Report of the Independent Scientific Advisory Board Regarding a Research Proposal for Inclusion in the 1997 Smolt Monitoring Program

Proposal Reviewed: Comparative Survival Rate Study of Hatchery PIT Tagged Chinook

January 13, 1997

ISAB-97-2
Independent Scientific Advisory Board
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Introduction

Estimates of the effects of the hydroelectric system on the health of salmon populations are essential to guide development and implementation of salmon mitigation policy for the Fish and Wildlife Program (FWP) of the Northwest Power Planning Council, and the Endangered Species Act Biological Opinion on Operation of the Federal Columbia River Power System of the National Marine Fisheries Service (BiOp). Together the FWP and the BiOp represent the collective understanding of the region and the nation on how to protect the salmon resources from some of the most onerous of the effects of human development of the Columbia River basin. Measuring the adequacy of the suite of salmon protection measures which has been implemented according to the specifications of the FWP and the BiOp is of vital interest to the region, the United States, and Canada. Success in the implementation of salmon conservation actions is vital because each action can influence the future of the economic cornerstones of agriculture, transportation, and electric power on which we all depend.

Solving the complex puzzle which describes the fate of a small salmon as it finds its way to the sea through the 344 miles of reservoirs and eight dams of the lower Snake and Columbia Rivers has consumed large quantities of scientific talent and financial resources for six decades, yet the puzzle has been slow to yield its secrets. It is only during the past decade that advances in the technology of marking fish have made it feasible to simultaneously monitor the fates of a large number of individual fish over very short periods of time within the hydroelectric system. Yet while it has been technically feasible to gather highly detailed information to guide the implementation of the FWP and the BiOp for nearly a decade, such information is now available for only a limited number of localities and time periods for only a few types of salmon. The programs necessary to adapt and implement state-of-the-art fish marking and monitoring technologies within the Columbia River basin have apparently lagged substantially behind the advent of the technologies. The subject research proposal seeks to advance the application of a state-of-the-art fish marking technology, the passive integrated transponder tag (PIT tag), within the Columbia River basin.

The proposal lists four objectives

(1) Estimate smolt-to-adult survival rate (SAR) for transported wild and hatchery stream-type chinook.

(2) Determine if SAR rates of wild chinook are significantly different from the interim SAR hydroelectric goal.

(3) Compare SARs of transported and down river indicator stocks of chinook.

(4) Estimate Transport/Inriver ratio and inriver survival concurrently over a number of years in order to span a range of environmental conditions.

For implementation on salmon which emigrate in late winter and spring of the current year, 1997, the proposal requires applying the PIT tags to a relatively large number of juvenile salmon which will shortly be moved to holding facilities where, it is our understanding, such marking would not be feasible. Therefore, time is of the essence in the implementation of the tagging phase of the proposed study. If the FWP and the BiOp are to have the information on the juvenile salmon emigration of 1997, funding is required as soon as possible.

As part of its review of the request for funding of the proposed study, the Northwest Power Planning Council (NPPC) requested the ISAB to conduct a review of the scientific basis of the proposal. The results of ISAB response to the NPPC request follow under the headings of Summary of Findings and Recommendations, General Questions and Concerns, and Statistical Methodology Questions.

Summary of Findings and Recommendations

We found it necessary for the purposes of our review to separate the immediately pressing issue of applying the PIT tags to the juvenile salmon from the balance of the issues surrounding review and approval of the proposal for longer-term study. It is possible to do so, since the issues surrounding how to analyze and interpret the information generated from the proposed tagging and release can be dealt with on a longer time frame than the issue of whether or not to proceed with the tagging for 1997. The ISAB concludes that new information of relevance to the evaluation of the mainstem passage hypotheses of the Fish and Wildlife Program and the NMFS biological opinion will be generated by the proposed marking, and we recommend that it proceed. With regard to the balance of the proposal , we commend the authors for developing a proposed strategy and design for PIT tagging juvenile salmon. The proposal addresses the need for new information which is not now being gathered for the FWP. However, we also find that the balance of the proposal does not presently provide an approach to fully utilizing the advantages of the PIT tag technology. The proposal would need substantial revision to achieve a degree of scientific rigor sufficient for the ISAB to endorse it as a basis for longer-term study of these relationships. However, we believe that it would be in the interest of the FWP and the BiOp to vigorously seek further development of the proposal.

We therefore recommend funding of tagging in 1997 be approved but that funding of the balance of the proposal be deferred until a revision which includes a comprehensive, multidisciplinary operational plan on juvenile survival estimation can be prepared. We believe such an analytic strategy can be put into action in time to guide tagging by the 1998 release season. We also recommend that a technical team, including at least one professional statistician, should be impaneled to assist in the preparation of the operational plan and experimental design for analysis and for planning for future tagging.

It is clear that estimates of the survival of juvenile salmon in the hydroelectric system need to be made and studied in relation to physical factors such as flow and spill which are critically important to the survival of all salmon species. Estimates of survival of salmon in the hydroelectric system also need to be compared to estimates of salmon survival at other life history stages in the estuary and marine environments. What is not clear from the proposal, however, are approaches which can focus and integrate the analysis and synthesis of the many programs which use fish tagging information on solutions to questions posed by the NMFS biological opinion and the Fish and Wildlife Program. Each year there are fewer and fewer juvenile salmon to tag, yet more and more demands are put on tagging information by the legal requirements of the Endangered Species Act and the questions surrounding implementation of the Fish and Wildlife Program. The proposal needs to be part of a comprehensive multidisciplinary study which describes how tagged fish from all relevant research programs are to be used to answer the full range of critical questions for ESA and NPPC policy makers.

In addition to the objectives of the proposed study, there are many other uses to which the data generated by the PIT tagged hatchery juvenile salmon could be put. For example, high levels of snow pack have created the expectation that 1997 could be the highest water year of the past 35 years in the Snake River basin. The potential for uncontrolled spill and the gas supersaturation attendant to very high river flows create circumstances appropriate to the study of the effects of gas bubble disease on juveniles by means of a cumulative dose model. Given the questions which are being posed by the Oregon Department of Environmental Quality with respect to the scientific basis of its support for increased allowable levels of total dissolved gas under the voluntary spill program of the BiOp, it is appropriate to go ahead and tag the fish as proposed for 1997, but better integration of programs is necessary in the future.

The expense of the proposed tagging appears minor relative to the cost of the mitigation programs which the tagging allows us to understand. We did not find that the proposal involves PIT tagging "huge" numbers of juvenile salmon. On the contrary, based on concerns expressed in our commentary on determining the number of fish to tag, it may be especially prudent in 1997 to PIT tag more juvenile salmon under expectations of poor survival, and the fact that NMFS does not plan to apply PIT tags within the hydrosystem. Although PIT tagging at the hatcheries may cost more than PIT tagging run of the river juveniles in Lower Granite Pool for the purposes of studying reach survivals, there are several important types of information which cannot be obtained any other way. Tagging at the hatcheries can provide information on the geographic and stock specific variation of reach survivals which tagging run of the river juveniles cannot do. Further, only by tagging at the hatcheries (or in tributaries) can two long standing questions about the efficacy of the juvenile fish barging program be settled; 1) the ability of transportation to return adults to the spawning location, and 2) the degree of stock specific differences in transportation benefits. Finally, tagging at the hatcheries in 1997 provides a means to gain information on reach survivals and effectiveness of transportation programs without handling any wild juvenile emigrants in a year of extremely low wild stock abundance. The question of the best distribution of the tags among geographic localities is open, but the proposed geographic distribution of tagging may be as good as present information permits. However, in the apparent absence of information on between stock (hatchery) survivals, perhaps a shotgun approach which distributed tags across all hatchery populations in proportion to the number of smolts produced would yield the information necessary to address the question of optimum geographic distribution of tags and to assess survival and return rates among hatcheries.

We recommend considering the suggestion that some combination of PIT tags and CWTs might serve the purposes of objectives 1 and 3 at a lower cost of tagging. However, we offer the following caveats. Although reach survivals may be estimated by relatively small numbers of PIT tags, the ability to compute SARs from PIT tagged members, which requires many more tags, would be an important advance in knowledge. Advancing understanding of hydroelectric mitigation requires separating the different sources of mortality in each life history stage by locations, both inside and outside the hydroelectric system. Tagging with CWTs cannot provide information on the fate of the individual fish, and CWTs cannot provide the same spatial and temporal resolution of effects which PIT tags provide. Further, CWTs can only be read by sacrificing the animal, whereas PIT tags can be read without killing or handling the animal. Further the use of CWTs in conjunction with PIT tags requires the assumption that the CWT marked fish are analogous in their behavior to the PIT tagged fish. Some researchers believe that CWTs may affect homing ability, depending on how, and at what age they are applied. But homing of transported fish is a key uncertainty in transportation. Longer-term indices of trends in SARs may be less expensively monitored by maintaining CWT programs, but the question of whether CWT marked members are comparable to PIT tagged members is open. Although CWTs are useful for computing SARs and provide for sampling and recovery in ocean fisheries, information in addition to monolithic SARs is clearly needed. SARs which are composites of estimates of survival in the hydroelectric system and in the estuary-ocean need to be made using PIT tags.

Finally, we strongly recommend that a high priority of NPPC and NMFS efforts be directed to increasing the detection rates of PIT tags in juvenile salmon at sites below McNary Dam, and especially at, and below, Bonneville Dam. It is critically important to develop the capability to sample for PIT tagged juvenile salmon at sites not associated with hydroelectric dams, such as in the river below Bonneville Dam, and elsewhere in the freshwater environment.

Feasibility studies and pilot scale examinations should be solicited immediately if we are to maximize the value of any PIT tag program. To fully solve the problem of estimating the effects of the hydroelectric system on juvenile salmon, finding adequate means of detection of PIT tagged juveniles below Bonneville Dam is essential.

General Questions and Concerns

In this section we present and elaborate the questions which were raised by the review panel. Following this we offer some specific numbered questions which follow from the preceding text. We make it clear that we do not expect point by point answers to these questions in the revision. The concerns and questions are offered to help in the revision of the proposal.

Outstanding questions relate to the number of fish which need to be tagged, whether the effects of the hydroelectric system can be estimated from the use of down river stocks as controls for up river stocks, and whether policy makers have been consulted in determining the error tolerances on conclusions. The term, error tolerance, describes how averse policy makers are to embracing a false mitigation concept, or to rejecting a correct mitigation concept. The error tolerances of policy makers determine the bulk of the expense of the PIT tagging study by determining the number of tags sufficient to answer a given question. As the error tolerances of administrators change, so change the costs of implementing research.

Specific technical questions remaining are outlined below, however general questions relate to the operation of the hydroelectric system during the juvenile migration in terms of flow, spill and transportation, and the effect of these operations on the models employed to estimate survival and the effects of attendant factors. The routes of hydroelectric passage available to the juvenile salmon depend on hydroelectric system operation, and determining the influence of the routes of passage on the survivals of the juveniles is one of the objectives of the research proposal.

There is a good chance that the proposed study design will not improve our understanding of salmon mitigation measures. While the study proposes good objectives in very general terms, it is not clear that effective mitigation of salmon survival can be attained by the use of SARs alone. The concept of using long time series of SARs to evaluate smolt migration mitigation actions within the hydroelectric system, given little experimental control over how the hydroelectric system is managed, seems flawed. We question whether or not it is possible to use

SARs as proposed, based on either coded wire tags (CWTs) or PIT tags. Are there other objectives which could justify the tagging without reliance on the SARs, or without reliance on the success of the upriver to down river comparisons?. How can the region use the PIT tagging data to understand the effects of hydroelectric mitigation actions on juvenile salmon if the comparative SAR strategy fails? The SAR, although a valuable tool which is useful for many purposes, is a blunt instrument for examining hydroelectric mitigation when compared to reach survivals and recapture histories. Alternative objectives need to be defined and explored.

The use of the SARs of down river stocks to measure the effects of the estuary and the ocean, thereby isolating the effect of the hydroelectric system on the stocks from farther up the river, is a risky strategy. Tagging data from single species within a watershed show that salmon originating in a relatively small geographic area can go to very different areas in the ocean to rear. Is there any way the study design could help evaluate how good a control these are? The use of one salmon stock to serve as a control for another over the large span of time and geography involved in an SAR probably will not stand close scientific scrutiny. There are far too many assumptions and possible comparisons to systematically evaluate. There is concern that using SARs confounds the effects of the environment on several life history stages. In the present case there is a need to break down survival into a minimum of two estimates; hydroelectric and estuary-ocean. Further subdivision of mortality estimates in time and space is highly desirable, and this can only be done through the use of PIT tags. We expect the information provided by PIT tags to pay off handsomely once enough detector sites are operational below McNary Dam. Once the detection sites are completed, the upriver to down river comparison is not necessary. An additional problem with SARs is that their use in hydroelectric mitigation evaluation prolongs the time to get an answer, yielding only one data point every five years, or so. Nonetheless, it may be that there are some hypotheses which can only be evaluated through the use of SARs, but it is highly desirable that the SARs be the composite of estimates made at multiple life history stages whenever possible.

A further problem in the proposal occurs in the critical matter of determining how many fish to tag. The proposal used past survivals as an average, rather than relying on the interannual variability in survivals to design tagging scenarios which might cope with lower than average SAR. When SARs are much lower than average, will the corresponding levels of precision in the estimates permit any degree of understanding of the effects of hydroelectric mitigation? It is recognized that predicting the precision of estimates, and the power of tests to distinguish among estimates of alternatives, based on tagging levels is at best an educated guess, given normal biological variability. It would, however, strengthen the proposal to make full use of the information in the historical data in approaching the question of how many fish to tag.

It is essential to understand the relative efficacy of mitigation actions, such as transportation, in terms of the geographic origin and stock of each salmon life history type. Estimates of transport survivals for hatchery salmon are valid estimates for those stocks, but inferences about their appropriateness for wild salmon may not be. The effectiveness of transportation for hatchery and wild salmon remains to be investigated and tested. For example, estimates of two stocks' SARs may be correlated but differ in magnitude. As a general principle, estimates obtained by tagging provide answers for those stocks which are tagged, hatchery or wild. It remains to be seen if the efficacy of transportation varies among stocks, and if it does, is the average effect of transportation across all stocks a meaningful statistic for management purposes? If transportation works well for a few highly abundant stocks, hatchery or wild, but not for a large number of stocks of low abundance, average transport benefit ratios would be high, but protection of genetic diversity could not be served by transportation. Does the efficacy of transportation vary according to the geographic origin of salmon stocks, due to such differences as the state of maturity on arrival at collector dams? Concern over the protection of the genetic diversity of salmon populations makes the same questions about among stock variability important to address for all mitigation measures.

The great value of PIT tagging technology is the ability to directly measure the survival of individuals within specific scales of time and space; but the scientific value of this information decreases as the number of detections decreases, and as uncertainties regarding the causes of the mortality increase. In studies such as this, there are three major sources of uncertainty: 1) decreasing probability of recoveries of tags, particularly in the reaches of the lower Columbia River, 2) the natural variability inherent in the river flows and other critical variables of concern to the FWP and the BiOp, and 3) the confounding of the effects of mortality factors in the freshwater environment, including the hydroelectric system, with those in the estuary and marine environments. The latter cause of uncertainty is unavoidable unless defensible estimates of juvenile survival rates in freshwater can be made; marine survival could then be estimated independently. Smolt to adult survival is an important measure of the success of a salmon recovery program, however the features of the NPPC FWP and the BiOp focus on the means of improving freshwater survival. Adequate partitioning of survival into freshwater and marine components is therefore essential. Policy makers need adequate assurance that measures of the effects of mitigative measures will be of adequate precision and accuracy to be of use. PIT tags offer an important tool for critically examining survival of juvenile salmon in relation to flow and other operational characteristics of the hydroelectric system, but to progress in our understanding of such relationships, each of these sources of uncertainty must be addressed. For example, statistical designs and analyses should be developed to determine overall freshwater survival of wild salmonids including the direct measurement of juvenile freshwater survival of transported salmonids; and we suggest improving the probability of tag detection at down-stream facilities.

1) How many years are planned for the study and how will data be combined and modeled for analysis of factors influencing within and among year comparisons? Please explain the meaning of "long-term" in units of time.

2) What is the basis for the statistical power computations on which form the basis for determining the numbers of fish to mark? Although the computations presented appear to be based on the assumption of independence of individual fish within a category, the method of computation is not consistent with this assumption.

a) Are the fish within a batch independent? If not, what is the proper experimental unit? What is the sample size for the proper experimental unit. The study may provide valuable data and usable point estimates, but questions will arise concerning measures of precision.

b) The power computations and recommended numbers of fish to mark appear to be based on the assumption of independence of individual fish within a category. If independence is assumed, there are unanswered questions concerning use of normal distribution and differences of proportions for setting sample sizes. The relationship of values on page 10 to the theory on earlier pages is unclear. Ratios of ratios of random variables have complicated statistical properties. References should be given or computer simulations should be conducted to justify the numbers of smolts to be marked.

3) How may the PIT tagging experiment be designed and implemented on a sufficient scale to directly estimate the relevant mortalities associated with available management interventions such as transportation, spill enhancement, flow enhancement, and reservoir draw down?

4) Explain how the SARs of spring chinook salmon stocks originating in the lower Columbia River may be used to control for the effects of mortality which occurs upriver before juveniles of all stocks become fully mixed. On the basis of what data can the ocean distribution and timing of the control stocks be examined for similarity to that of the upriver stocks? If there are differences in the migratory behavior of the control stocks and the upriver stocks such that the controls and upriver stocks never become fully mixed, how can these differences be observed and evaluated? Why is the use of among stock comparisons for evaluation of hydroelectric system effects preferred to direct measurement of the mortalities of tagged members within the hydroelectric system?

5) To what extent have the decision makers made a commitment to support experimental outcomes at the specified error tolerances (false negative rates of 5% or 10% and false positive rates of 10% or 20%) with management actions? The expense of the project depends on how many tags need to be applied, which in turn depends on the error tolerance of managers. Have the managers already stated a readiness to change the way they do business (decisions about transport, spill, flow, and reservoir draw down) if the results of this experiment come out one way or the other, meeting these error tolerances? For a less expensive study could they tolerate higher errors? These two error tolerances (false negative and false positive), and two decision quantity scenarios (the threshold for deciding positive, and the true value reference point for evaluating false positives) largely drive the calculation of the required numbers of fish to tag. Therefore it is important that these specifications of error tolerances and decision scenarios really correspond to a decision criterion to which decision makers have agreed.

6) The present proposal is strongly focused on estimating smolt to adult survival, to the neglect, perhaps, of estimates of the downstream passage mortality of juveniles by itself. Both are needed if we are to maximize the information returned from PIT tagging programs to guide the NPPC and NMFS decisions. The smolt to adult survival is important to check for delayed effects of the different passage routes. But it must be borne in mind that the smolt to adult survival is heavily influenced by ocean survival, which varies considerably from year to year, and this fact will confound attempts at comparing transport and in-river mortalities over more than one year at a time. For the latter purpose, it would be preferable to base the analysis on survival data confined to the downstream migration period of the life cycle.

7) The potential for interaction between the proposed research study and the surface flow bypass (SFB) research at Lower Granite Dam (LGR) needs to be explicitly addressed. To what extent do the objectives of the surface flow bypass (SFB) research at (LGR) impact the number of fish to be tagged and the attainment of proposed objectives? Operation of LGR to optimize PIT tag detections for the proposed research study could be different from operations suitable to the SFB study. Operations suitable to SFB could reduce the rate and number of PIT detections at LGR, since the SFB is likely to divert juveniles that would otherwise go on to be detected in the juvenile sampling facility at LGR.

8) How will the survival of PIT tagged smolts which are transported be evaluated between the time of entry into the barge and release below Bonneville?

Statistical Methodology Questions

The proposal is unclear on many critical points with heavy use of jargon and undefined terms.

The objectives of the study are not clear and should be rewritten. For Example:

> Task 1b. The objective seems to be high power to reject the hypothesis H0: r <= 1 (vs. H1:r > 1) when r = 1.5. (See the proposed wording for 3c below)
>
> Task 2a: Survival can be partitioned. The objective is to estimate each component of the partitioned survival.
>
> Task 2d: As written, "increasing mark size" could mean increasing the physical size of the tag.
>
> Task 3a: What does "compute annual hatchery survival rates" mean? From hatchery to adult return? From hatchery to Lower Granite Dam? From hatchery to ocean? From hatching to release by the hatchery (within hatchery survival)?
>
> Task 3c: This task should probably read "Test that the ratio of upper river hatchery survival to lower river hatchery survival is greater than 1.0 in such a way that if the true ratio is 2.0, then we have a high probability of obtaining a significant test statistic ."
>
> Task 3d: Same comments as task 3c.

Estimates of parameters needed for power analysis (and for other purposes) should be cited with a source or reference. For example, a critical number for sample size is cited on page 10 as "the minimum (1989) smolt-to-adult return rate (SAR) was 0.2% and the average across 7 years of study was approximately 0.4%." Also it appears that the variation in estimation of the smolt to adult return rate (SAR) has not been taken into account in determining the number of smolt to be marked. Literature citations are missing.

The statistics behind the estimation procedures proposed in this study may not be the best available. Ratios of ratios of random variables are the basic statistics discussed (e.g., bottom of page 7, $R_1 = S_t / S_{i1}$). Questionable theory based on the normal distribution tends to be used, except for some incomplete references to bootstrapping. Not all data should be bootstrapped the same way. Bootstrap is not an accepted technique with one accepted methodology, as is ANOVA. It is more a category like "ordination", and, as is the case with ordination, how it is conducted can affect the results.

Given that normal distribution theory can be used, formulas for power calculations on page 8 appear to be incorrect as written. They should be similar in form to the following:

> Let z_α be that number such that Pr ($Z_{0,1} > z_\alpha$) = α , where $Z_{0,1}$ is a standard normal random variable. The power of the test if the true ratio is 1.5 and if the estimates follow a normal distribution is 1 - Pr $\{Z_{0,1} < [z_\alpha - 1.5]/se(R)\}$.

Some of the symbols are not defined, and the usage of others is inconsistent. For example see page 7 where "m" appears to be used for number of dams in one place and number of fish in another place.

Jolly-Seber methods are referenced, but it is not clear that multiple capture-recaptures are always involved. The proposal needs to be more specific. There are many different ways of performing a mark-recapture Jolly-Seber study.

The proposal points out the limitations imposed on science by lack of PIT tag detection at critical dams and locations for both smolts and adults. If detectors were in place, then in addition to the comparison of overall statistics, it would be possible to consider analytical approaches suggested by scientists at the University of Washington and National Marine Fisheries Service (Iwamoto, Muir et al. 1994; Smith, Skalski et al. 1994) for the hydroelectric system as a whole. For example, the following approach might be considered for the Group T and Group I2 fish.

> Assume the last dam the fish must pass on their way to the sea is dam 4. The only difference between Group T fish and Group I2 fish is that the Group T fish were transported below dam 4 on barge while the Group I2 fish had to swim through all the dams during their downstream migration. One group receives the transport treatment and the other group receives the inriver treatment. Assuming four dams, the five capture occasions after release are dams 4,3,2,1 and the hatchery as the fish migrate upriver as adults. Compare survival between Group T and Group I2 via the methods outlined inthe American fisheries Society monograph (Burnham, Anderson et al. 1987).

Literature Cited

Burnham, K. P., D. R. Anderson, et al. (1987). Design and Analysis Methods for Fish Survival Experiments Based on Release-Recapture. Bethesda, Maryland, American Fisheries Society.

Iwamoto, R. N., W. D. Muir, et al. (1994). Survival estimates for the passage of juvenile chinook salmon through Snake river dams and reservoirs. Seattle, Northwest Fisheries Science Center, National Marine Fisheries Service.

Smith, S. G., J. R. Skalski, et al. (1994). Statistical Survival Analysis of Fish and Wildlife Tagging Studies, SURPH.1. Seattle, Center for Quantitative Science, School of Fisheries, University of Washington.