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MEMORANDUM

TO: Tom Rien, ODFW

Michele DeHart

FROM: Michele DeHart, FPC

DATE: August 17, 2016

RE: Review, "Factors influencing the survival of outmigrating juvenile salmonids through multiple dam passage: an individual –based approach". Elder, Woodley, Weiland, Strecker, June 23, 2016

In response to your request the Fish Passage Center staff has reviewed, *"Factors influencing the survival of outmigrating juvenile salmonids through multiple dam passage: an individual-based approach"* which was published in the online journal entitled Ecology and Evolution in June of 2016. In addition, the FPC staff reviewed the appendices attached to this article. We offer the following review comments for your consideration. Our overall conclusion after review of the analyses and appendices is that the analytical conclusions are not supportable by the data utilized or the analyses conducted. Even the most complicated and advanced statistical methodologies must reflect underlying biological processes and data when applied to ecological and biological resources questions. There are no statistical analytical methods or approaches that substitute for a thorough understanding of the data sets, assumptions, and biological processes being considered. This analysis appears to be an instance in which an interesting R-package was applied to a data set with little concern for the quality of the data, detailed understanding of the data set, and little understanding of the limitations of the statistical approach utilized. Further, the analysis utilizes a small data set collected in only one year, therefore assuming no seasonality or year effect which is not plausible. **The subject analysis is so extensively flawed that the conclusions reached are not credible or applicable to any fish passage management questions.** Our conclusions are listed below followed by a detailed discussion of each point.

- **The data set utilized by the authors is not applicable to the identified analytical question, regarding the effect of multiple dam passages on out-migrating juvenile salmon and steelhead. The authors fail to account for passage history up to the point the test fish are captured at John Day Dam, including previous route of passage: spillway or powerhouse. Further, the authors fail to account for the environmental variables encountered by individual test fish up to the point of capture at John Day Dam. The authors do not recognize that individual fish in their data set have varying passage experience before they arrive at John Day.**
- **The authors fail to consider the well-known, significant limitations of the acoustic tag data they utilized in this analysis, which resulted from a test/control study design to assess project survival.**
- **The authors fail to address the documented differences in juvenile survival rates, smolt to adult return rates, and delayed mortality that result from spillway passage versus powerhouse passage.**
- **The authors do not have a clear understanding of the environmental variables they have included in their analysis, nor do they understand the relationship of these variables and biological processes affecting juvenile salmon migration.**
- **The machine learning, "Random Forest" methodologic approach utilized does not support statistical inference as attempted by the authors.**
- **Any statistical analyses application is dependent upon a detailed understanding of the underlying data set, the biological and ecological processes in question, and whether or not the data set and analytical method utilized accurately represents these processes in the natural world.**
- **The source journal should be considered when journal articles are contemplated for citation and utilization. Not all journals can be considered to be equal in terms of the range of quality they present in publications.**

The data set utilized by the authors does not apply to the identified analytical question of the effect of multiple dam passages on out-migrating juvenile salmon and steelhead. The authors fail to recognize and account for passage history up to the point of being captured at John Day Dam including route of passage: spillway or powerhouse. Further, the authors fail to account for the environmental variables encountered by individual fish up to the point of capture at John Day Dam. The authors do not recognize that individual fish in their data set have varying passage experience before they arrive at John Day.

The authors present the premise that they are looking at the difference in juvenile survival based on fish passing one, two, or three dams. This premise is seriously flawed because the authors did not recognize that each fish in their data set had varying previous passage histories. Fish for this study are collected from the juvenile bypass passage system at John Day Dam. In addition to the handling and high grading of test fish that occurs due to the size and cost associated with the acoustic tag, all fish in this data set have already passed one dam powerhouse, as evidenced by the fact that they were collected in the bypass system at John Day Dam. The authors also ignore the fact that fish collected at John Day Dam had different and varied passage histories prior to collection at the John Day project. Fish could have additionally passed through anywhere from zero to five or six upstream dam powerhouses (bypass and turbine routes) prior to being captured and tagged at John Day Dam. Powerhouse passage prior to collection at John Day Dam is certainly a factor that would affect subsequent survival (Petrosky and Schaller, 2012; Haeseker et al., 2012; Schaller et al., 2014).

In addition, the specific fish collected at John Day Dam included in this data set were exposed to levels of spill in the Snake and Upper Columbia rivers that, particularly for the second half of May, were close to, or in excess, of 130% total dissolved gas (TDG). That prior route of passage history, as well as exposure to high levels of TDG will have had an effect on subsequent survival.

The authors fail to consider the significant limitations of the acoustic tag data they utilized in this analysis, which resulted from a test/control study design to assess project survival.

Smolts used in performance testing do not represent the run at large. Smolts that fall outside of size requirements or exhibit physical conditions such as disease, injury, or descaling are not included. The rejection of fish least likely to survive dam passage will inflate survival estimates over actual conditions. Rejection rates due to descaling, disease, and other deformities in 2011 were 10.5% for yearling Chinook and 15% for steelhead. These rejection rates were considered too high, so in 2012 the tagging criteria were relaxed to include more representative tagging (Skalski et al., 2013). The limitations of the acoustic tag data are widely known and have been provided, in writing, to two of the co-authors (Woodley and Weiland) and the original funding agency for this acoustic tag study (the US Army Corps of Engineers). These are available to the public at www.fpc.org.

The experimental design used for performance testing consists of a release above the dam, a control release in the tailrace, and a second control released downriver. These release sites are chosen for their applicability as dam passage and control groups, not to measure survival through multiple reaches. Tailrace releases in 2011 had lower survival over the following reach than downstream releases, potentially due to higher predation in the tailrace. By combining multiple releases throughout the hydrosystem as homogenous samples, the variation in survival for each release is not incorporated and may impact the estimates of dam survival.

The authors fail to address the documented differences in juvenile survival rates, smolt to adult return rates, and delayed mortality that result from spillway passage versus powerhouse passage.

Based on the description of how survival estimates were calculated, it appears that the subject analysis is not using Cormack-Jolly-Seber (CJS) methodology in estimating survival and, therefore, is assuming 100% detection probabilities at all acoustic arrays. This assumption is not true, as detection probabilities at the acoustic arrays ranged from 0.83 to 1.0 in 2011 (Weiland et al., 2013). Therefore, the assumption that non-detected fish were mortalities may not be true. Without accounting for detection probabilities, survival estimates may be unreliable.

The survival estimates provided in the subject analysis do not account for route of passage when estimating survival from what the authors refer to as, one, two, or three dam passages. The performance standards tests from which the subject study's data originate were specifically developed to assess differences in survival between passage routes. These performance studies tests have documented differential survivals between passage routes (spillway, bypass systems, or powerhouse) (Weiland et al., 2013; (Johnson et al. 2011, Ploskey et al. 2013, Skalski et al. 2013, Skalski et al. 2013a, Skalski et al. 2013b, Skalski et al. 2013c, Skalski et al. 2013d, Skalski et al. 2015a, Skalski et al. 2015b, Weiland et al. 2013). . To ignore the route of passage when estimating survivals past one, two, or three dams, when this information is readily available from the fish included in the test, limits the applicability of the study to accurately assess the impact of environmental factors on survival.

In addition, when assessing the effects of environmental variables on one, two, or three dam passages, the authors seem to ignore significant differences in survival within treatment groups. For example, Chinook and steelhead in the 1 Dam Passage groups had significant differences in survival between the different dams passed as did steelhead in the 2 Dam Passage groups (see Table 1 from Elder et al., 2016). These differences in survival within treatment groups are never discussed in the subject study and only presented in a table. Despite these significant differences, it appears the authors draw most of their management conclusions for one-dam and two-dam passages based on the average survival rates.

Finally, the consideration of only the juvenile life stage is inadequate when assessing dam passage effects. The authors have failed to consider the existing significant body of scientific work based upon individual passage history, which has shown that route of passage through a dam is related to smolt to adult return rates. A broad range of studies and analyses have documented the many effects that the collection/bypass systems at mainstem dams can have on salmonids, including: juvenile migration delay (Beeman and Maule, 2001; Muir et al., 2001b; Tuomikoski et al., 2010), delayed mortality (Budy et al., 2002; Schaller and Petrosky, 2007), reduced smolt-to-adult return rates (SARs) (Sandford and Smith, 2002; Williams et al., 2005; Tuomikoski et al., 2010; Buchanan et al., 2011), and reduced adult success (FPC, 2015; FPC, 2016; Crozier et al., 2014; Tuomikoski et al., 2010).

Analyses of the effects of multiple dam passages on smolt-to-adult survival utilizing individual PIT TAG detection histories throughout their downstream migration through the hydrosystem, documenting the number of powerhouse passages experienced has been conducted and allows for the determination of the number of bypass systems each fish encountered. PIT tag detection of these fish as returning adults allows assessment of return rate relative to juvenile passage history. These analyses show that for both chinook and steelhead, cumulative bypass encounters resulted in an 11% reduction in odds of survival from Bonneville to Bonneville with each bypass encounter. Juvenile salmon and steelhead, which experience bypass passage, have a lower smolt-to-adult return rate than fish that experience non-bypass passage (i.e., spillway passage). These analyses have shown that each powerhouse passage reduces smolt-to-adult return rates for salmon and steelhead. (Tuomikoski et al., 2010; McCann et al., 2016 in preparation). In addition, these analyses have shown that multiple bypass passage experiences further reduce smolt-to-adult return rates when compared with fish that have passed downstream over spillways. The authors have failed to consider this important mechanism when considering juvenile survival and have completely failed to address the relationship between passage history and adult returns.

The authors do not have a clear understanding of the environmental variables they have included in their analysis, nor do they understand the relationship of these variables and biological processes affecting juvenile salmon migration.

The authors' use of forebay measurements to represent total dissolved gas (TDG) exposure is misleading. Fish migrating through the hydrosystem in May of 2011 were exposed to TDG levels as high as 130% prior to, and subsequent to, collection at John Day Dam. The forebay TDG represents gas levels after dissipation from the upstream project. Dissipation is a function of several factors, including environmental factors as well as the length of the reservoir. Consequently, forebay TDG levels are always less than upstream tailrace measurements and do not accurately depict acute exposure. Using the forebay TDG measurement is misleading in that it will always result in the authors showing an impact (if one exists) at a lower TDG level than fish actually experienced.

It is not clear why the authors choose to use barometric pressure as a predictor variable affecting survival. It is true that when the barometric pressure (BP) equals the total gas pressure (TGP) the system is at equilibrium, while when the BP<TGP the system is in a supersaturated condition with respect to dissolved gas and conversely when BP>TGP the system is undersaturated. However, BP is directly used in the calculation of TDG and it therefore, is already incorporated in the analysis. The authors introduce the concept of Δ P (difference of barometric pressure and gas pressure), which is only applicable when TDG is uncompensated at the surface. When depth compensation is taken into consideration, the concept of ΔP is not applicable. Consequently, it is unclear why the authors devote discussion to barometric pressure as an important variable that has "received little attention" in recent years.

They authors' understanding of the physics and chemistry of TDG with respect to temperature is flawed. The authors' hypothesize that the reason why survival increases with increasing temperature "…is related to the inverse relationship between water temperature and dissolved gas concentrations. Weitcamp and Katz (1980) report that as water temperatures rise its capacity to hold dissolved gas in solution decreases, thus reducing the risk of gas bubble trauma for fish." What Weitkamp and Katz (1980) actually stated in their review was "As the temperature of a volume of water increases the volume of dissolved gas it will hold at equilibrium decreases. Thus, increasing water temperatures will produce supersaturation in water that is initially saturated." That is to say - if pressure remains constant and water temperature increases – the solubility of the gas in water decreases, but the overall TDG as a percent supersaturation actually increases as it moves from the saturated to supersaturated state. Consequently, the authors' conclusion that the increasing temperature decreases TDG is incorrect.

It appears as if the authors are attempting to isolate total dissolved gas as an issue for fish survival, without any real data to back up their contention. There was no attempt to consider the survival of these fish through the adult life stage to even validate whether their hypotheses were consistent with smolt-to-adult return rates. The authors' lack of understanding of the management of the Columbia River hydrosystem is apparent. The 110% State of Oregon's water quality standard is not the appropriate reference of TDG when assessing involuntary spill. There is a waiver from the State of Oregon during this time period to manage to a tailrace TDG of 120%. Additionally, uncontrolled spill by definition cannot be addressed through management actions in years of high flow as stated by the authors, since by definition it is spill that occurs beyond management actions.

The use of average spill volume to characterize spill is also problematic. Recent analyses, including acoustic telemetry studies, have shown that spill passage efficiency is not one to one. The authors make no attempt to account for spill efficiency or the presence of surface passage structures and instead create a grand mean volume of spill. Not only is the variable not meaningful in terms of characterizing fish passage via spill, but it is likely more highly correlated to flows because the analysis focused on a year when there were large periods of uncontrolled spill which is a function of how much flow surpasses powerhouse capacity.

The authors used PCA analysis to explore collinearity in the explanatory variables. PCA indicated that release date, outflow, spillway discharge, water temperature and dissolved gas were positively correlated. The authors do not explain how they account for this in subsequent analysis or in interpreting results. They did state that some of the variables were orthogonal. The authors state that "Fish length, barometric pressure, and fish velocity were orthogonal in the PCA (i.e., uncorrelated) and were therefore interpreted with more confidence in subsequent analyses." It is unclear where in the analysis these correlations or lack of correlations affected interpretation of subsequent analyses. The resulting plots only show the poorly defined relationships between survival and the explanatory variables. The authors should have more carefully considered which variables were important in their analysis and should have more clearly stated the effects of using multiple collinear variables.

The machine learning, "Random Forest" methodologic approach utilized does not support statistical inference as attempted by the authors. The authors do not understand the significant limitations of the Random Forest method.

Elder et al. (2016) assessed the relationship between eight environmental and biological variables (water temperature, outflow discharge, spillway discharge, total dissolved gas, atmosphere barometric pressure, fish migration rate, fish length, and release date) and survival of Chinook and steelhead using a random forests classification technique. The random forests method, as suggested by the name, combines many classification trees to achieve a more accurate classification than a single tree. During a standard classification process, a classification tree splits the data into homogeneous groups based on the variables in the model through an algorithm called the recursive binary partitioning. The algorithm finds the optimal cut-off value (for continuous variables) or code (for categorical variable) that yields the most homogeneous groups at each splitting of a classification tree. The splitting of a classification tree stops when each subgroup becomes completely homogeneous, or at the specifications set by the modeler. During a random forests process, the modeling goes beyond one standard classification tree and fits multiple trees to a data set using a resampling method. The modeler specifies the amount of classification tree in the forest, and each tree is fit to a randomly selected portion of the data using a small number of predictor variables at each splitting. Each end-product tree in the forest is cross-validated using the reminder of the data in order to estimate its accuracy/error rates. Finally, an importance measure for each variable in the model is calculated based on the misclassification rates of the model. Cutler et al. (2007) provided a thorough overview of the random forests classification technique. The Cutler et al. (2007) was heavily cited by Elder et al. (2016) for their use of random forests technique.

Elder et al. (2016) stated that barometric pressure, dissolved gas concentrations, outflow discharge, spillway discharge, water temperature, and fish velocity were identified by random forests analysis as the more important predictor variables for Chinook and steelhead survival, depended on number of dams passed by the fish. Using partial dependence plots, the authors identified at what levels the variables may start to negatively impact fish survival. However, their interpretations of the relationship between environmental variables and fish survival were overly generalized. Because a partial dependence plot isolated the partial effect of a single predictor variable on fish survival while averaging out the effects of other variables, interpretations of fish survival based on this assessment focused on individual variables. While isolating a single variable could help with visualizing the relationship between a single variable and fish survival, it was misleading to interpret the relationship using that variable alone without explaining the interactions with other variables. For the same reason, the values provided by Elder et al. (2016) in their model interpretations could not be trusted because these numbers were provided without considering the complexity of the system as a whole.

Unfortunately, if Elder et al. (2016) had attempted to explain the interactions between the environmental variables, random forests would not have a simple representation to explain interacting relationships between variables and to interpret variable values. During a random forests process, the algorithm randomly selected a portion of the sample and which variables to use during the classification process of each tree. Because each tree could be split differently than others in a random forests, there was really no feasible way to plot a random forests. Therefore, it was extremely difficult, if not impossible, for a modeler using random forests to characterize the hierarchical relationship and interactions between variables. To summarize our view regarding utilization of random forests, we quote Cutler et al. (2007) from their overview of random forests classification technique,

> *"Random forests is not a tool for traditional statistical inference. It is not suitable for ANOVA or hypothesis testing. It does not compute p values, or regression coefficients, or confidence intervals. The variables importance measure in random forests may be used to subjectively identify ecologically important variables for interpretation, but it does not automatically choose subsets of variables in the way that variable subset selection methods do. Rather, random forests characterizes and exploits structure in high dimensional data for the purposes of classification and prediction." (p.2792)*

Because of this lack of simple representation in random forests, we believe that Elder et al. (2016) overly generalized the relationship between the environmental variables and fish survival, and they did not give a fair interpretation of their model. Most importantly, without considering the complex interactions between variables, interpreting relationships based solely on values provided in partial dependence plots was misleading and a poor practice of statistical inference.

Any statistical analyses application is dependent upon a detailed understanding of the underlying data set, the biological and ecological processes in question, and whether or not the data set and analytical method utilized accurately represents these processes in the natural world

The authors attempt statistical inference regarding juvenile fish survival and dam passage and total dissolved gas without a clear understanding of either the test group characteristics or the environmental variables analyzed. The authors attempt to draw conclusions on the basis of passage characteristics of a non-representative test group of juvenile fish under non-representative environmental conditions. By drawing conclusions on the basis of data from only one year, 2011, the authors have failed to recognize the seasonality and year to year variation in both fish passage characteristics and environmental variables, which result in year effects on survival. For example, the single year analyzed by the authors (2011) had the 4th highest January-July runoff volume at The Dalles Dam in the 83 year record (1929-2011) (FPC, 2012). This resulted in unusually high flow and spill in excess of hydraulic capacity at hydroelectric projects upstream and downstream of John Day Dam for portions of the juvenile outmigration which exceeded established spill levels for fish passage mitigation. There is no comparison of the impacts of the environmental variables on fish survival in a more average or low flow year.

As a result of not understanding the detailed characteristics of the data set they used, the authors failed to recognize that the characteristics of the data set they used could not be applied in their analyses of relationships of dam passages, spill, dissolved gas, and survival. All fish that were used in the subject study were collected at JDA, tagged, and released throughout the FCRPS between BON and above JDA. Prior to being collected at JDA, potential study fish were exposed to various levels of TDG upstream of JDA, which at times exceeded 130%. According to Weiland et al. (2013), study fish were held for 18 to 30 hours in holding tanks prior to being transported for release into the river. Research shows that water depth affects the incidence of gas bubble trauma in fish. Holding fish in shallow tanks, particularly after they have been exposed to high levels of TDG, could precipitate gas bubble trauma. Although this would be apparent in research fish that died in the holding tanks, sub-lethal effects may not be as obvious. These sub-lethal effects could, however, affect study results and would not necessarily represent the run-at-large. Furthermore, given the variable levels of exposure prior to entering the study and prolonged holding periods in shallow tanks, average forebay TDG at the time of each project passage (JDA, TDA, and/or BON) does not accurately reflect the total dissolved gas exposure level of the test fish. This lack of recognition of the serious limitations of the acoustic tag data set has a profound effect on the scope of inference of these data to the attempted analyses.

The serious limitations of the acoustic tag data set, the failure to recognize actual passage histories of test fish, and the failure to recognize the extreme environmental variables (flow, spill, dissolved gas) that occurred in the single year of study are magnified by authors’ use of the machine learning, Random Forest methodology. The “Random Forest” approach utilized by the authors is particularly vulnerable to flawed and non- representative data sets, since this approach builds “learning trees” on the basis of a portion of the initial subject data set and then resamples from the same data set then averages over all of the resampled data sets. The significant limitations of the acoustic tag data set utilized and the author’s lack of understanding of fish passage and environmental variables effecting passage and survival are magnified and expanded through the entire Random Forest, dooming resulting conclusions to a total lack of credibility.

The source journal should be considered when journal articles are contemplated for citation and utilization. Not all journals can be considered to be equal in terms of the range of quality they present in publications.

The premise of the on line journal that published this article is to publish articles that might otherwise have been rejected. The journal states: “The philosophy of our journal is to be author friendly and to look for reasons to publish rather than reject.” It is certainly recognized that because of the volume of articles written, and the limitations in being able to publish all articles received, that some worthwhile scientific findings may go unpublished. From that perspective, this on-line journal fills a niche.

However, there are papers that are not worthy of publication and consequently “looking for reasons to publish rather than reject” is not appropriate. That is the case with this article. This paper should have never been published. A rigorous peer review would have identified a myriad of incorrect statements, misrepresentations, and a lack of understanding of the basic underlying biological principles. This paper would have been rejected based on a lack of sound scientific data and analyses.

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