Review of Studies of Fish Survival in Spill at The Dalles Dam

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Assignment

The Independent Scientific Advisory Board (ISAB) was asked in a memo dated November 10, 1999 from Brian J. Brown, Chair, Implementation Team (IT), addressed to Michael Schiewe and Chip McConnaha, to review the issue of appropriate spill levels at The Dalles Dam. The IT asked the ISAB two specific questions: **Question 1**. Based upon a comprehensive review and analyses of the study design, methodology, empirical data and results, are there real and significant differences between the survival of fish through 30% and 64% spill levels at The Dalles Dam? **Question 2.** Based on a comprehensive review and analyses of existing empirical data, what are the most appropriate future research steps, including a recommended study design and methodology, to determine an operational plan at The Dalles Dam that maximizes juvenile passage survival?

Summary of Response

The studies of 1997-1999 did not include all relevant factors influencing the mortality of juvenile salmon, but as designed the studies were conducted well and with as high a level of scientific quality and rigor as can be expected from field studies constrained by fish availability and dam operations. The weight of evidence suggests that it is likely that there are real and significant differences in survival of spilled smolts between spill levels of 30% and 64%, with 64% spill probably resulting in a lower per capita survival rate. Rather than conducting further studies of survival in spill at either high or low spill for an entire migration season, we recommend concentrating on several spill levels in the 30% to 50% range. In future experiments, test spill levels should be maintained for approximately a week. Required fish sample sizes likely limit experiments to two spill levels per year. The results at The Dalles cannot be generalized to other projects because of the unique characteristics of this project.

Review Process

The ISAB reviewed the materials supplied to us by the Systems Configuration Team (Bill Hevlin, NMFS, personal communication). A subcommittee of the ISAB attended the U.S. Army Corps of Engineers' 1999 Annual Research Review of the Anadromous Fish Evaluation Program held in Walla Walla, Washington, November, 1999. Earl Dawley, NMFS, Tim Counihan, USGS-BRD, Shane Bickford, Douglas County PUD, Gene Ploskey, USACE, and Bob Heinith, CRITFC presented their research results at our January 5 and 6, 2000 ISAB meeting in Portland. They were asked to review research results and to answer a list of questions supplied to them in advance of the meeting. The presenters provided relevant reports and hard copy material to the ISAB (all materials are identified in the reference list or Appendix 1).

Background

There has been controversy for over 20 years about spilling water at The Dalles Dam for the benefit of migrating juvenile salmon. At a general level, many people believe that more spill is better for fish passage and survival. Reducing spill has been thought to be detrimental to survival, because it forces more fish through the turbines, where mortality is believed to be high. The studies conducted so far at The Dalles have not convinced all parties that one spill level is better than another or that the best experimental protocol has been followed to determine an optimum spill level. Several alternative experimental designs have been proposed. The IT asked the ISAB to provide an independent assessment of the situation, with emphasis on interpretation of the study results to date and guidance on future research.

Despite some evidence that spill at high levels at The Dalles Dam might be detrimental to survival (hydraulic models showed tailrace conditions potentially detrimental to juvenile salmonids above about 40% spill (Dawley et al. 1998)), NMFS's 1995 Biological Opinion set the goal of high spill, purportedly to achieve an 80% fish passage efficiency (proportion not going through turbines; FPE). The specific reference to 64% spill comes from calculations in NMFS reports referenced in the Biological Opinion. Preference for high spill did not consider survival during spillway passage or in the tailrace where predation may be high. Presently, there is a working hypothesis that predator concentrations may be especially severe at certain tailrace locations, e.g., the sluiceway outfall near the powerhouse (a third route for passage). A working hypothesis also exists that predators concentrate around a set of islands on the south side of the tailrace and the river downstream, potentially leading to high mortality of juvenile salmonids entering that area of slowly moving water.

Most recent evaluations have neglected earlier studies at The Dalles Dam by Willis (1982), that showed that the 80% fish passage goal of NMFS and the Council could likely be achieved with about 40% spill. He released marked fish upstream from the dam and recovered them in the sluiceway. He also showed that spill draws fish away from the sluiceway, which is effective at passing fish, at a non-linear rate.

In 1995, NMFS began to evaluate spill levels at The Dalles Dam to find an optimal level for smolt survival through the project. In a memorandum to the IT dated April 15, 1999, Brian Brown stated the NMFS perspective that "The purpose of the 1999 The Dalles Spillway Study [subsequent to 1995-1998 studies] is to add critical information regarding the spillway route. In subsequent years, once concerns about the potential effects of the current spill level are better understood, NMFS will work to develop necessary information on sluiceway survival, mortality mechanisms, possible structural modifications, and other relevant information." The memorandum also states "Determination of an optimum spill level will require a more complete assessment of fish passage efficiencies and survivals through all routes of passage at The Dalles Dam… ". In addition, the Brown memorandum provided perspective on the specific spill levels used in the studies. "…NMFS is not saying that either 30% or 64% is the appropriate spill level for the purposes of the more [all encompassing] project survival estimation that we hope to begin in 2000. Rather, these are the parameters selected for the test to maximize the differences between alternative spill levels and thus confirm or refute other information that is the basis of NMFS' concerns." The ISAB believes that recognition of this overall perspective is important for resolution of current controversies.

Description of Studies

NMFS first designed a study to evaluate FPE under field operating conditions, starting in 1995 with radiotelemetry and in 1996 with hydroacoustics. Survival tests were initiated in 1997 using relative recovery rates of PIT-tagged fish released above the spillway and at a "reference" location below The Dalles Dam. The PIT-tagged fish were subsequently detected at Bonneville Dam and below. A comparison of survival in spill has been made between high spill (64%) and low spill (30%), to conform to NMFS' objectives stated in the Brian Brown memorandum of April 15 quoted above – to maximize the difference between alternative spill levels in order to increase the likelihood of detecting differences in survival. The survival studies conducted are, however, complicated by different spill locations and daytime and nighttime regimes for spill patterns and different volumes of river discharge, especially between years. The comparative study of the effects of high (64%) and low (30%) spill was begun in 1997 but high runoff precluded doing the 30% spill regime that year and data were obtained only for 64% spill. In 1998 and 1999, both levels were tested.

Hydroacoustic studies were conducted in 1996, 1998 and 1999 to estimate percentages of fish that passed The Dalles Dam by way of the three passage routes (spill, sluiceway and turbines) under the two different spill conditions (Ploskey et al., presentation at the January 6 ISAB meeting and 1999 draft report). Radio tracking of juvenile and adult chinook salmon and steelhead was also conducted at The Dalles Dam in 1999 (Allen et al. 1999, Hansel and Beeman 1999, T. Counihan, USGS, personal communication).

Results of Studies

The results to date generally have confirmed that higher percentages of spill carried more fish through that route of passage resulting in fewer fish going through the sluiceway or turbines. Contrarily, reduced spill caused relatively more fish to go through the sluiceway and through the turbines (Ploskey et al. 1999, Hansel and Beeman 1999). Thus, strictly from a passage-route perspective, higher spill appears to be effective as a means of increasing FPE without reference to project survival.

However, the objective is survival through the project. If the survival rate in spill is the same at both spill levels and higher than in passage through turbines and sluiceway, then there is a gain in total survival by having more water spilled. For clarity, we need to be specific about whether we are considering only relative survival in spill or total survival past the project including all passage routes. The studies so far have concentrated on comparing survival in spill at the two spill levels (as this survival is affected by the environment experienced to the point of detection at Bonneville Dam or below) and not the effect of spill on overall survival past the project.

The numerical results of NMFS PIT tag studies are presented in Appendix 2. We base our analysis on these data. However, the level of precision of point estimates within years and seasons is low (i.e., there is low power within years and seasons) and hence we use the consistency of relationships between survival in spill at the two spill levels in arriving at overall conclusions. Consistent relationships are not expected unless there are real differences in effects of the two spill levels.

The three years of survival studies have consistently shown that the point estimates of survival of fish passing in spill at the 30% level are larger than the survival of fish passing in spill at the 64% level. Our conclusion is that survival of fish in 64% spill is not equal to the survival of fish in 30% spill. In fact, there is an indication that the survival of fish in 64% spill is less than survival of fish in 30% spill, although the strict interpretation of statistical significance would leave the answer equivocal. If survival of fish passing the spillway at 64% spill is truly lower than survival of fish passing the spillway at 30% spill then the increased FPE may not compensate for the assumed higher mortality during turbine passage (or sluiceway passage). This is the core of the controversy, and it is discussed further below.

Based on the velocity maps we reviewed, the hydraulics of the tailrace and river reach through the islands varies with river discharge and percentage of spill. At lower river discharge rates and low spill, the water from both spillway and powerhouse passes mostly in the deep channel at the north side of the tailwater. Only a small portion of the total river flow, much of it derived from the powerhouse, flows among the bridge islands. At higher discharges and percentages of spill, the water spreads out southwestward among and over the islands. Velocities are slower in the islands and there are more eddies. These hydraulic relationships with discharge and spill are critically important for understanding overall smolt survival because the islands include habitat for predators and they create eddies in which smolts can be delayed.

Answers to Questions

Based on our analysis, the ISAB has the following responses to the two questions asked by the Implementation Team.

Question 1. Based upon a comprehensive review and analyses of the study design, methodology, empirical data and results, are there real and significant differences between the survival of fish through 30% and 64% spill levels at The Dalles Dam?

Answer

The short answer is that there probably are differences. The evidence is strongest that survival in spill at the 64% level is somewhat lower than survival in spill at the 30%

level. This answer should not be taken at face value, however, without considering the following analysis.

Study Design and Methodology. The study design employs what has become a rather straightforward application of the paired release method of estimation of relative survival, and as such provides useful, though limited, estimates of survival. The study design could be improved to provide more information, as we note in detail in the answer to question 2 below. The methodology also appears to conform to current standard practice for this sort of design.

Results. While the study results suggest that survival at the two spill levels is probably not the same, the extent of the difference is quite variable and seems to depend on covariates not accounted for. The confidence intervals for the point estimates of survival at the two spill levels show that the differences in survival between 30% spill and 64% spill could be large in some cases (e.g., 1998). On the other hand, the 1999 studies suggested that any differences might be quite small. However, none of the studies suggested that survival at 64% spill was higher than 30% spill, i.e. all of the estimates of survival at 30% spill are higher than or approximately equal to those at 64% spill. In the summer of 1998, tests with fall chinook resulted in particularly low estimates of survival. The point estimate for 64% spill was 25% mortality and for 30% spill it was 11% mortality. These estimates could represent no more than ordinary variation in sampling or some breakdown in the study protocol. On the other hand, they could represent real estimates of survival of particular groups such as fall chinook under certain conditions, and in that case should be a stimulus for action to correct a possible problem.

These data suggest that survival at night is higher than during the day (Appendix 3). This would comport with the hypothesis that predation may be a factor in survival of juvenile salmon passing in spill at The Dalles Dam and so is not unexpected. The rate of survival also seems to be best at the so-called juvenile spill pattern that concentrates spill near the north shore.

Are there Real and Significant Differences? Low detection rates for PIT tagged fish at Bonneville Dam and sites downstream, combined with constraints on the numbers of fish released, and a limited number of replications of the study (years) do not allow statistically definitive conclusions regarding the differences in survival of the study fish at the two spill levels. Biological significance of any difference would be defined in this case as being a difference in rate of survival associated with spill passage that would affect the total survival of fish passing the project to a degree that would be of concern to the IT. The degree of difference that would be of concern remains to be specified by the IT. No one really knows the level of difference that would be biologically significant for populations of migrants.

The basic question regarding biological significance is whether *total* survival of juveniles passing The Dalles Dam would be different at 64% than at 30% spill, taking into account different passage routes. To arrive at an estimate of total survival requires combination of several estimates, including 1) the estimate of survival in spill, 2) an estimate of survival in the sluiceway and 3) an estimate of survival through the turbines, along with 4) estimates of the portions of total fish approaching the dam that pass through each of the three routes at each spill level. From the hydroacoustic and radio tracking studies, as well as the studies of Willis (1982), estimates of the portions of fish passing by the three routes at various spill levels are available. An estimate of survival in sluiceway passage was made in the 1998 study only. The summary data provided to the ISAB included graphs showing estimates of total project survival in the 3 years 1997, 1998 and 1999. We transcribed those graphs into tabular form (Appendix 4). The numbers are useful in identifying the effects of converting the estimates of survival in spill into estimates of total survival. With the spring studies, the effects of converting point estimates of survival in spill into estimates of total survival were small, less than 2% and the average effect was to reduce the estimate of survival in spill by less than 1%. Therefore, the IT might reasonably conclude that its decisions on spill in the spring could be based upon the point estimates of survival in spill, without the need to adjust to total survival (assuming coho are a reasonable surrogate for spring chinook). These survival estimates in spill have the further advantage of being provided with confidence intervals to assist in interpretation of any differences. On the other hand, the estimates of total survival for summer migrants (fall chinook subyearlings) differed by as much as 5% from the estimates of survival in spill, a reflection of the poor guidance efficiency of these fish as estimated by hydroacoustics. Decisions on summer spill levels should be made based on expected values of total survival, and not survival in spill alone.

There is a strong suspicion that the high volume of river discharge experienced during the 1997 study may have been responsible for the low survival estimate that resulted. Not only was the percentage of spill high (64%), but the volume of water spilled was especially high. Photographs of the dewatered tailwater in Normandeau Associates, Inc. et al. (1996) show the physical hazards to spilled migrants in the form of concrete baffles and a vertical end sill in the tailwater. Unfortunately, the high discharge in that year precluded study at the 30% spill level, so it is impossible to judge from the existing data whether spill survival at that level would also be lower at high river flows. We discuss this issue further in response to question 2, as it bears on the issue of study design.

Question 2. Based on a comprehensive review and analyses of existing empirical data, what are the most appropriate future research steps, including a recommended study design and methodology, to determine an operational plan at The Dalles Dam that maximizes juvenile passage survival?

Answer

The short answer is that a new study design is needed, one that incorporates covariates, concentrates on spill levels in the 30% to 50% range, and alternates experimental spill levels within a year. The following points support this answer.

1. A basic change is needed in the design and analysis of passage survival studies of juvenile anadromous fishes in the Columbia Basin to take advantage of new developments that allow for inclusion of covariates in the analysis. The design and analysis of release-recapture studies presented in Burnham et al. (1987) represent the basis for the current design and analysis of most of the PIT tag and radio telemetry survival studies conducted in the basin. Results in that book were constrained by two problems: first, the perceived need to use batch marks on fish in a given treatment or control group, and second, models for measuring and assessing the effects of unique covariates of individual tagged fish were not yet developed (Lebreton et al. 1992, Skalski et al. 1993). Use of the models of Lebreton et al. and Skalski et al. and extensions of these models not only eliminate the need for some of the assumptions required by the models of Burnham et al., but allow the prediction of the effect of covariates such as route of passage on survival from radio-telemetry studies and number of detections in bypass systems from PIT-tag studies. We recommend that these newer approaches be adopted in subsequent studies.

2. Given that PIT-Tag detection is not presently possible at The Dalles Dam, and that PIT-Tag detection at Bonneville Dam and beyond is lower than radio-tag detection, both radio telemetry and NMFS PIT-Tag survival studies should be conducted. Both approaches to survival studies will produce information useful in development of an operational plan that maximizes juvenile passage survival. These two techniques offer overlapping, but complementary possibilities, and production of some unique information concerning survival of juvenile anadromous fishes during their migrations. Procedures for conducting radio-telemetry studies should continue to be developed and improved for use in solving unique passage problems over relative short reaches of the rivers. Investigators need to be reminded, however, that recent studies have shown that estimates of survival of radio tagged fish may be compromised after useful, but limited time periods and travel distances (Shane Bickford, personal communication, Hockersmith et al. 2000). An additional problem arises in judgements as to which radio tag detections are legitimate versus some that are spurious. We believe this problem can be dealt with in a properly designed study. We note that the same problem was encountered early in development of hydroacoustic technology and adjustments had to be made, recognizing that absolute certainty will not be achieved.

3. Data from radio-telemetry and PIT-TAG studies in the basin are under-analyzed, including the 1999 radio-tag study conducted at The Dalles Dam (Counihan et al. 1999) . More useful information can be extracted, which may reduce the need for some additional field studies. Analysis of past and future radio-tag and PIT-Tag data should include consideration of methods for estimation of the effects of covariates measured on individual fish including: route of passage, size of fish, species, hatchery or wild, etc. (Lebreton et al. 1992, Skalski et al. 1993). Survival by route of passage (turbine, sluiceway, or spill) as a function of characteristics of dam operations (% spill, volume spill, tailrace flow conditions, etc.) at the time of passage and characteristics of the individual fish (size, species, hatchery or wild, etc.) can be modeled and estimated by techniques which are over seven years old. PIT-Tag data from above Lower Granite and above the mid-Columbia dams to below Bonneville Dam should be analyzed by these techniques which allow the separate estimation of the effects on survival of covariates such as size and the number of times a fish is detected in bypass systems.

4. The current proposal for passage survival studies at The Dalles Dam in 2000 (Dawley, et al. 1999b) is an observational monitoring and evaluation study of fixed operating conditions that seems to offer little new in the way of information useful for optimizing an operational plan at The Dalles Dam. What is needed is a study to continue to evaluate several spill levels and establish optimum operating conditions. The proposal should be modified to incorporate suggestions we made in the three paragraphs above.

It appears, judging by the description in the Methods section, that the design of the study is hampered by a shortage of fish for marking, as well as the low recovery rates at Bonneville Dam and below. A useful exercise would be to provide an estimate of the numbers of fish and recoveries that would need to be employed in order to achieve estimates of some specified precision. This procedure was used by Normandeau Associates et al. (1996) to good advantage. The IT should be asked to specify a biologically significant difference in survival they would hope to detect in the study, and the study designed accordingly. Otherwise, further studies may only arouse further controversy.

5. There is little justification for studying spill levels as high as 64% in a continuing optimization study. The weight of evidence suggests that this level is too high for good smolt survival. Other levels need testing. However, we are not comfortable with the conclusion implicit in the study proposal for 2000 that 30% spill is optimum and that it should be the sole focus of study. With a single fixed spill level each year varied among years, one can expect the common criticism of observation studies that “this year was different” and comparative results among years cannot be trusted for decision making. Studies with a fixed spill level for the entire migration study would not seem to provide sufficient information for decisions to be made within a reasonable number of years.

One argument for a fixed level of spill throughout a test year was the suspicion that predators fail to establish territories under the test conditions when flows are switched back and forth within a few days. This failure would result in higher survival during switching years than if constant flow were tested. However, setting a constant percentage of spill does not ensure a constant volume of spill and thus constant predator habitats throughout spring and summer. Predator habitats are bound to change with changes in volume of spill even as percentages are held relatively constant. Tests should be conducted at different spill levels within a year, but holding the spill conditions longer than previously. Perhaps a week would be sufficient. A concurrent study of predators and their movements at different flows and spill levels would help interpret the results of survival studies.

It is difficult for the ISAB to make specific recommendations for study design, because we are not aware of all logistical constraints, including fish availability and operation of the hydropower system. We understand that other levels, such as 40% and 50% are being considered. The 40% level is of interest, because Willis’ (1982) estimates of spill efficiency suggest something around 40% might lead to the 80% FPE, which is NMFS and the Council's goal. Arguments might still be made for further tests at higher levels, because such spill will occur naturally at times of high flow.

6. Unanswered questions

Legitimate unanswered questions remain regarding expected survival rates during high flow years and/or a constant 30% spill rate. For example, constant 30% spill rate may allow predators to increase predation rates on juvenile anadromous fish relative to the alternating spill pattern (cycling between 30% and 64%) utilized in 1998 and 1999. Additional effort to answer these questions could clarify the results obtained so far.

There is an unanswered question about the cause of the somewhat higher mortality in releases from the south spill bay (difference of 3%) compared to releases from the north bays found by Normandeau Associates Inc. et al. (1996). Information from the radio tracking study documents "predation events" that were more frequent during spill from the south spill bays than the north bay, or from control releases near the north shore. Residence time of radio tagged fish in the tailrace was longer when spill came from the south bays versus the north at both 30% and 64% spill levels. Evidently, total residence time was lower at 64% than 30%. The location and cause of higher mortality from south bay releases need to be identified.

A study useful for the IT decisions might be designed to attempt to reconcile the differences between the survival estimates of Normandeau Associates Inc. et al. (1996) and those of Dawley et al. (1998, 1999a). The technique employed by Normandeau et al. estimated direct mortality in spill at north and south spill bays (1% for the north and 4.5% for the south). Dawley et al.'s 1999 estimate (4% mortality in spring) includes elements of indirect or delayed mortality, and the method released fish upstream of the center of the spillway, so the fish might have passed through a mix of north and south spill bays. It might be useful to the IT to design a study to locate or identify the cause of the apparent 3% difference in the estimates. Such a design would have to take into account the rather large sample sizes needed to detect an expected 3% difference.

7. A study plan should be d eveloped to obtain further estimates of juvenile survival in passing through the sluiceway and through the turbines, which are next on NMFS' list, according to the Brian Brown memo cited. We have previously noted that such estimates ought to be possible using the radio tracking data already available. Future verification by concurrent PIT tag and radio tracking studies would be desirable, as we suggested above. These could be compared to the 1998 estimate of Dawley et al. (1998) for verification. These studies could show opportunities for major improvements in guidance efficiency and survival by using the sluiceway more effectively.

8. Considering the likely importance of tailwater hydraulics to passage routes, travel times, physical damage during spill, and probable predation losses around the islands, additional study of both fish trajectories and hydraulics at different spill levels and river discharges could be useful for interpreting overall survival through the project. Further data analysis and synthesis of existing hydraulic and fish data may suffice.

9. In addition to the suggestions provided above, we give below our specific recommendations for the design and analysis of future passage survival studies at The Dalles Dam in 2000, realizing that many details need to be filled in by the Principal Investigators and Implementation Team. Our recommendations for future study design and analysis are:

a. More than one spill level should be included in the study, with spill varied over time periods that would allow some stability to develop in local conditions, perhaps one-week periods rather than the three-day periods used previously. This would provide contrasts among levels of important covariates, help identify sources of mortality and allow modeling of survival in radio telemetry and PIT-tag studies. The design should include scheduled variation in spill percentage, spill volume, tailrace conditions, etc. The design should also include radio-telemetry studies of aquatic predators and visual (or radio-telemetry) observations of avian predators to evaluate distribution of predators under different spill conditions and the changes, if any, in distribution under different dam operations.
b. Analyze flow patterns and other hydraulic characteristics that might help adjust the spill volume (or percentage) relative to sluiceway and powerhouse volumes (or percentages) to avoid predation and physical injury. Attempt to identify the flow conditions (splits between powerhouse, sluiceway, and spill, including high flow conditions) that might lead to high survival. Develop working hypotheses around which future work could be focused.
c. Use both radio-telemetry and PIT-Tag methods in 2000 to estimate survival by route of passage so that results can be compared and possible biases eliminated. Maintain strict randomization in assigning personnel, equipment, and fish to treatment groups and other quality control to ensure comparable sources of test fish, and equal handling and transport conditions. Maximize detection probabilities for radio tagged fish to improve the precision of the estimates as much as is practical.
d. Evaluate the use of one release site for radio-tagged fish rather than one release site above and one below The Dalles Dam. If a valid sample of run of the river fish are radio-tagged (i.e., no selection bias), then we see no reason to use two release sites and suggest that the sample should be concentrated and the sample size increased by releasing all fish under common conditions above The Dalles Dam. Further, evaluate if radio-tagged fish released at John Day Dam can be monitored at The Dalles Dam for the radio-telemetry study of passage survival at The Dalles Dam.
e. Consult with Drs. John R. Skalski and Steve G. Smith on appropriate analyses to fully utilize currently available and future information and estimate effects of covariates (route of passage, % spill, volume spill, fish size, etc.) on passage survival of anadromous fishes from both radio-telemetry and PIT-Tag studies.
f. Use juvenile survival estimates rather than adult returns as a criterion. Evaluation of the optimum operating conditions at a dam will realistically have to be based on estimated survival rates of juvenile passage because estimation of adult return rates associated with different routes of passage would require very large sample sizes and results would potentially be confounded with downstream operations. Although it is logical that decisions about operating regimes should be based on adult returns rather

than juvenile passage, this approach is not attainable now. However, this need underscores the urgency of fitting dams for better monitoring of tagged adult returns, better ability to track PIT-tag detections throughout the life cycle and better ways to effectively search the databases for relevant, long-term survival data.

g. Recognize that tests will not represent all species and life stages. The Radio tracking study has shown there is a difference in FPE between species (yearling chinook and steelhead). We recognize that there is a practical limit on the size of fish that can be PIT tagged successfully, i.e. without inducing undue mortality. The IT needs to be aware of that problem and to err on the side of being conservative in the absence of complete knowledge as to differences among species and stocks.

Concluding Remarks

While the 1997-1999 studies did not include all factors influencing mortality of juveniles, we find that they were conducted well and all reasonable attempts were made at scientific quality and rigor. They are not perfect, and the region should not expect them to be. To expect more is unreasonable and reflects a lack of appreciation of the difficulties of conducting such field studies. However, improvements and logical next steps can be made based on experience, and these should be tried.

Evaluation of the 1997-1999 survival studies represents a balancing between scientific (statistical) rigor and professional judgement based on weight of evidence. Mathematical rigor of hypothesis testing in the complex environment of river and dam operations is difficult to attain, in spite of noble attempts. Thus, we can often be grateful for rigor when it is successful but must accept less rigorous (if often subjective) impressions when that is most of what we have. We applaud the attempts of the investigators to attain rigor and hope that the research continues in that direction.

The weight of evidence of several years of study appears to us to be as follows:

1. Mortality of smolts at high spill rates (represented by 64%) in the spring is somewhat higher than at 30% spill. Details of comparisons with 30% spill and related statistics not withstanding, the level of mortality estimated in the summer (possibly as high as 11% - 25%) should not be allowed to persist at any spill levels. Mortality in summer at both spill levels in 1998 was estimated to be at or above levels expected from passage through turbines. Although an experiment comparing survival in passage through alternative routes has not yet been done at The Dalles, the generally accepted mortality rates for turbines and preliminary results for spillway survival can be used for comparison.
2. There seems to be no technical reason to manage project operations to obtain high spill percentages at The Dalles, if maximal survival is the objective. The 80% passage efficiency goal can likely be achieved with 40% spill. On the other hand, high spill levels will continue to occur naturally at high flows, which speaks to the desirability of developing a better understanding of the low survival estimates at high spill levels.

3. The possibility of differences in survival in spring and summer are difficult to interpret because the test animals were different species and different in size. There may be differences in behavior or ability to maintain their orientation. This might result in different routes taken in the tailrace.
4. There is evidence from both hydraulic models and field studies that at lower spill more water remains in the main channel, whereas at higher rates of spill more water overflows the channel and flows among the bridge islands and islands immediately downstream. The islands slow water and fish passage, allowing greater opportunity for predation. The combination of more physical damage in the spillway stilling basin (such as from striking the momentum-breaking concrete structures) and a trajectory of damaged fish through predator-laden islands at high spill would logically add up to heavy losses.
5. The results of studies of survival in spill at The Dalles Dam can not be generalized to other projects. This project is unique in several respects, with its shallow stilling basin and downstream islands concentrated on one side of the river where flow from the powerhouse is concentrated and where high spill flows spread out.
6. More studies to refine the contrast between 64% and 30% spill are not likely to provide much stronger evidence than we already have, unless sample sizes can be increased. Another year will probably only add its own suite of complications. It would be more productive to move to a next phase of refining the estimates of survival at lower spill levels in conjunction with concurrent estimates of survival in the other two routes of passage, turbines and sluiceway. In this context, survival studies in the year 2000 of spill rates of about 30%, and 50%, using multiple techniques, would help define an optimum spill level. If resources and study fish are available, a third level at about 40% spill would help define the relationship between survival and spill parameters.

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U.S. Army corps of Engineers. Undated. Several maps of velocities and current directions in the forebay and tailwater of The Dalles Dam at different flow rates.

Appendix 2.

Relative Passage Survival of Juvenile Salmon @ The Dalles Dam Spillway & Ice and Trash Sluiceway, 1997-99.

Year	River flow (kcfs) Median	Range	Means and (95% C.I.) 64% Spillway	30% Spillway	Sluiceway @30%
Spring migration (coho or chinook and coho salmon)					
1997	455	380 - 527	87 (80 - 94)		
1998	347	196 - 445	89 (82 - 95)	97 (88 - 107)	96 (87 -105)
1999	273	239 - 361	94 (90 -98)	95 (91 - 98)	
Summer migration (subyearling chinook salmon)					
1997	301	242 - 529	92 (86 - 99)		
1998	212	167 - 275	75 (68 - 83)	89 (80 - 99)	89 (81 - 98)
1999	300	221 - 352	96 (92 -100)	100 (96 - 104)	

Appendix 3.

Day vs. Night -- Adult vs. Juvenile Spill Pattern
1997, 1998, 1999 Data Combined

Spring Migrants		Ln Survival %		Back Transformed		
	N	Mean	StDev	Mean	SE	Probability
30% spill, Day	16	4.541	0.134	93.8	12.6	
30% spill, Night	11	4.607	0.116	100.2	11.6	0.18
64% spill, Day	22	4.463	0.119	86.7	10.3	
64% spill, Night	24	4.516	0.156	91.5	14.3	0.2
Summer Migrants						
30% spill, Day	14	4.465	0.218	86.9	18.9	
30% spill, Night	11	4.649	0.133	104.5	13.9	0.02
64% spill, Day	21	4.447	0.187	85.4	16.0	
64% spill, Night	20	4.522	0.156	92.0	14.4	0.17

Appendix 4. Estimated Total Project Survival at The Dalles Dam at the Two Spill Levels

(From graphs provided by NMFS at the January 5, 2000 briefing.)
(Point estimates of survival in spill are given in parentheses for comparison.)

A. Spring Season

From Radio Telemetry

Spill Level	1997	1998	1999
30%		95 (97)	93 (95)
64%	88 (87)	89 (89)	94 (94)

From Hydroacoustics

Spill Level	1997	1998	1999
30%		95 (97)	94 (95)
64%	88 (97)	90 (89)	93 (94)

B. Summer Season

From Hydroacoustics

Spill Level	1997	1998	1999
30%		89 (89)	95 (100)
64%	91 (92)	80 (75)	94 (96)