May 30th and 31st period at LGO with or without this special operation and that approximately 15% (from Figure 2) of juvenile detections during that time occurred in the morning period of reduced proportion spill (0.3), it seems reasonable to conclude the percentage of juveniles passing during the reduced spill period would be less than 15% since PITPH is likely higher at 0.3 proportion spill than the 0.385 that would have been the average for these hours without the special operation.

Again, we disagree with the use of powerhouse hourly passage timing to characterize full dam passage timing. Overall, our re-analysis indicates that special operation at LGS resulted in an increase in PITPH at LGS and LMN, when compared to estimates of PITPH without the special operation (see response to questions 2, 4, and 5, Appendix A, and Appendix B). The increased PIT-tag detections in evening hours (Figure 2 from June 1 memo), is consistent with increased delay in the forebay related to the time period when powerhouse discharge was highest (i.e. during day-time hours). Overall, the impact, measured over a 24-hour period is best captured by estimates of PITPH.

Similarly, we estimated from the TMT Website project hourly data, that the increased nighttime proportion spill at LGO on May 30th and 31st averaged 0.449. If approximately 75% (from Figure 2) of juvenile PIT detections on May 30th and 31st occurred during the period of increased nighttime spill, and the increased nighttime proportion spill at LGO on May 30th and 31st averaged 0.449, it would seem to follow that the percentage of juveniles passing LGO during the increased spill period during the special operation would be higher than 75%.

Again, we disagree with the IDFG assumption that hourly powerhouse passage timing is representative of spillway passage timing. There is evidence that juvenile fish passage is delayed in the forebay in front of the powerhouse longer than in front of the spillway, and powerhouse passage increases through the powerhouse during night time hours. Our analysis of PITPH assumes uniform fish arrival and distribution throughout the 24-hour period.

4. We agree with the approach that evaluating juvenile effects is best accomplished by estimating likely changes in PITPH associated with the special operation. We suggest comparing estimates of PITPH that occurred for each day (Note: since this special operation began at 0400, the start of each evaluation day should likely also start at 0400) of the special operation with estimates of PITPH that would *likely* have occurred without the special operation would provide a more accurate estimate of the effect of the operation on juveniles. We suggest this could be accomplished by:
   - For each of the three operation blocks (Note: using hourly data would be appropriate as well), estimate the total number of PIT-tagged juveniles passing LGO using the number of juvenile PIT detections, average flow, and average spill proportion in that block or hour. Summing the block or hour estimates would provide a daily estimate of the total number of PIT-tagged juveniles passing LGO in that day.
   - Estimate the daily number of PIT-tagged juveniles entering the powerhouse by dividing the daily total juvenile PIT detections by the estimated proportion of juveniles detected entering the powerhouse.
   - Divide the daily estimate of PIT-tagged juveniles entering the powerhouse by the daily estimate of PIT-tagged juveniles passing the project to estimate PITPH with the special operation.
   - The daily average flow and spill proportion, and the CSS PITPH equations can then be used to estimate what PITPH would have been without this special operation.

   If there is a more appropriate method than what we propose we would welcome a discussion before conducting the analysis to insure collective agreement of the most suitable approach.

   We consider the IDFG assumption of using hourly powerhouse passage timing to characterize overall hourly dam passage inappropriate. Expanding those detections to an index proportional to spill volume would inaccurately depict passage. Furthermore, the IDFG proposed methodology for evaluating powerhouse passage is somewhat circular and unnecessary and indicates that IDFG does not understand how PITPH is estimated. PITPH represents an estimate of the proportion of fish passing via the powerhouse and is a function of a combination of flow, spill proportion, spill volume, the presence of a surface passage structure, and estimated Fish Guidance Efficiency (FGE). Therefore, evaluating the impact of different operational scenarios on PITPH simply requires estimates of these different variables under the different operational scenarios.

   In our re-analysis, we estimated spill proportions and PITPH at LGS, LMN, and IHR under the special operation (what actually occurred). In addition, we isolated the effect of the special operation by estimating spill, spill proportion, and PITPH at these three projects without the special operation. When isolating the effect of the special operation, we found that the special operation increased PITPH for yearling Chinook and steelhead at LGS 0.01-0.03 (Table A.2). Therefore, we stand by our original conclusion: the special operation at LGS resulted in decreases in spill proportions and increases in PITPH at LGS and LMN.

5. We agree with the FPC that effect on PITPH at LMO and ICE from this special operation should also be estimated. This special operation resulted in greater flow and spill proportion fluctuations within a given day than would have occurred otherwise and the effect will vary depending on juvenile passage timing within those days. We recommend using the method described above for LGO, with the additional adjustments:
    - Establish the start of each evaluation day as the time of the first decline in flow and spill proportion resulting from the special operation.
    - The estimates of PIT-tagged juveniles passing the projects will need to be made hourly instead of using the three blocks.

    When isolating the effect of the special operation, we found that, in general, the special operation increased PITPH for yearling Chinook and steelhead at LMN by 0.01-0.02 (Table A.3). The one exception to this was on the last day of the special operation where PITPH for steelhead under the special operation was lower than that without the special operation. There was no net effect of the special operation on spill proportions or PITPH at IHR.

Based on our re-analysis, we stand by our original conclusion that the special operation at LGS resulted in a decrease in spill proportions at LGS and LMN and, as a result, an increase in powerhouse passage (PITPH). Spill proportions and PITPH did not appear to change at IHR as a result of the special operation at LGS. When isolating the effect of the special operation, our re-analysis indicates that spill proportions would have been higher and PITPH would have been lower at both LGS and LMN without the LGS special operation.

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MEMORANDUM

TO: Fish Passage Advisory Committee

FROM: Michele Dehart

DATE: June 22, 2018

SUBJECT: Review of technical comments on adult upstream survival memo

On June 5, 2018 IDFG contacted FPC staff by telephone to discuss questions regarding the March 6, 2018 FPC memo to FPAC entitled "Incorporation of FPAC recommendations; upstream survival of hatchery and wild spring Chinook, response to variability in travel times in the Lower Snake River" (FPC 2018). During the June 12, 2018 FPAC meeting, the IDFG representative raised the same questions regarding this same March 6 memo. The specific questions regarding the March 6 memo were taken from the formal recording of the June 12 FPAC meeting and the June 5 telephone conversation between FPC and the IDFG staff. These comments are listed below followed by the formal response to those questions.

After reviewing the IDFG comments our overall conclusion are that the results of the original analyses described in detail in the March 6, 2018 memorandum are valid and relevant to fish passage managers when considering operational decisions that balance risk of operations on multiple life stages of salmon and steelhead. The analysis presented in the March 6 FPC memorandum was one part of a larger body of analytical work which identified variables affecting adult passage. The fishery managers make operations decisions and recommendations that require balancing risk among life stages. In these decisions it is important to consider all of the analytical results that have been presented. The suite of analyses provided to FPAC are analytical products that are intended to assist the fishery managers in assessing risk to multiple life stages of specific project operations. At times a management decision to benefit one life stage will have adverse impacts on another life stage. The analyses presented to FPAC provide the managers with a knowledge base to recognize and accept those adverse impacts. These analyses have all been presented to FPAC, and include:

- Adult salmon and steelhead that were subject to the smolt transportation program have slower upstream migration, have lower upstream migration success, and higher dam re-ascension rates, all contributing to delay.
- When considering adjusting operations to aid adult passage, consideration must also be given to downstream passage of juvenile salmonids. Each juvenile powerhouse encounter reduces subsequent SAR by a relative 9-13% (Chapter 7, McCann et al. 2016).
- Water temperatures, fishway temperatures, TSW operations, seasonality, distance to point of origin, specific project operations, and flow all affect upstream migration rates. The TSW operation in particular appears to negatively affect adult passage rates.
- Little evidence of negative effects on adult upstream survival has been found for Snake River spring Chinook relative to the time spent in the Ice Harbor to Lower Granite reach or the Lower Monumental to Little Goose reach.

IDFG Comment:

P-values associated with parameter estimates of some of the alternative models (travel time thresholds of 5, 10, and 15 days) were close to 0.05. IDFG contends that this indicates support for travel times under 20 days (Ice Harbor-Lower Granite) having a negative effect on survival. IDFG contends that conclusions drawn by FPC staff that "travel times below 20-days (ICH-LGR) are not likely to affect the probability of an individual's upstream success" (For wild Snake River spring Chinook) overstate the conclusions of the statistical results. Models showing p-values close to the traditionally accepted 0.05 imply there is an effect of travel time on survival below the 20 day threshold described for wild Snake River spring Chinook in the FPC analysis.

FPC Response:

The IDFG comments indicate a misunderstanding of the appropriate use of p-values, and a lack of consideration for the body of evidence presented in this modeling effort. P-values do not show the probability of a particular hypothesized relationship being true, they are a calculated probability that the difference between two groups being compared is due to chance. Using individual model parameters and associated p-values as the only basis for informing conclusions regarding this analysis is not appropriate, and it ignores well established statistical methods and best practices. When assessing an individual model, a p-value is one way to describe how likely there is to be a relationship between two variables under that particular models assumed structure. The purpose of using multi-model comparisons is to test which hypotheses regarding the magnitude and structure of those relationships presents the most plausible explanation for the variation we observed in reality (i.e. data), among all possible scenarios. Because alternative models are all fit to the same data, statistical correlations may appear in some models, even when only part of the variability is being described by that model. The FPC used a standard model selection process that is widely utilized in the scientific literature to assess which of the modeled scenarios best describe the variation in the data. In general, the best practice for this type of analysis is to draw inference from the top fitting model(s) because it best describes the variation in the data compared to the alternatives.

Akaikes Information Criterion (AIC) was used in the analyses from the March 6 FPC memo to assess a suite of binomial linear models that described different possible scenarios for *the relationship between successful upstream migration and travel time. Our conclusions are based on the best fitting models of the suite because they presented the most plausible explanation for the variation observed in the data. FPC summarized the top models in our conclusions, but also included modeling outputs from the alternative models in an effort to provide a completely transparent record of the analytical process. Some of the parameter estimates in these alternative models did include p-values that were close to 0.05, but those models ability to describe the variation in adult upstream survival was markedly inferior to the top models. Making inferences based solely on an inferior model may lead to misleading conclusions, especially when results and context of a better fitting model remain unconsidered. Individually, each model might make a compelling argument for the strength of a hypothesized relationship, but the goal of comparison is to decide which model posits the best explanation, and therefore, matches what we see in the observed data closest. In this case, the top two models explained the variation in the data substantially better, and therefore we concluded that the other models are not likely to be the best explanation for what is causing the observed pattern in upstream survivals. To further illustrate this point we have also included an example (see the discussion later in this document, entitled: Illustration of Model Selection and Interpretation of Results).*

IDFG Comment:

The use of the term "survival" is not an accurate characterization of what is being tested. Because there is no information regarding if these fish actually spawned, we cannot say that travel time (ICH-LGR) does not affect upstream survival.

FPC Response:

We disagree with the IDFG characterization of this analysis. This analysis evaluates how survival to the most upstream detection point possible is related to travel time through the lower Snake River for adult Snake River spring Chinook. Throughout the Columbia Basin, including analyses by IDFG, survival of groups of adult and juvenile fish is assessed from point to point and management decisions are based upon those survival estimates. For example, decisions regarding Springfield Hatchery rearing practices are based on juvenile survival to Lower Granite Dam. The analyses was presented exactly as an assessment of the relationship between time fish spent in the Ice Harbor to Lower Granite and Lower Monumental to Little Goose river reach and survival to the most upstream detection point. The FPC analysis used the best available data to the furthest upstream point on record. Data that was used to inform the final detection of these fish was aggregated from antenna detections, spawning ground surveys, adult weir recaptures, and hatchery returns. Because the final detection criteria was heterogeneous in nature, we stated clearly and conservatively that the test was whether or not individual fish were able to survive to their basin of origin (Clearwater, Grande Ronde, Imnaha, or Salmon Rivers).

Additionally, in the case of hatchery spring Chinook used in this analysis, it is worth noting that we found no support in the data for travel time between ICH-LGR or LMN-LGS being a significant predictor of adult success in returning to their basin of origin, at any time threshold. Most of the final detections for these fish occurred either at the hatchery of origin, or *at antennas arrays within close proximity to their hatchery of origin. Therefore, these detections are much more analogous to successful spawning.*

IDFG Comment:

Due to low detection probabilities in some basins in certain years (Clearwater River specifically), this analysis mischaracterizes survivals, in what may be simply low detection probabilities as a function of limited detection arrays deployed.

FPC Response:

We disagree that survival estimates were mischaracterized in the March 6^{th} memorandum. This analysis looked at differentials in the rate of survival as a function of individual travel time through the lower Snake River, not average survival of a population. If there is low detection probability in a given year due to limited array deployment, that detection probability applies to all fish within that basin and year. Unless detection probabilities differed substantially as a function of individual fish travel times specifically, this would not have bearing on the ability of this analysis to differentiate between survival rates. We made the assumption that even with low detection probabilities in some years, for some basins, fast and slow fish would have equal probabilities of being detected at any given array that was deployed.

Further, the *survival estimates provided describe the minimum estimate for only those PIT-tagged adult spring Chinook that were detected at both Lower Monumental and Little Goose Dams, or Ice Harbor and Lower Granite Dams, and as such, are necessarily a subset of the larger adult cohort. The survival metrics that were provided are purely a summary statistic to describe the dataset, and have not been presented as a population level estimate. This is clear in the March 6^{th} memorandum.*

Illustration of Model Selection and Interpretation of Results:

In an effort to address these concerns, we would like to take this opportunity to further detail the analytical foundations of our conclusions, as well as the methodology behind them. In regards to the first IDFG comment, a brief example detailing model selection criteria, p-values, and how to interpret the results presented in the aforementioned memo may be helpful to this end. Specifically, the concern that p-values close to 0.05 in models that were not the top performing models may indicate a negative effect of shorter travel times (ICH-LGR) on upstream survival.

Methods:

It is sometimes difficult to interpret results of data analyses' because in most cases we do not know the answer beforehand. Therefore, it can be helpful for our understanding of model performance to simulate data, and then see how the models perform when the answer is known in advance. In order to evaluate different models that are attempting to describe how travel time may effect survival, we simulated travel times for 1500 hypothetical fish that matched the general structure of the travel times observed in spring Chinook between Ice Harbor and Lower Granite Dams (Figure 2.1). For those fish that had travel times of less than 20 days (TT<20d) we assigned random survival values with a probability of survival of 95%. For those fish that had travel times in excess of 20 days (TT>20d), we assigned random survival values with a survival probability of 85%. The result of this simulation is a dataset that has distinctly different groups that are defined precisely by having more or less than 20 day travel times, and distinctly different survival probabilities based on that threshold (0.95 vs 0.85). To evaluate how to interpret the data, we added the same travel time related covariates into the dataset (TT, T5, T10, T15, T20, T25, T30), corresponding to the analogous travel time groupings in the original memo.

Binomial linear models were fit in Program R (R Development Core Team 2018) using the 'logit' link function. Each explanatory variable was included in a regression, and model summaries are presented in Table 2.1.

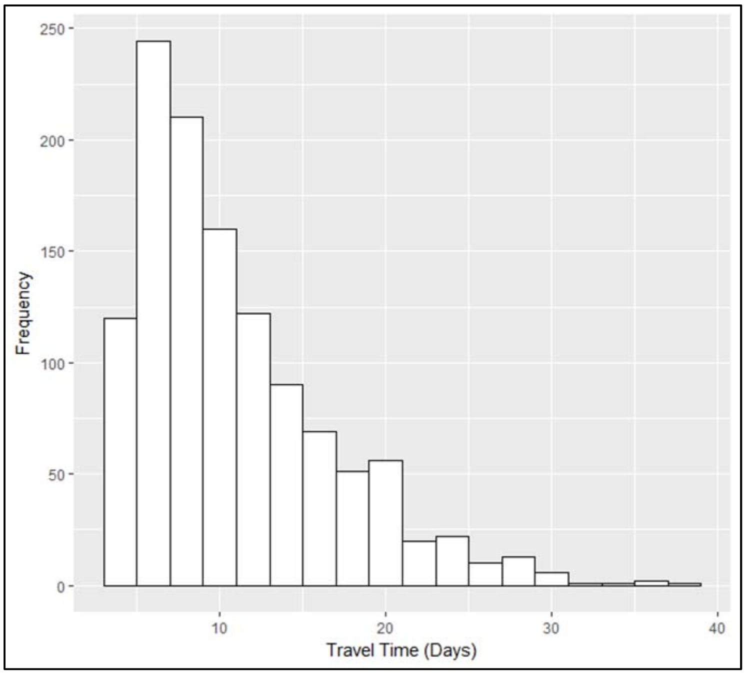

Figure 2.1. Distribution of Simulated travel times for hypothetical fish

Table 2.1. Summary statistics for all models fit to simulated travel time/survival data.

Model	**TT**	**T5**	**T10**	**T15**	**T20**	**T25**	**T30**
AIC	374.18	387.59	383.96	378.96	373.09	377.26	386.56
Parameter Estimate	-0.0815	0.1207	-0.588	-0.9625	-1.5193	-1.8215	-1.313
P-value	9.69e-05***	0.803	0.0578	0.0021**	1.92e-05***	0.000141***	0.224

Results:

The resulting summary statistics show that both travel time by itself, travel times in excess of 10 days, in excess of 15 days, and 20 and 25 days all appear to be parameters that are statistically significant (or nearly so) in explaining the variation in survival observed in the simulated data. However, we know with certainty that the cause of the differential in survival in the simulated data is whether or not a fish had a travel time over 20 days or under. So, how do we explain these apparently ambiguous results?

The answer is model selection. Akaike's Information Criterion is one way to assess relative support for a statistical model within a set, which balances model parsimony with how well the model explains the variation in the data. In this case, the top performing models according to AIC are the Travel Time model, and the T20 model. Therefore, those are the models that we should use to draw our inference, as those are the models that best explained the variation in survival rates. By using these two models to explain patterns in variation of survival rates, you could conclude that travel time appears very likely to be a factor in determining relative survival of individuals, as indicated by the excellent performance of the travel time model. However, digging slightly deeper, the equally good performance of the T20 model tells us that travel time by itself might not be the entire explanation, and there appears to be good support for a threshold, in this case, it has been correctly identified as the 20-days used to simulate this data. Because the two top models explained the variation seen in the data substantially better, based on AIC rankings, we can conclude that the other models are not likely to be the best explanation for what is causing the differential in survivals.

So, what about the p-values that show travel times less than 20 days as significant explanatory variables? The answer to this question is not that travel times in excess of 10 days, or 15 days also have a significant negative effect on survival, we know that is not true with the simulated data. To understand this, it helps to keep in mind these are models attempting to explain the data and then being compared within the suite of models being tested. They aren't wrong, they simply don't explain the variation as well as another model. An example that might illustrate this point is if you looked at the average survival of fish with TT>15d, and compared it with the average survival of fish with TT<15d. The over 15 day group average survival would certainly be less than 95%, and that difference may even be statistically significant, but that difference is being driven entirely by the survival of fish with TT>20d (average=85%). If T10, or T15 was the only model that was fit, the conclusion may be different, but within the suite of models tested, the models with lower travel time thresholds were not the ones that describe the pattern of variation in survival best, despite having low p-values. The model that explained the variation the best was the T20 model, which most accurately defined where the threshold for variation in survival was occurring.

Similarly, in this case, one of the top performing models, TT, showed a significant relationship between travel time and survival. This was entirely due to the fact that the fish with substantially longer travel times (TT>20d) had lower survival, and by fitting a regression to the data, travel time by itself appears to be a significant explanatory variable of that variability, despite there being no linear relationship in the simulated data. Because the T20 model was similarly supported, we can use this for context, to see that travel time is important, but not as a simple linear relationship. When considering modeling alternatives, it is important to evaluate model outputs in the context of all of the models tested, and how they are explaining the variation in the data. The models with the most statistical support are the ones we should be using to inform management decisions.

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Appendix A

Analysis of changes in spill, spill proportion, and PITPH at Lower Granite, Little Goose, Lower Monumental, and Ice Harbor dams under the special operation at LGS, compared to without the special operation.

In response to IDFG's concerns, the FPC redid our analysis of estimating spill proportions and PITPH at Little Goose (LGS), Lower Monumental (LMN), and Ice Harbor (IHR) dams, both before and during the 2018 LGS Special Operation. The original FPC analysis was conducted on June 1, 2018 and, therefore, only included data from May 28th through May 31st. For this reanalysis, we added Lower Granite (LGR) and added data through June 5th. Below is a detailed explanation of our methods for this re-analysis, along with our results and conclusions.

Methods:

FPC staff summarized hourly flow and spill data at LGR, LGS, LMN, and IHR over the period of May 28th through June 5th. This includes two days prior, the four days of, and two days after the 2018 special operation at LGS. In addition, FPC staff estimated what hourly flow and spill at LGS, LMN, and IHR would have been if the special operation had not occurred. The shaping of flows during the LGS special operation did not affect the shape of the flows at LGR, as this project is upstream of LGS. Therefore, we did not estimate flow, spill, or PITPH for this project without the special operation. The special operation has been described as having no net effect on daily average flows. What is effected is the way that those flows are shaped throughout the day in order to accomplish the reduction of spill during the 0400-1200 time frame, passage of inflows from 1200 to 1600, and the release of stored water from 1600-0400. Therefore, to estimate what flow and spill would have been without the special operation, FPC assumed the same daily average flows as had occurred on each of the special operation days, only that daily average flow was assumed to have occurred in all hours of the day, instead of being shaped for the special operation. This effectively isolates the effect of the special operation under the descending hydrograph. During this period, flows were sufficiently high that powerhouse capacity was exceeded. Therefore, we assumed that hourly spill without the special operation would have been the hourly flow minus hourly powerhouse flows and hourly miscellaneous flows (e.g., adult ladders).

In its 2015 Annual Report, the Comparative Survival Study (CSS) provided a detailed write-up of the methodology for using PIT-tag data to estimate the fraction of fish passing through the powerhouse (bypass and turbine routes combined), which is termed PITPH (McCann et al. 2015, Appendix J). Depending on the project and species, estimates of PITPH are a function of a combination of flow, spill proportion, spill volume, the presence of a surface passage structure, and estimated Fish Guidance Efficiency (FGE). Similar to the original analysis, the FPC staff estimated hourly PITPH for yearling Chinook and steelhead at LGR, LGS, LMN, and IHR using equations derived from the CSS methodology (see Equation A.1 for yearling Chinook and Equation A.2 for steelhead) over the entire time period of our re-analysis.

Yearling Chinook

$$LGR = \frac{\text{Exp}(1.5651 - 0.0055 \cdot \text{Flow} - 7.5713 \cdot \text{SpillProp} + 0.0237 \cdot \text{Spill})}{1 + \text{Exp}(1.5651 - 0.0055 \cdot \text{Flow} - 7.5713 \cdot \text{SpillProp} + 0.0237 \cdot \text{Spill})} / 0.78$$

$$LGS = \frac{\text{Exp}(0.8561 + 0.0071 \cdot \text{Flow} - 8.8597 \cdot \text{SpillProp} + 0.0185 \cdot \text{Spill})}{1 + \text{Exp}(0.8561 + 0.0071 \cdot \text{Flow} - 8.8597 \cdot \text{SpillProp} + 0.0185 \cdot \text{Spill})} / 0.80$$

[A.1]

$$LMN = \frac{\text{Exp}(-0.6181 + 0.0107 \cdot \text{Flow} - 7.379 \cdot \text{SpillProp} + 0.0176 \cdot \text{Spill} - 0.2556 \cdot \text{Weir})}{1 + \text{Exp}(-0.6181 + 0.0107 \cdot \text{Flow} - 7.379 \cdot \text{SpillProp} + 0.0176 \cdot \text{Spill} - 0.2556 \cdot \text{Weir})} / 0.80$$

$$IHR = \frac{\text{Exp}(-1.2703 + 0.0158 \cdot \text{Flow} - 5.0724 \cdot \text{SpillProp})}{1 + \text{Exp}(-1.2703 + 0.0158 \cdot \text{Flow} - 5.0724 \cdot \text{SpillProp})} / 0.86$$

Steelhead

$$LGR = \frac{\text{Exp}(2.4229 - 0.0024 \cdot \text{Flow} - 7.595 \cdot \text{SpillProp} + 0.0249 \cdot \text{Spill} - 0.862 \cdot \text{Weir})}{1 + \text{Exp}(2.4229 - 0.0024 \cdot \text{Flow} - 7.595 \cdot \text{SpillProp} + 0.0249 \cdot \text{Spill} - 0.862 \cdot \text{Weir})} / 0.83$$

$$LGS = \frac{\text{Exp}(0.4188 + 0.016 \cdot \text{Flow} - 7.8669 \cdot \text{SpillProp})}{1 + \text{Exp}(0.4188 + 0.016 \cdot \text{Flow} - 7.8669 \cdot \text{SpillProp})} / 0.87$$

[A.2]

$$LMN = \frac{\text{Exp}(-0.8413 + 0.0161 \cdot \text{Flow} - 4.965 \cdot \text{SpillProp} - 0.6506 \cdot \text{Weir})}{1 + \text{Exp}(-0.8413 + 0.0161 \cdot \text{Flow} - 4.965 \cdot \text{SpillProp} - 0.6506 \cdot \text{Weir})} / 0.94$$

$$IHR = \frac{\text{Exp}(-0.5026 + 0.0188 \cdot \text{Flow} - 7.0273 \cdot \text{SpillProp})}{1 + \text{Exp}(-0.5026 + 0.0188 \cdot \text{Flow} - 7.0273 \cdot \text{SpillProp})} / 0.95$$

We assumed a value of 1 (weir present) for those sites/species where the surface passage structure (i.e., Weir) term was included in the PITPH equation. For comparison, FPC staff also estimated hourly PITPH for the special operation period (May 30 0400-June 3 0400) at LGS, LMN, and IHR, if the special operation had not occurred, based on the estimated hourly flow and spill during this period. It is worth noting that the CSS has not developed PITPH equations for subyearling Chinook, which would likely be effected by the special operation the most. FPC staff inquired with the CSS and was advised that, based on AICc values for the Fish Travel Time and Z models, the PITPH equations for yearling Chinook are a better predictor for subyearling Chinook than the steelhead equations (S. Haeseker, personal communication).

Finally, as suggested in the IDFG comments, we calculated daily average flows, spill, spill proportions, and PITPH from the hourly data, based on the period of the special operation. This means that daily averages for a single day included the hourly estimates from 0500 that day to 0400 the next day. For comparison, we estimated these daily averages both with and without the special operation at LGS, LMN, and IHR. As mentioned above, this effectively isolates the effect of the special operation.

Results

Lower Granite Dam

Average flows, spill volumes, and spill proportions at LGR declined from May 28th to June 4th (Table A.1). As a result, average PITPH at LGR increased for both yearling Chinook and steelhead. This is evident in the hourly data as well (Figure A.1).

Table A.1. Daily average flow, spill, and spill proportion and estimated PITPH (Chinook and steelhead) at Lower Granite Dam (May 28-June 4). Daily averages included the hours between 0500 the day of to 0400 the next day. For example, the daily average reported for May 28 spans from 0500 on May 28 to 0400 on May 29. Shaded rows depict the period of the LGS special operation.

Date	Avg. Flow (Kcfs)	Avg. Spill (Kcfs)	Avg. Spill Proportion	Avg. PITPH (Chinook)	Avg. PITPH (Steelhead)
5/28	164.2	56.0	0.34	0.46	0.59
5/29	160.2	51.7	0.32	0.47	0.61
5/30	156.8	48.2	0.31	0.49	0.62
5/31	149.9	42.1	0.28	0.52	0.64
6/1	152.6	44.3	0.29	0.51	0.63
6/2	137.5	32.5	0.24	0.57	0.68
6/3	118.7	30.7	0.26	0.54	0.62
6/4	113.6	31.0	0.27	0.52	0.60

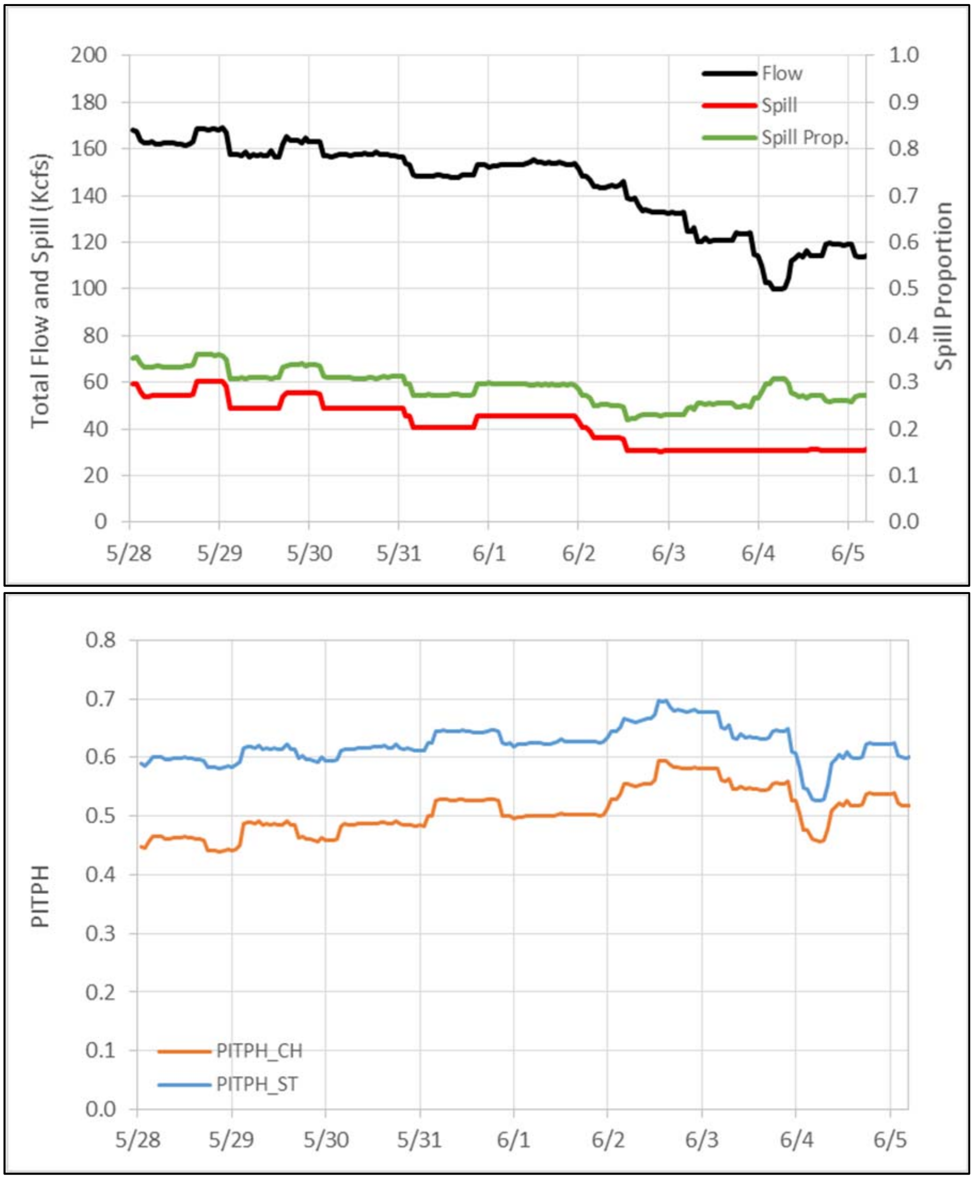

Figure A.1. Hourly flow, spill, and spill proportions (Top) and hourly estimates of PITPH (yearling Chinook and steelhead) (Bottom) at Lower Granite Dam (May 28-June 4).

Little Goose Dam

The special operation at LGS began at 0400 on May 28th and was terminated at 0400 on June 3rd. As mentioned above, during the special operation, flows were shaped at LGS in order to accomplish the objective of reducing spill to 30% during the 0400-1200 period, pass inflows during the 1200-1600 period, and release stored water during the 1600-0400 period (Figure A.2). Daily average spill volume and spill proportion for May 29th were abnormally high. This is because screen cleaning activities on this date necessitated a reduction in powerhouse capacity and, therefore, spill was increased during this period.

Daily average flow, spill volumes, and spill proportions all declined from May 28th to June 4th (Table A.2, Figure A.2). In addition, daily average PITPH increased for both yearling Chinook and steelhead over the entire period. While it is true that spill proportions declined and PITPH increased during this period, our analysis also indicates that daily average PITPH would have been lower during the period of the special operation if the special operation had not occurred (Table A.2). For example, with the special operation in place, the estimates of daily average PITPH for yearling Chinook and steelhead on May 30th were 0.49 and 0.49, respectively (Table A.2). However, without the special operation, we estimated that the daily average PITPH for yearling Chinook and steelhead would have been 0.46 and 0.47, respectively (Table A.2). This same pattern of higher PITPH under the special operation, compared to without the special operation, was evident in all four days and both species at LGS.

One reason why the special operation resulted in higher estimates of PITPH, when compared to without the special operation, has to do with the flow, spill volumes, and proportion spill that occurred during the 1200-1600 and 1600-0400 periods. The general thought for this special operation was that, while spill is reduced to 30% for 8 hours (0400-1200), any impacts on juveniles from this reduced spill will be negated by increased spill during the period when inflows are passed (1200-1600) and/or when the stored water is released (1600-0400). This implies that the spill proportions during these two periods will increase significantly enough to negate the decreases during the 0400-1200 period. Based on our analysis, this was not the case. For example, on the first day of the special operation (May 30th), spill proportions were 0.30 (on average) for the period of 30% spill (0400-1200), increased to 0.40 (on average) for the period of passing inflows (1200-1600), and increased again to 0.46 (on average) for the period of releasing stored water (1600-0400) (Figure A.2). This resulted in a daily average spill proportion of 0.39. However, without the special operation, we estimated that spill proportions on May 30th would have been 0.41 (on average) for the 0400-1200 period, 0.41 (on average) for the 1200-1600 period, and 0.40 (on average) for the 1600-0400 period, which would have resulted in a daily average spill proportion of 0.40 (Table 2, Figure 2). Therefore, the special operation appears to have resulted in a 12-hour reduction in spill proportion (0400-1600) followed by a 12-hour increase in spill proportion (1600-0400). Overall, the magnitude of the 12-hour reduction was larger than the magnitude of the 12-hour increase, resulting in an overall reduction in spill proportion and increased PITPH (Table A.2, Figure A.2). The pattern described in the above example appears to have occurred on all four days of the special operation, for both species.

Table A.2. Daily average flow, spill, and spill proportion and estimated PITPH (Chinook and steelhead) at Little Goose Dam (May 28-June 4), both with and without the Special Operation. Daily averages included the hours between 0500 on the day of and 0400 the next day. For example, the daily average reported for May 28 spans from 0500 on May 28 to 0400 on May 29. Shaded rows depict the period of the LGS special operation.

	With Special Operation (Actual)					Without Special Operation (Estimated)			
Date	**Avg. Flow (Kcfs)**	**Avg. Spill (Kcfs)**	**Avg. Spill Prop.**	**Avg. PITPH (CH)**	**Avg. PITPH (ST)**	**Avg. Spill (Kcfs)**	**Avg. Spill Prop.**	**Avg. PITPH (CH)**	**Avg. PITPH (ST)**
5/28	157.2	67.7	0.43	0.45	0.45	---	---	---	---
5/29*	157.1	78.6	0.50	0.35	0.33	---	---	---	---
5/30	150.2	60.6	0.39	0.49	0.49	60.9	0.40	0.46	0.47
5/31	142.6	52.9	0.37	0.50	0.52	53.3	0.37	0.49	0.51
6/1	146.6	57.2	0.38	0.49	0.50	56.4	0.39	0.47	0.49
6/2	131.3	41.2	0.31	0.56	0.59	40.7	0.31	0.57	0.60
6/3	112.4	25.6	0.23	0.66	0.69	---	---	---	---
6/4	109.9	25.3	0.23	0.64	0.68	---	---	---	---

* Due to screen cleaning activities, the daily spill volume and spill proportion at LGS on May 29th were abnormally high and not indicative of normal operations at this time.

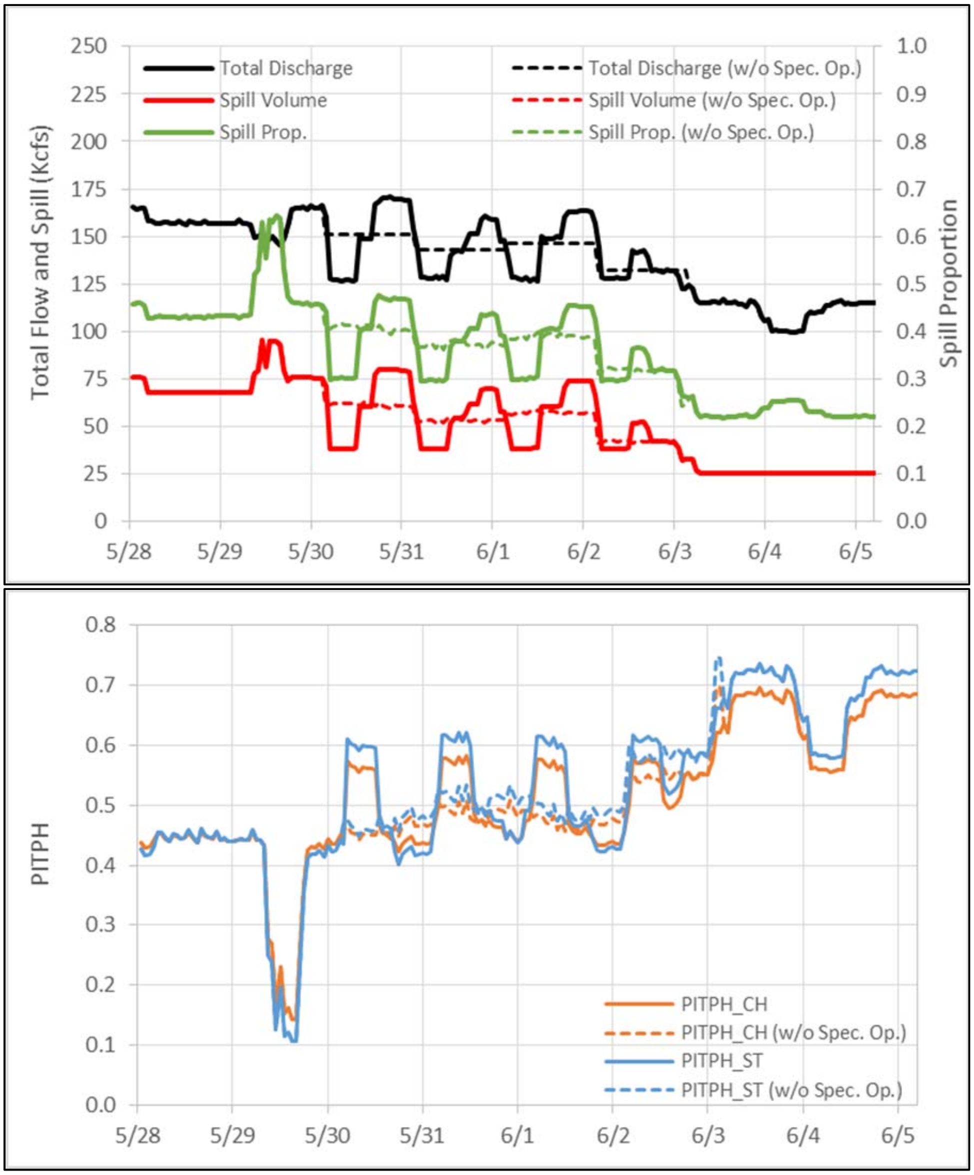

Figure A.2. Hourly flow, spill, and spill proportions (Top) and hourly estimates of PITPH (yearling Chinook and steelhead) (Bottom) at Little Goose Dam (May 28-June 4). Estimates of hourly flow, spill, spill proportion, and PITPH without the special operation are provided as dashed lines.

Lower Monumental Dam

The shaping of flows at LGS to accomplish the objective of the special operation resulted in a similar shaping of flows at LMN, without the necessity to store water into the LMN forebay (Figure A.3). Daily average flow, spill volumes, and spill proportions all declined from May 28th to June 4th at LMN (Table A.3, Figure A.3). In addition, daily average PITPH increased for both yearling Chinook and steelhead over the entire period.

Although the magnitude was not as large, we found similar results from our analysis of LMN operations as we observed at LGS. While spill proportions declined and PITPH increased during the period of the special operation, our analysis at LMN indicated that, in general, daily average PITPH would have been lower during the period of the special operation if the special operation at LGS had not occurred (Table A.3). For example, with the special operation in place, the estimates of daily average PITPH for yearling Chinook and steelhead at LMN on May 30th were 0.31 and 0.28, respectively (Table A.3). However, without the special operation, we estimated that the daily average PITPH for yearling Chinook and steelhead at LMN would have been 0.29 and 0.26, respectively (Table A.3). Unlike the results for LGS, the pattern of higher PITPH under the special operation, compared to without the special operation, did not occur for all four days at LMN. Furthermore, the magnitude of the difference at LMN seemed to decrease as the four days progressed. For example, by the last day of the special operation (June 2nd), the daily average PITPH for yearling Chinook and steelhead at LMN were 0.24 and 0.22, respectively (Table A.3). Without the LGS special operation, we estimated that the daily average PITPH would have been 0.24 for yearling Chinook and 0.23 for steelhead. This represents no net change in PITPH for yearling Chinook and an increase in PITPH for steelhead.

The same explanation that we provided for the results at LGS applies to LMN. For example, on the first day of the special operation (May 30th), spill proportions at LMN were 0.32 (on average) for the 0400-1200 period, increased to 0.37 (on average) for the 1200-1600 period, and increased again to 0.46 (on average) for the 1600-0400 period (Figure A.3). This resulted in a daily average spill proportion of 0.40 (Table A.3). However, without the special operation, we estimated that spill proportions on May 30th would have been 0.41 (on average) for the 0400-1200 period, 0.42 (on average) for the 1200-1600 period, and 0.41 (on average) for the 1600-0400 period, which would have resulted in a daily average spill proportion of 0.41 (Table A.3, Figure A.3). Therefore, the special operation at LGS appears to have resulted in a 12-hour reduction in spill proportion at LMN (0400-1600) followed by a 12-hour increase in spill proportion (1600-0400). As we observed at LGS, the magnitude of the 12-hour reduction at LMN was larger than the magnitude of the 12-hour increase, resulting in an overall reduction in spill proportion and increased PITPH on May 30th (Table A.3, Figure A.3). However, as noted above, the pattern described in the above example did not occur at LMN on all four days. On the last day of the operation (June 2nd), daily average spill proportions were the same with and without the special operation, as was PITPH for yearling Chinook. The estimated PITPH for steelhead was 0.22 for June 2nd under the special operation but 0.23 without the special operation (Table A.3).

Table A.3. Daily average flow, spill, and spill proportion and estimated PITPH (Chinook and steelhead) at Lower Monumental Dam (May 28-June 4), both with and without the Special Operation. Daily averages included the hours between 0500 the day of to 0400 the next day. For example, the daily average reported for May 28 spans from 0500 on May 28 to 0400 on May 29. Shaded row depicts the period of the LGS special operation.

	With Special Operation (Actual)					Without Special Operation (Estimated)			
Date	**Avg. Flow (Kcfs)**	**Avg. Spill (Kcfs)**	**Avg. Spill Prop.**	**Avg. PITPH (CH)**	**Avg. PITPH (ST)**	**Avg. Spill (Kcfs)**	**Avg. Spill Prop.**	**Avg. PITPH (CH)**	**Avg. PITPH (ST)**
5/28	157.2	68.9	0.44	0.29	0.26	---	---	---	---
5/29	153.2	65.0	0.42	0.29	0.26	---	---	---	---
5/30	150.3	62.0	0.40	0.31	0.28	61.8	0.41	0.29	0.26
5/31	141.5	52.8	0.37	0.30	0.28	53.4	0.38	0.29	0.27
6/1	145.2	56.6	0.38	0.30	0.28	55.5	0.38	0.29	0.27
6/2	130.0	52.8	0.41	0.24	0.22	53.3	0.41	0.24	0.23
6/3	112.0	27.5	0.25	0.34	0.31	---	---	---	---
6/4	106.1	27.0	0.26	0.30	0.28	---	---	---	---

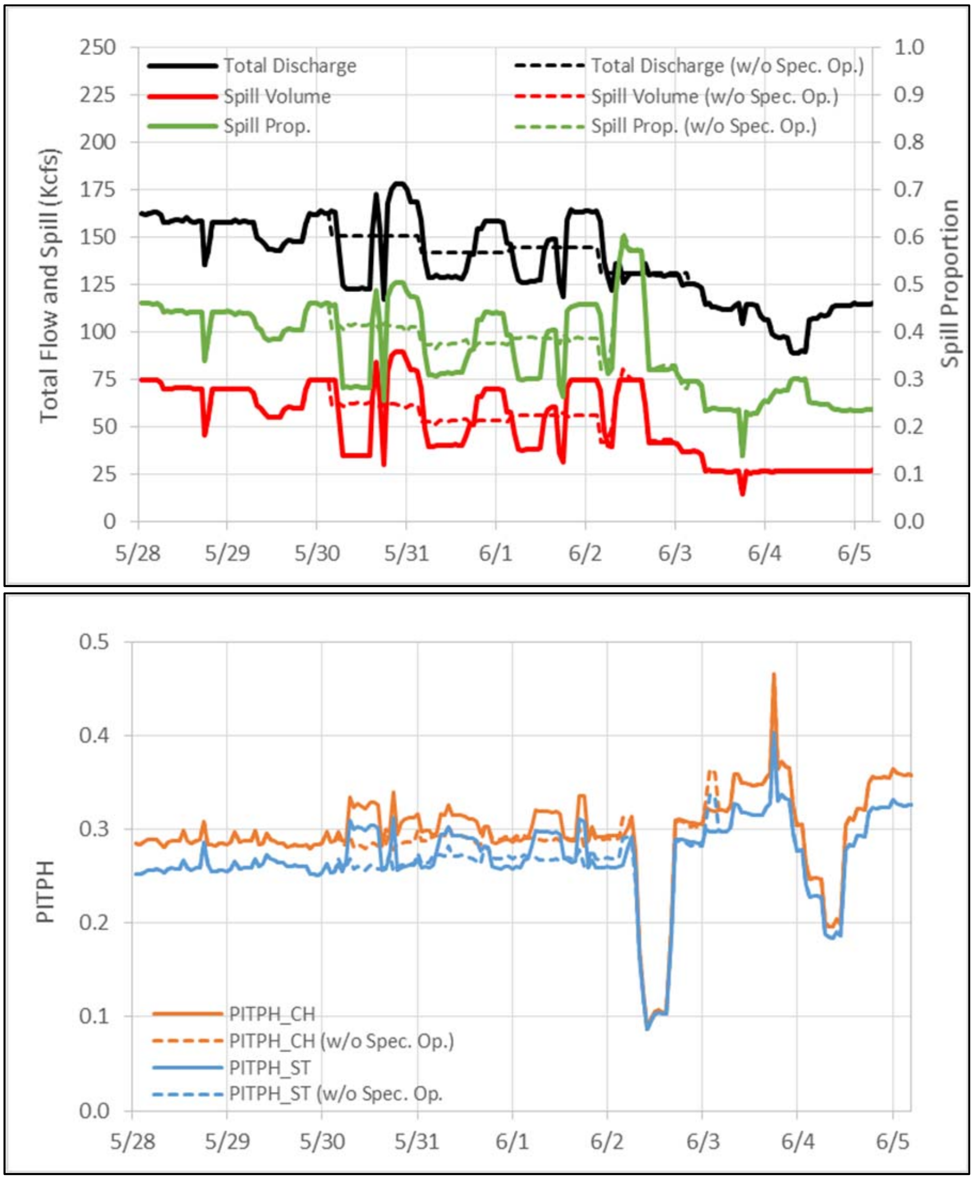

Figure A.3. Hourly flow, spill, and spill proportions (Top) and hourly estimates of PITPH (yearling Chinook and steelhead) (Bottom) at Lower Monumental Dam (May 28-June 4). Estimates of hourly flow, spill, spill proportion, and PITPH without the special operation are provided as dashed lines.

Ice Harbor Dam

The shaping of flows at LGS to accomplish the objective of the special operation also resulted in a shaping of flows at IHR, without the necessity to store water into the IHR forebay (Figure A.4). Daily average flow and spill volumes both declined from May 28th to June 4th at IHR (Table A.4, Figure A.4). However, daily average spill proportions were relatively stable for most of this period and even increased on June 4th. This is likely due to the higher prescribed spring spill level at IHR compared to the other Snake River projects. The prescribed spill level at IHR during this period was 80 Kcfs, whereas that for the other Snake River projects was in the

26-31 Kcfs range. Similar to daily average spill proportions, daily average PITPH was relatively stable for most of the period we analyzed, except for the last two days (June 3rd and 4th), when PITPH estimates decreased significantly. By this time, flows had decreased to a level that hydraulic capacity was no longer exceeded and spill proportions increased to 0.67-0.71, due to the high prescribed spill level at IHR, generally low hydraulic capacity, and the decreasing flows.

In general, the pattern we observed at LGS and LMN, where PITPH was higher under the special operation than without the special operation, was not observed at IHR (Table A.4). This is not a surprise, as there seemed to be no change in spill proportions at IHR from the special operation (Table A.4). For example, with the special operation in place, the estimates of daily average spill proportion for May 30th at IHR was 0.65 and the estimated PITPH for yearling Chinook and steelhead were 0.13 and 0.12, respectively (Table A.4). Without the special operation, we estimated that the daily average spill proportion at IHR would have remained at 0.65 and the daily average PITPH for yearling Chinook and steelhead at LMN would have been 0.13 and 0.11, respectively (Table A.4). The decrease in PITPH for steelhead on May 30th without the special operation is the only occurrence of this type for IHR.

Table A.4. Daily average flow, spill, and spill proportion and estimated PITPH (Chinook and steelhead) at Ice Harbor Dam (May 28-June 4), both with and without the Special Operation. Daily averages included the hours between 0500 the day of to 0400 the next day. For example, the daily average reported for May 28 spans from 0500 on May 28 to 0400 on May 29. Shaded rows depict the period of the LGS special operation.

	With Special Operation (Actual)					**Without Special Operation (Estimated)**			
Date	**Avg. Flow (Kcfs)**	**Avg. Spill (Kcfs)**	**Avg. Spill Prop.**	**Avg. PITPH (CH)**	**Avg. PITPH (ST)**	**Avg. Spill (Kcfs)**	**Avg. Spill Prop.**	**Avg. PITPH (CH)**	**Avg. PITPH (ST)**
5/28	162.5	107.5	0.66	0.13	0.12	---	---	---	---
5/29	160.0	105.5	0.66	0.13	0.11	---	---	---	---
5/30	157.0	102.3	0.65	0.13	0.12	101.9	0.65	0.13	0.11
5/31	149.3	95.5	0.64	0.12	0.11	96.5	0.64	0.12	0.11
6/1	152.1	100.4	0.66	0.12	0.10	98.5	0.66	0.11	0.10
6/2	138.3	85.2	0.62	0.12	0.10	87.2	0.62	0.12	0.10
6/3	119.8	80.7	0.67	0.07	0.05	---	---	---	---
6/4	113.9	80.3	0.71	0.05	0.04	---	---	---	---

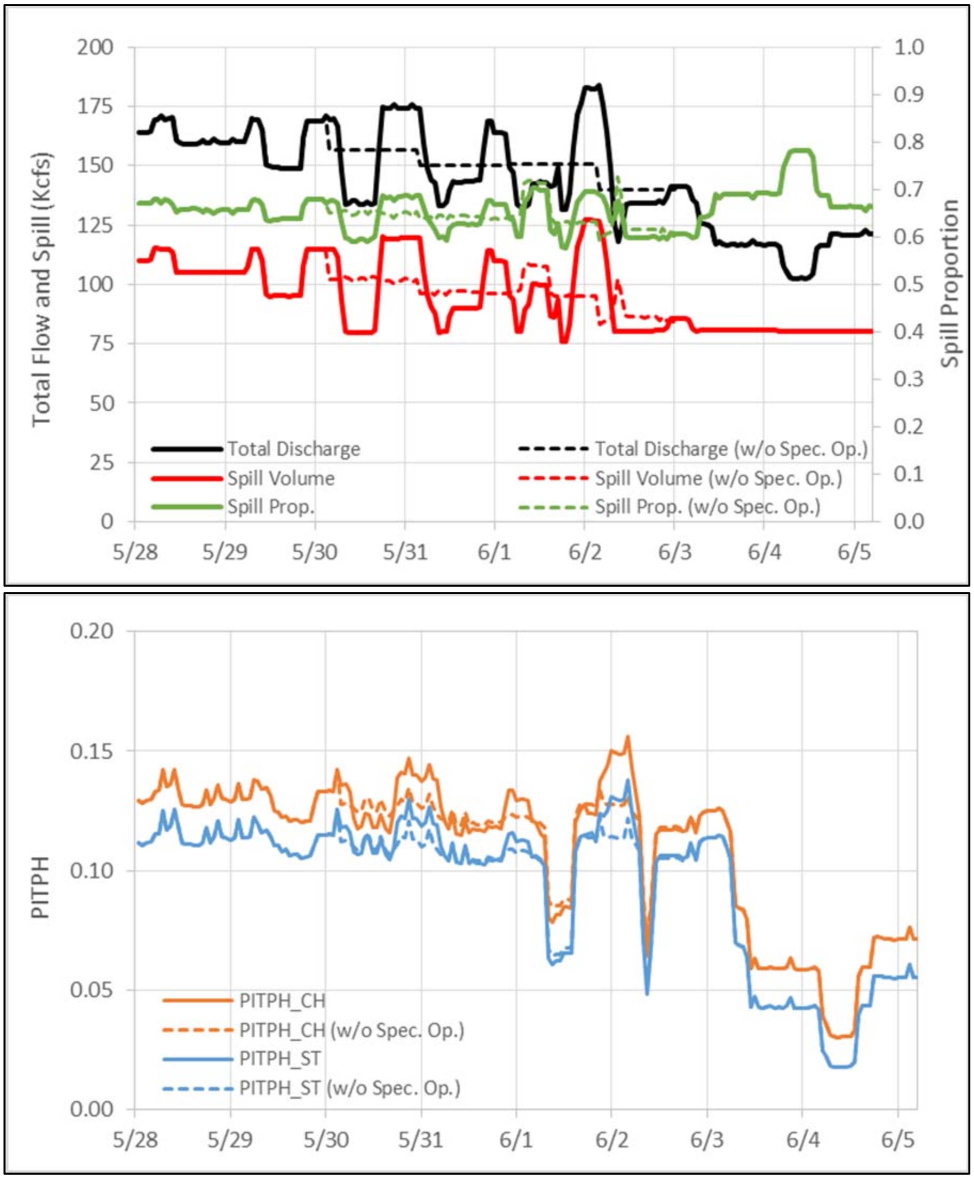

Figure A.4. Hourly flow, spill, and spill proportions (Top) and hourly estimates of PITPH (yearling Chinook and steelhead) (Bottom) at Ice Harbor Dam (May 28-June 4). Estimates of hourly flow, spill, spill proportion, and PITPH without the special operation are provided as dashed lines.

Conclusions

By estimating hourly spill, hourly spill proportion, and PITPH, at LGS, LMN, and IHR without the special operation in place, we effectively isolate the effect of the special operation. After re-analyzing the data this way, we stand by our original conclusion that the special operation at LGS resulted in a decrease in spill proportions at LGS and LMN (to a lesser degree) and, as a result, an increase in powerhouse passage (PITPH). Spill proportions and PITPH did not appear to change at IHR as a result of the special operation at LGS. When isolating the effect of the special operation, our re-analysis indicates that spill proportions would have been higher and PITPH would have been lower at both LGS and LMN without the LGS special operation.

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Appendix B

Hourly PIT-tag Detections at Little Goose Dam

We analyzed bypass detections of PIT-tagged subyearling Chinook at Little Goose Dam during the ponding and reduced spill operations that occurred between May 30th and June 2nd. In addition, we compared passage timing prior to the start of the operation (May 28th and 29th) as well as two days after the operation (June 3rd and 4th). Figure B.1 shows the relative proportions of PIT-tags detected each hour of of the day in each two-day block. As can be seen in the figure, there are pronounced spikes in passage proportions of subyearling detections during the four days on which ponding operations occurred. All dates show increased detections from 2100 hours through 0400 but the two blocks associated with ponding and decreased spill during daytime hours (i.e., LGS special operation), showed the highest spikes in passage in the first few hours of darkness, and continued high passage through the night.

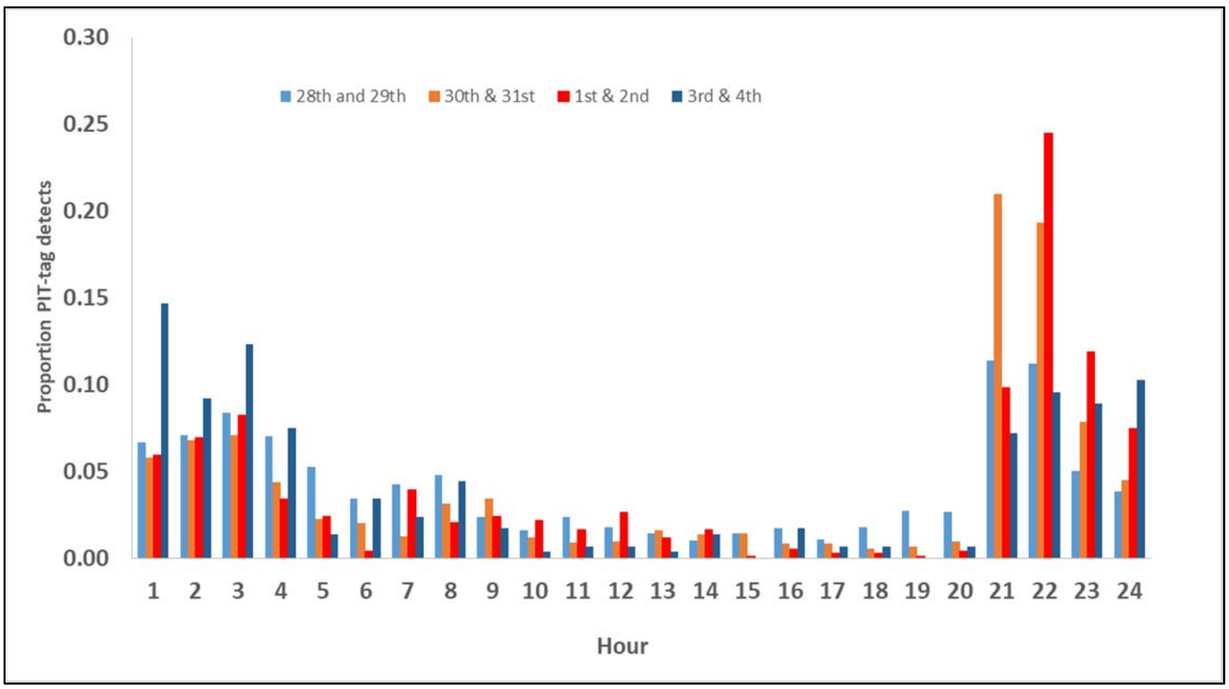

Figure B.1. PIT-tagged subyearling Chinook detections by hour of passage at Little Goose Dam in 2018. Data are grouped in two day periods; May 28 & 29 (light blue); May 30th and 31st (orange); June 1st and June 2nd (red); June 3rd and 4th (dark blue).

We interpret the shape of this passage data as indicitive of increased powerhouse passage at night, after daytime delay. We base this interpretation on the evidence that fish tend to delay in the forebay of the powerhouse during daylight hours and move more rapidly through the bypass at night (Beeman et al. 2009). Our findings are consistent with the Beeman et al. (2009) telemetry results. Delayed passage in day time at the powerhouse, followed by increased passage at night of those fish delayed during the day, would result in the very same passage distributions we found. Greater delay during the day should exacerbate the spike in passage at dusk as we observed.

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