Independent Scientific Review Panel
for the Northwest Power & Conservation Council
851 SW 6th Avenue, Suite 1100
Portland, Oregon 97204
www.nwcouncil.org/fw/isrp

Memorandum (ISRP 2009-43) **October 16, 2009**

To: W. Bill Booth, Chair, Northwest Power and Conservation Council

From: Eric Loudenslager, ISRP Chair

Subject: Review of AFEP project - Statistical Design for the Lower Columbia River Acoustic-Tag Investigations of Dam Passage Survival and Associated Metrics

Background

At the U.S. Army Corps of Engineers and Council's request, the Independent Scientific Review Panel (ISRP) reviewed the document "*Statistical Design for the Lower Columbia River Acoustic-Tag Investigations of Dam Passage Survival and Associated Metrics.*" This project is proposed for implementation through the Corps' Columbia River Fisheries Mitigation (CRFM) Program, specifically the Anadromous Fish Evaluation Program (AFEP). ISRP review of projects under this program was directed in 1998 by U.S. Congress Senate-House conference report for the fiscal year 1999 Energy and Water Development Appropriations bill. The ISRP's review responsibilities are also incorporated in the Council's 2009 Fish and Wildlife Program.

The Corps and staff from the Northwest Power and Conservation Council identified this proposal for ISRP review because the proposed survival model and experimental design will be used to measure dam passage survival in accordance with the 2008 NOAA Fisheries Biological Opinion Juvenile Salmon Dam Passage Performance Standards and to assure compliance with the Columbia Basin Fish Accords. The project's purpose is to develop a survival model and experimental design for estimating survival through the Lower Columbia River dams toward meeting the 2008 Biological Opinion performance standards. Further, this project represents the Corps' efforts to develop a standardized plan of study, intended to apply sound scientific principles to implementation of AFEP-funded survival studies. Moreover, although developed for simultaneous implementation at the three lower river projects, the basis for the design is not constrained to those projects.

The ISRP reviewed the proposal using our standard criteria that the project is: based on sound science principles; benefits fish and wildlife; has clearly defined objectives and outcomes; and has provisions for monitoring and evaluation of results. Our review follows below.

ISRP Recommendation

Meets Scientific Review Criteria

This project meets criteria of sound science, benefits to fish and wildlife, clearly defined objectives and outcomes, and contains provisions for monitoring and evaluation of results.

ISRP Overall Comments

The proposal is a thoughtfully prepared plan to evaluate how well the structural and operations improvements mandated for the Lower Columbia River (John Day, The Dalles, and Bonneville) projects are meeting the 2008 FCRP BiOp and Columbia River Fish Accords survival targets for yearling and subyearling Chinook and Steelhead. The supporting material, providing details of the statistical design and analysis, is comprehensive and useful. The survival model is grounded in standard statistical methods and uses advances that have recently appeared in the literature. The authors have sought outside advice, have done preliminary experiments, have learned from those experiments, and have adjusted the protocols to reflect that experience.

The experimental design for this project is well reasoned, justified, and described. Procedures are given to assure quality control, to trouble-shoot problems that may occur with data collection, and to verify key assumptions. Experience to date with the juvenile salmon acoustic tagging system (JSATS) has been encouraging; nevertheless, the scale and complexity of the proposed project makes it probable that modification of the experimental design will be necessary during data collection.

The investigative team is relying on detection capabilities of fish implanted with JSATS rising to 90% or greater below Bonneville in this current year, and the sample sizes have been *tentatively* set on the basis of this assumption. There is also uncertainty concerning which of the detector arrays downstream of Bonneville will provide the best detection rates, and some trial and error evaluation will be necessary in an effort to "calibrate" the design. Detection rates reported in the statistical design, while much improved over those of previous years, are still in need of further improvements. The extra acoustic arrays that are planned should certainly improve the situation, but contingency planning for the case where detection rates remain 50%, or rise only to 60%, 70%, 80%, but not to 90%, would be wise. In the presence of reduced detection probability, the uncertainty of survival probability estimation increases, as do the sample sizes needed to counter the loss of statistical resolution.

The assumption runs throughout the proposal that "tagging effects" will be relatively small. There is literature showing that any handling of smolts, and implantation of acoustic tags in particular, can result in increased mortality. The project will assess departures from the assumption of "no tag effects," but assumes they will be small. Over the time frame necessary to migrate from the tailrace of McNary Dam to the Columbia River estuary, the cumulative effects of the acoustic tags may be larger than anticipated, perhaps large enough to obviate the advantages of the three-project design. As acoustic tags become smaller, carrying them should become less of a burden, but handling and implantation will remain issues. This may require

modification of the experimental design after the initial results are evaluated. The plans for regularly evaluating model assumptions as the study progresses are essential.

The ISRP notes that there is legitimate debate about how to determine sample size. The important point is that it would be good to set the sample sizes large enough to be sure to detect differences from the BiOp survival rates with high probability. One should set the sample sizes large enough to ensure that large shortfalls are almost certainly detected and that smaller ones are detected with respectable probability. The ISRP believes an essential objective of this evaluation effort should be to estimate the *true* survival rates, whatever they are, rather than simply rejecting the null hypothesis of "no significant departure" from the BiOp standards.

In addition to addressing the BiOp standards, the proposal addresses other critically important issues. In particular, data about the specific routes juvenile salmon and steelhead take on their downstream migration will be collected, and the relative success rates from these different routes will be assessed. Such information makes it possible to parameterize the models required for making management decisions. Knowing how many fish take each route makes it possible to understand whether structural changes, such as modifications in the spillways and bypass systems, are improving fish survival, providing direction for changes that should be pursued or abandoned.

It is important that these data be preserved and made available at an accessible online site. In the long term, improvements in analysis of the data will come with improvements in physical filtering to separate noise from signal and in digital filtering to improve the sample size and to separate live fish from background noise. This will lead to a better understanding of fish behavior. In particular the 3-D data need to be protected to allow extracting information about routes fish take through projects. The COMPASS model was developed with the ability to take advantage of such data, and it is important that this ability be fully utilized in management experiments.

ISRP Specific Comments

The objectives of the project are to provide information required by the 2008 Biological Opinion and by the 2008 Columbia River Fish Accords. The goals are many and intricate, involving assessment of survival, travel times, and routes-of-passage through the system. The overall goals are to evaluate the performance of actions designed to benefit juvenile salmonid passage at John Day, The Dalles, and Bonneville dams. Dam passage survival and associated metrics for yearling and subyearling Chinook salmon and steelhead will be estimated and compared to performance standards for the three dams. Although the furthest upriver release point is 42 km upstream from John Day Dam, attention focuses primarily on the Boat Restricted Zone of each of three projects, John Day, The Dalles, and Bonneville. The essence of the study is to use acoustic transmitters implanted in the smolts, tracked in great detail by large arrays of receivers deployed in strategic places, and allowing very close tracking of the fish. This information can be used to identify problem areas or conditions that might be improved to help meet BiOp performance standards. The objectives are clearly stated, seem quite worthy of the investment, and are explicitly addressed in the proposal.

There are five performance measures stipulated in the BiOp that constitute project objectives:

1. Dam passage survival. Performance should be >96% survival for spring stocks (i.e., yearling Chinook salmon and steelhead) and >93% survival for summer stocks (i.e., subyearling Chinook salmon). Survival should be estimated with a standard error (SE) <1.5%.
2. Spill passage efficiency
3. Forebay residence time
4. Tailrace egress time
5. Forebay-to-tailrace survival

In addition to objectives from BiOp/Accords, project-specific objectives were identified for John Day (JDA), The Dalles (TDA), and/or Bonneville (BON) dams.

1. Estimate survival for the following zones of inference: JDA TDA BON
    a. Passage route survival (every major route)
    b. Forebay survival (forebay entrance to passage)
2. Estimate standard passage efficiency metrics:
    a. Spillway passage efficiency JDA TDA BON
    b. Sluiceway passage efficiency TDA BON (B1 and B2 Corner Collector)
    c. Spillway passage efficiency (with Temporary Spillway Weirs, TSW) JDA
    d. TSW discovery, entrance, and passage efficiency and effectiveness (if tested) JDA
3. Estimate passage distributions: JDA TDA BON
    a. Horizontal
    b. Diel
4. Estimate residence times: JDA TDA BON
    a. Forebay retention (100 meters upstream of the dam to time of passage)
    b. Tailrace egress (passage to tailrace exit line)
    c. Project passage (forebay entrance line to tailrace exit)
5. Characterize forebay approach paths and relate to passage distribution: JDA
    a. Compare forebay approach paths of turbine vs. bypass vs. spill vs. TSW passed fish.
6. Subsample smolts to assess population-level fitness: JDA
    a. Characterize fitness of in-river fish relative to fish selected for dam survival studies
    b. Compare differences in fitness of in-river fish to those selected for survival studies
7. Estimate approach distribution relative to configuration of the Second Powerhouse BGS pending 2009 results. BON
    a. Estimate the proportion of fish passing the Behavior Guidance System (BGS) through the gap between the BGS and north shoreline and through the gap between the BGS and the south shoreline.
    b. Estimate passage distribution for fish passing through the north or south gaps.
8. Evaluate and compare dam passage survival for subyearling Chinook salmon under two spill operations (85day/TDG (Total Dissolved Gas) night vs. 24 hr 100 kcfs spill). BON
9. Estimate passage survival for subyearling Chinook salmon at the Powerhouse 1. BON
10. Assess the fitness of in-river and tagged salmon using the sort-by-code system in the lower Columbia River. BON

Methods

The proposal and supporting documents clearly describe the elements of this complex acoustic telemetry study at the three lower river dams as an integrated unit. Integrating activities across dams should provide economies of scale and enhanced information that would not be available if planning and implementation were conducted independently for separate projects. The potential for confounding results posed by the increased complexity of the integrated study are a concern, but the proponents seem to be aware of this potential and have identified strategies for adaptation. An advantage of the methods proposed is that project-specific objectives will most often be met by using the tagged fish detections from the BiOp/Accords work.

The choice of the Juvenile Salmon Acoustic Telemetry System (JSATS) micro-acoustic transmitters is justified by noting the relatively small size of tags and the high detection probabilities of arrays of underwater listening devices. The study design involves estimating the survival of virtual releases of fish known to have passed through a dam and tailwater reach, relative to a paired-release-survival estimate for fish released at two locations in the downstream tailwater. The statistical justification for the estimation methodology is presented in substantial detail in Skalski's August 7, 2009 document, "Statistical Design for the Lower Columbia River Acoustic-Tag Investigations of Dam Passage Survival and Associated Metrics."

Release-recapture survival models require that certain conditions (assumptions) must be satisfied. Of the eight required assumptions identified by this proposal, it is likely that the most problematic will prove to be Assumption 8: that "...releases experience the same survival probabilities in the lower river segments they share in common." The proposal acknowledges that estimates of dam-passage survival will be negatively biased if post-tagging mortality of virtual-release fish continues (or if the mortality rate increases) as the fish move downstream. Fortunately, because survival can be estimated for fish released at different upstream sites as they pass through specific reaches, data analysis should allow the size of this effect to be estimated. Also, if tagging-related mortality does continue for some time after release (Rub et al. 2009), the experimental design allows for the possibility of reducing this source of bias by using only virtual-release fish released above each of the lower two dams, rather than aggregated groups from all upstream releases.

In addition to possible delayed effects of tagging on survival, Assumption 8 (and Assumption 7) may not be fully satisfied for other reasons related to the differing periods that the various release groups have been in the river, the distances they have traveled, and the reaches (and dams) they have experienced prior to reaching downstream sampling points. Smolts experience strong predation pressure in the power system reservoirs, and several studies have reported evidence for size-selective mortality during reservoir passage (e.g., Zabel et al. 2005). Although the project statistical design document states that size-dependent mortality of tagged yearling Chinook salmon migrating 300 km through the lower Columbia River reservoirs was "not obvious" in a 2008 study (Appendix C, p.9; reply to USGS comments), such an effect may nonetheless occur. Condition-dependent mortality may also occur but would be difficult to identify. Both size-dependent and condition-dependent mortality would presumably have greater effects on fish

migrating longer distances through the hydropower system, and in particular, on virtual release fish.

Although these concerns are not fully addressed by the statistical design document, the document does explicitly acknowledge that it is unrealistic to expect that all bias can be eliminated from the study results. Procedures are described to identify major sources of bias during the first year of the study, so that they can be reduced, eliminated, or corrected in later years. Analysis of preliminary data, as they become available ("preliminary pseudo-real-time analyses"; p. 42 in September 2009 full proposal) should help with early identification and resolution of problems with the experimental design, data collection, or analyses.

Releases of fish at stations R2 to R7 (paired-release groups) will be timed to allow for mixing with the appropriate groups of comparison fish as they migrate downstream. The release schedules are (presumably; this is not explained in the proposal) based on "average" historical travel times between sites. Completion of the planned 16 (for spring migrants) and 14 (for summer migrants) release cycles may not be possible if fish travel times are longer or shorter than the average, i.e. in the event of a low-flow or high-flow spring season. Contingency planning for the project should take alternative flow scenarios into consideration.

The sampling schedule calls for collection of fish over a 4-d period for each release cycle. In some instances, the composition of the run will change over a 4-d period, as different stocks of fish move downriver. The greatest concern is that the proportion of wild to hatchery fish will change substantially during a release cycle, because wild and hatchery fish differ physically, physiologically, and behaviorally. One approach to minimizing the effects of changing proportions of wild and hatchery fish would be to hold the ratio of adipose-fin clipped to unclipped fish constant during each tagging cycle: all of the clipped fish would be of hatchery origin, and the majority of the unclipped fish of natural origin.

Reviewer comments and sponsor responses highlighted areas of concern including the adequacy of estimated sample sizes. Discrepancies in estimates of required sample size appear to arise from different interpretations of BiOp requirements. One interpretation is that the BiOp specifies that a 95% confidence interval for estimating dam passage survival should be based on a standard error of less than 0.015. The sponsors estimate the required sample size based on the confidence interval interpretation, then adjust the estimate upward by 25% to allow for unknown uncertainties. The proposal does not provide theoretical or empirical justification for the 25% adjustment.

Another interpretation is that the sample size should be determined in order to consider the power to detect meaningful differences from BiOp specifications. The power of the test depends on just how far the true survival probability departs from the null (BiOp) value. Just to illustrate, consider a BiOp-mandated target survival rate of 0.96, the spring target, but assume that the true (field) survival rate is somewhere between 0.90 and 0.96. Whatever the sample size, even if it is sufficient to ensure that the standard error of the estimated survival probability is less than or equal to 0.015, we also need to ensure that for true survival rates between 0.90 and 0.96, we have adequate statistical power to be reasonably sure to detect the difference. The BiOp does not identify the desired level of power, so it would be quite useful to obtain a sense of how power

behaves with increasing sample sizes. It may be that larger sample sizes are needed than originally suggested in the proposal to accomplish a high level of statistical power, though the numbers would seem to be within reach for reasonable power. The ISRP requests that the design team evaluate how power changes with increasing divergence between actual, but unknown, survival probability and the BiOp-mandated target. Included in this evaluation should be consideration of detection rates. The latter point is particularly cogent below Bonneville, because to date, the design is predicated on the anticipation that detection rate will improve to 90% in that zone. These evaluations represent a simulation exercise that is well within the capabilities of this design team. Whether the requisite sample sizes will be within the 25% hedge is unclear, but they should not be excessive in any event.

The proposal specifies that all yearling and subyearling Chinook salmon and steelhead smolts released in this study will be obtained from the John Day Smolt Monitoring Facility. Although there are plans to compare fitness for subsamples of run-of-river fish and fish selected for tagging, it is not clear that dam passage survival and other performance measures will be representative of any fish other than those obtained from the John Day Smolt Monitoring Facility. Even though a mixture of many stocks will be used throughout the migration season a concern is that the diversion and collection of fish at this particular facility may not be representative of run-of-river fish.

Relevance to the BiOp

The experimental design directly addresses key monitoring and evaluation requirements set forth by the BiOp. In addition, the study design will provide information on survival of fish passing the dams by different routes (spillway, powerhouse and bypass) under various flow and operating conditions. Although this information is not required by the BiOp, it will nonetheless be useful for identifying problem areas or conditions that might be improved to help meet BiOp performance standards.

The only way to determine whether the BiOp objectives are being met is to monitor. It remains necessary to continue monitoring hydrosystem survival under a wide variety of configuration changes, as these are attempted. That will also mean that it is necessary to look at the fine details of passage routes and myriad small adjustments, project by project. The proposed design is configured to provide measures of collective project passage success, while explicitly allowing focused studies at each project.

References cited

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