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MEMORANDUM

TO: David Leonhardt, USACE
Portland District

FROM: Michele DeHart

DATE: March 29, 2016

RE: Review comments on *Predation Impacts on Juvenile Salmonids by Double-crested Cormorants and Caspian Terns Nesting on East Sand Island in the Columbia River Estuary*

At my request, the Fish Passage Center staff has reviewed and provided comments on the draft report *Predation Impacts on Juvenile Salmonids by Double-crested Cormorants and Caspian Terns Nesting on East Sand Island in the Columbia River Estuary*. This report summarizes efforts to estimate predation rates on juvenile salmonids by double-crested cormorants and Caspian terns on East Sand Island based on the recovery of PIT tags.

FPC staff's comments are specifically focused on the sections of the draft report on predation rate calculations (pages 8–13) and factors influencing predation rate calculations (Appendix D, pages 55–58). A shortened summary of the salient points of this review is provided in the bullets below. Our biggest concern with this draft report is that Appendix D is incomplete as it stands. Standard reporting of multiple regression analyses would show estimated coefficients, standard errors, confidence intervals, and p-values for the variables in the top selected models. Without this information, it is impossible to evaluate the strength, direction, and reliability of these results. The reader cannot assess which of two variables determined to be important, for instance colony size or spill percentage, have a larger effect on avian predation rates without this information. We recommend that this information be included or Appendix D be removed from the final report if more thorough results cannot be provided in the final draft. In summary:

- The reported avian predation rates are likely positively biased relative to the entire population of smolts susceptible to predation because only transported and bypassed fish were utilized to calculate predation rates. The Comparative Survival Study (CSS) has found that bypass encounters tend to be associated with reductions in SARs and thus omitting spillway passed fish from these analyses may misrepresent the entire population susceptible to predation.

- A powerhouse passage index (McCann et al. 2015, Appendix J) should be included in the multiple regression analyses aimed at examining the factors influencing avian predation rates. Powerhouse passage can result in injury or trauma to fish, which makes them more susceptible to avian predation (Hostetter et al. 2012).
- Appendix D is incomplete and does not provide enough information to interpret the relationships that are suggested and the statistical significance of these relationships. There are also other concerns which include a very limited data set which appears to consist of only 13 data points from years 2000–2012.
- An assessment of additive compared to compensatory mortality needs to be conducted and reported alongside these results. Without this assessment, management actions guided from this study may not result in the intended effect while resulting in detriment to avian colonies on East Sand Island.

Predation Rate Calculations

Smolt Availability

Predation rate calculations were calculated from transported or Bonneville and Sullivan Dam bypassed fish. Using these individuals provides a straightforward way to calculate predation rate as one can assume that the number of smolts that are susceptible to predation, termed smolt availability, is fixed and known without error. Limiting predation calculations only to transported and bypassed fish at Bonneville and Sullivan Dam requires the assumption these fish are representative of their entire population of smolts susceptible to predation, which also includes fish passing through turbine and spillway routes at Bonneville and Sullivan dams. The CSS has conducted analyses to evaluate the effects of cumulative bypass encounters on smolt-to-adult (SAR) survival rates (Tuomikoski et al. 2010, Chapter 7). This study found that SAR rates tended to decrease for each additional bypass encounter. Given that the transition from freshwater to ocean habitats is a critical life-stage that explains a substantial amount of variability in SAR rates (Pearcy and McKinnell 2007), it is entirely plausible that estimates of bird predation during this life-stage based only on bypassed fish will be positively biased if encounters with bypass systems lead to reductions in SARs compared to spillway-routed fish.

We recommend that the authors of this study:

- Clearly state their assumption that transported and bypassed fish are equally as susceptible to avian predation as spillway and turbine passed fish. If the authors are not able to make this assumption, it should be clearly expressed that the results of this study are applicable only to transported and Bonneville and Sullivan Dam bypassed fish.

Deposition probability

The use of a Bayesian model provided a practical way to incorporate uncertainty into deposition probability through the use of an informative prior distribution for this parameter. However, it is common and recommended in Bayesian analysis to explore the sensitivity of the choice of the informative prior distribution as this is a subjective decision (Gelman et al. 2004). Thus, instead of always using the same prior distribution, analyses should also explore how sensitive the results are to changes in the center, shape and spread of this assumed prior distribution.

Sensitivity analyses should also explore the robustness of the assumption that deposition probability is constant across all 16 years in this study. The authors justified this assumption by stating that the results of deposition experiments indicated that these probabilities did not vary significantly between years. However, these deposition experiments lasted only 2 to 3 years (2004–2006 for Caspian terns and 2012–2013 for double-crested cormorants), which is not a long enough time series to evaluate whether or not deposition probability is indeed constant from year to year.

We recommend that the authors of this study:

- Explore the sensitivity of their results to their assumed informative prior distributions for deposition probability. Sensitivity analyses should explore changes in the center, shape and spread of this distribution. Sensitivity analyses that allow this prior distribution to vary from year to year should also be conducted.

Detection probability

PIT tags were intentionally sown on East Sand Island to estimate detection probability. Having a reliable estimate of detection probability is paramount to reliable estimates of predation probability. As so, the methods for estimating detection probabilities should be carefully reviewed and documented in this draft report. The detection probability estimates rely on the assumption that hand-sown tags reflect the on-island deposition process. Has this assumption been thoroughly evaluated?

Other methods that don't rely on hand-sown tags should also be explored. For instance, Frechette et al. (2012) present an approach using an Open Jolly-Seber model to correct for tags deposited on an avian colony, but not detected during surveys. This method was able to estimate the same parameters of interest to this study on East Sand Island, but without reliance on hand-sown tags.

Finally, justification for the assumption that PIT-tag detection probability is a linear function of week needs to be justified. No rationale for this assumption was stated. It is not hard to conceive a situation where this assumption is not true. Quadratic, cubic or spline-based methods that allow for more flexibility in trends in weekly detection probability should also be explored.

We recommend that the authors of this study:

- Further evaluate the assumption that hand-sown tags reflect the on-island deposition process.
- Explore other methods that don't rely on hand-sown tags (Frechette et al. 2012).
- Provide justification for the assumption that PIT-tag detection probability is linear and explore other functional forms that allow for more flexible relationships.

Factors Influencing Predation Rates (Appendix D)

Incomplete Analysis

Appendix D presents cursory results of several multiple regression analyses aimed at examining the environmental and management factors influencing avian predation rates on East Sand Island. This is an important initial step forward toward making informed management actions based on an understanding of the multiple drivers of avian predation dynamics. However, as it stands, this analysis is incomplete because it does not provide the results of the models necessary to understand the magnitude and significance of the environmental and management factors deemed to be important. Appendix D should not be included in the final version of this report unless the authors provide the complete results of their findings which would include the estimates, standard errors, and p-values of the environmental and management-related variables. Without the complete results of these parameters, it is impossible to examine the magnitude and significance of the variables that the authors suggest are important. It's also impossible to rank and compare factors (e.g., spill percentage versus colony size) influencing avian predation rates.

We recommend that the authors of this study:

- Provide the estimated coefficients, standard errors, and p-values of all the variables, from all the models, in their multiple regression analyses.

Interpretation of spill variable

When interpreting the results of the multiple regression analyses in Appendix D, it was suggested that the importance of the mean spill percentage variable is a new finding that should be viewed as preliminary. The importance of spill percentage in explaining SAR rates, however, is not a new finding (Haeseker et al. 2012). Thus, it is not surprising that this variable is also important in explaining avian predation rates, which is one component of an overall SAR rate. However, it is surprising that the authors found positive relationships between spill percentage and avian predation rates. Recent work (Haeseker et al. 2012) has found positive relationships between spill percentages and SAR rates, and based on this, the relationship between spill percentage and avian predation rates should be negative instead of positive. The authors also suggest that the importance of this variable can be explained by the relationship between total river discharge on the estuary environment (Weitkamp et al. 2012). While this may be true, it is also known that increasing spill percentages help to reduce to power house passage (McCann et al. 2015, Appendix J) which causes injury and stress to fish (Budy et al. 2002). Thus, higher spill percentages should result in fish in better overall condition, and fish in better condition tend to be less likely consumed by avian predators (Hostetter et al. 2012). The importance of the spill variable and the latter interpretation of it could be corroborated if a power house passage index variable were included in the multiple regression analyses.

We recommend that the authors of this study:

- Include an index of power house passage in their multiple regression models.
- Provide an alternative explanation of the importance of the spill percentage variable that is related to fish condition.

Environmental and management variables comparison

Comparing the influence of environmental and management related variables on avian predation rates is a useful comparison to make. However, comparing R^2 values of the five selected models with only environmental variables, to models with both management and environmental variables doesn't necessarily address whether one variable is more important than the other, and which variables have the largest effect on avian predation rates. Also, this process does not account for uncertainty in the selection of the five best models. To better compare environmental- and management-related variables, multi-model inference techniques (Burnham and Anderson 2002) should be used to rank all models considered. Following this, the relative variable importance factor, which weights variables based on the corresponding model AIC value and variable inclusion or exclusion in that model, should be calculated. Summarizing variables by their relative variable importance in this context would be very useful, and would further account for uncertainty in the model selection process.

We recommend that the authors of this study:

- Use multi-model inference techniques to rank and compare all the models with solely environmental variables, and combinations of environmental and management variables.
- Calculate the relative variable importance to determine the most important factors related to avian predation dynamics.

Concerns with the modeling approach

There are number of other concerns with the multiple regression analyses presented in Appendix D. These concerns are listed below, but are not elucidated on for brevity:

- A log transformation was used to model predation rates. This transformation is useful for normalizing skewed response variables, but also assumes that the relationship between an environmental or management factor and avian predation rates exponentially increases without bounds. A logit transformation, which bounds predation rates between 0 and 1 could be a better transformation to use.
- A number of the variables included in multiple regression models are expected to be highly correlated (e.g., the suite of larger scale environmental indices). It is unclear

whether variance inflation factors (VIFs) were checked and one of the pair of variables with high correlation removed. Doing so ensures that accurate standard errors of parameters are estimated.

- It appears that only 13 data points from years 2000–2012 were used to inform the relationships in the multiple regression analyses. Utilizing small sample sizes will result in more uncertain results particularly if a large number of parameters are included in the model. The models fit all had at least 8 parameters fit to only 13 data points resulting in very few error degrees of freedom. In essence, three replicates of yearly predation rates are available for groups of fish originating from the 3 ESUs or DPSs. There are two predation rates that could be calculated per year by hatchery or wild rearing origin. There are also two predation rates that could be calculated per year based on migration history, transported or bypassed at Bonneville or Sullivan dams. Including more data, instead of collapsing it, should provide more accurate and meaningful relationships.
- The most recent data from years 2013–2015 was omitted from these analyses and were instead used to evaluate the ability of the model to predict data from the three omitted years. The authors should explore other model validation techniques (e.g., *k*-fold cross validation) that would allow them to include more recent data.
- The approach of ranking the five best models of the hundreds of models examined is unorthodox. The authors state that models were ranked by a combination of R^2 values, jackknife cross validation and their ability to predict 2013–2015 predation rates. This ranking process lacks a formula and is vague. More defensible model selection techniques commonly used to rank many competing models such as multi-model inference (Burnham and Anderson 2002) should be considered.

We recommend that the authors of this study:

- Consider the concerns that are expressed above and re-conduct analyses to address these concerns.

Overall Interpretation

Evaluation of compensatory mortality

The overall assumption that reductions in avian bird colonies will result in increases in overall SAR rates is predicated upon the assumption that mortality operates additively from life-stage to life-stage. The other possibility is that mortality operates in a compensatory fashion. Methods for quantitatively estimating levels of compensatory versus additive mortality are available in the scientific literature (Anderson and Burnham 1976, Burnham and Anderson 1984, and Nichols et al. 1984). A quantitative assessment of compensatory mortality is possible with this data. Assessment of compensatory mortality is necessary to determine whether or not predator controls will actually result in an increase of the population in question. As an example of the complexity of this ecosystem, PIT-tag data indicate that 4.8% of the PIT-tagged northern pikeminnow, another species that preys upon juvenile salmon and steelhead, released below Bonneville Dam in 2010 were deposited and detected on the East Sand Island cormorant colony.

Assuming the same 51% deposition rate for steelhead assumed in this study is also applicable to pikeminnow, this would indicate that cormorants removed 9.4% of the northern pikeminnow below Bonneville Dam in 2010. Single-species management actions that do not account for compensatory shifts in predator-prey relationships may not result in the anticipated effects because of compensatory responses (Ellis-Felege et al. 2012). For these reasons, a quantitative evaluation of compensation is warranted.

We recommend that the authors of this study:

- Conduct an assessment of compensatory mortality so that management actions informed by this study will result in the intended effect.

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