Northwest Power and Conservation Council

February 9, 2006

MEMORANDUM

TO: Council

FROM: Steve Waste, Manager Program Analysis and Evaluation

SUBJECT: ISAB Review of Spill Evaluations

This briefing is informational and does not require a Council decision. This briefing will provide overview of the results of the ISAB Review of Spill Evaluations (attached). The presentation will lead by ISAB member Tom Poe with support by Bob Bilby or Colin Levings.

Background

In October 2005, the Independent Scientific Advisory Board (ISAB) received a request from the Council to review the biological effectiveness of court-ordered summer spill operations in 2005 for benefit/recovery of ESA-listed Snake River fall Chinook. The National Marine Fisheries Service and the Columbia River Inter-Tribal Fish Commission approved the ISAB's assignment and added questions for the ISAB to consider in its review.

The 2005 court-ordered spill began on June 20 at the four lower Snake River dams and continued through August 31. At McNary Dam on the Columbia River, court-ordered spill was initiated on July 1 and continued through August 31. A large majority of the subyearling fall Chinook hatchery production fish emigrated through the lower Snake River prior to initiation of the spill, but a majority of the wild subyearling fall Chinook were exposed to the spill.

The ISAB found several studies relevant to the effect of the 2005 court-ordered summer spill on juvenile subyearling salmon survival, travel time, dam passage, and smolt to adult return rates. However, none of these studies was **specifically** designed to examine how summer spill may benefit recovery of ESA-listed Snake River fall Chinook. The attached report provides the ISAB's findings on the contribution of these studies to the understanding of the biological effectiveness of 2005 summer spill. The ISAB report also includes recommendations for additional research, monitoring, and evaluation studies needed to determine the efficacy of summer spill.

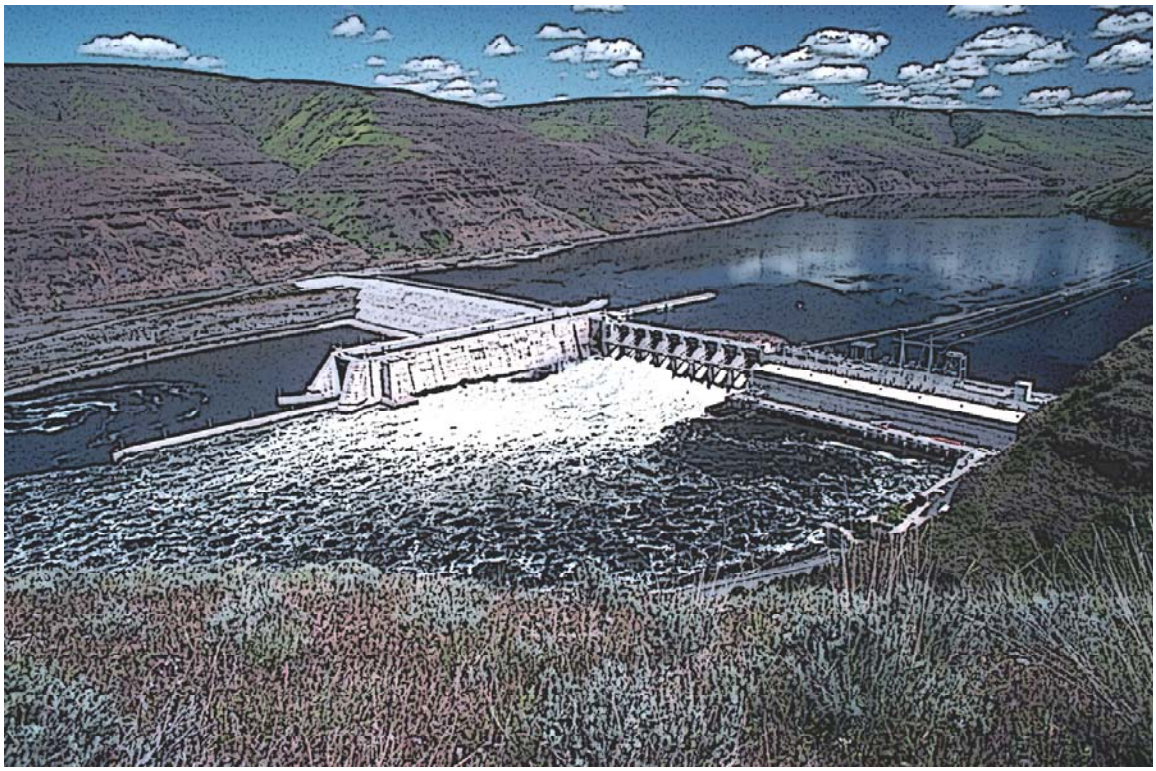
851 S.W. Sixth Avenue, Suite 1100
Portland, Oregon 97204-1348
www.nwcouncil.org

Steve Crow
Executive Director

503-222-5161
800-452-5161
Fax: 503-820-2370

Independent Scientific Advisory Board
for the Northwest Power and Conservation Council,
Columbia River Basin Indian Tribes,
and National Marine Fisheries Service
851 SW 6th Avenue, Suite 1100
Portland, Oregon 97204
ISAB@nwcouncil.org

Biological Effectiveness of 2005 Summer Spill



ISAB 2006-1
January 18, 2006

ISAB Members

Robert Bilby, Ph.D., Ecologist at Weyerhaeuser Company, an expert in riparian ecology.

Susan Hanna, Ph.D., Professor of Agriculture and Resource Economics at Oregon State University (also an IEAB member).

Nancy Huntly, Ph.D., Professor of Wildlife Biology at Idaho State University.

Stuart Hurlbert, Ph.D., Professor of Biology and Director, Center for Inland Waters at San Diego State University.

Roland Lamberson, Ph.D., Professor of Mathematics and Director of Environmental Systems Graduate Program at Humboldt State University.

Colin Levings, Ph.D., Research Scientist and Past Section Head Marine Environment and Habitat Science Division, Department of Fisheries and Oceans, Canada (also an ISRP member).

William Pearcy, Ph.D., Professor Emeritus of Oceanography at Oregon State University.

Thomas P. Poe, M.S., Consulting Fisheries Scientist, an expert in behavioral ecology of fishes, formerly with the U.S. Geological Survey (also an ISRP member).

Peter Smouse, Ph.D., Professor of Ecology, Evolution, and Natural Resources at Rutgers University, an expert in biometrics and population theory.

ISAB Review: Biological Effectiveness of 2005 Summer Spill

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Executive Summary

In October 2005, the Independent Scientific Advisory Board (ISAB) received a request from the Northwest Power and Conservation Council (Council) to review the biological effectiveness of court-ordered summer spill operations in 2005 for benefit/recovery of ESA-listed Snake River fall Chinook. The National Marine Fisheries Service (NMFS) and the Columbia River Inter-Tribal Fish Commission (CRITFC) approved the ISAB's assignment and added questions for the ISAB to consider in its review.

The 2005 court-ordered spill began on June 20 at the four lower Snake River dams and continued through August 31. At McNary Dam on the Columbia River, court-ordered spill was initiated on July 1 and continued through August 31. A large majority of the subyearling fall Chinook hatchery production fish emigrated through the lower Snake River prior to initiation of the spill, but a majority of the wild subyearling fall Chinook were exposed to the spill.

The ISAB found several studies relevant to the effect of the 2005 court-ordered summer spill on juvenile subyearling salmon survival, travel time, dam passage, and smolt to adult return rates (SARs). However, none of these studies was **specifically** designed to examine how summer spill may benefit recovery of ESA-listed Snake River fall Chinook, and none produced reports for review.

PIT-tag studies

- A joint study by the NMFS and the U.S. Fish and Wildlife Service (USFWS) was conducted in 2005 to compare smolt to adult survival rates (SARs) of Snake River fall Chinook under alternate transport and dam operational strategies. In order for this study to provide information relevant to the effectiveness of the 2005 spill it will be necessary to monitor the returning adults to establish SARs for the 2005 cohort. Draft post-release performance results of reach survivals are available for Snake River groups, but data from Clearwater groups are not yet available. Nor do these estimates account for "reservoir type" fall Chinook. The post-release performance (i.e. passage timing, spill exposure history, travel rate, and joint probability of migrating and surviving) of wild subyearlings and Lyons Ferry hatchery surrogate subyearlings were similar. Compared with either wild or surrogate subyearlings, production subyearlings emigrated much earlier, experienced almost no spill, and had higher travel rates and survival.

- The Fish Passage Center (FPC) used PIT-tag data from all tagged research, wild, and production fish to produce a preliminary 2005 reach survival estimate. This estimate may be a good indicator of a potential benefit of the 2005 summer spill for subyearling Chinook, but actual benefit cannot be assessed until SARs can be estimated. Most of the preliminary analyses focus on differences in survival estimates among years. These comparisons are of limited utility for direct

estimation of spill effects, given major variations in river hydrosystem spill operations among years and considerable interannual variation in migration timing and passage behavior of subyearling Chinook. Travel time estimates may be adequate for the entire population of migrating smolts but are inadequate for estimating travel times for wild fish and specific sub-groups of migrants (e.g. Clearwater fish).

- The survival estimates presented represent the joint probability of migrating as a subyearling and surviving through the reach of interest. Thus any differences in estimated in survival estimates observed among years could be due to a change in survival, a change in the proportion of fish migrating as subyearlings as opposed to yearlings, or both.

Radio-tag studies

- Radio-tag studies provided very useful data to determine passage behavior and survival estimates of subyearling Chinook at each of the lower Snake River dams and McNary dam during the court ordered spill. Data indicated that when provided with significant levels of summer spill subyearling fall Chinook juveniles passed through spillways at lower Snake River dams with little delay and high efficiency (96 to 99 % FPE).

- Data also indicate that the removable spillway weirs (RSW) tested at Lower Granite and Ice Harbor dams were efficient in passing a large proportion of the subyearling Chinook with high survival rates. Except for the on/off RSW tests, only one primary spill condition was tested; spill on for 24 hr/day. Controlled tests, varying amounts and duration of spill, would have given a better evaluation of spill effects on passage behavior and survival.

- Radio-tag data are very useful for evaluating overall spill passage behavior and survival at specific dams but not for multi-reservoir reach survival estimates (e.g. Lower Granite Dam to McNary Dam), system-wide survival estimates, or SARs because of relatively short-lived tag duration.

Subyearling fall Chinook Reservoir Type

- The USFWS PIT-tag data on wild subyearling Chinook are not useful for evaluating immediate effects of summer spill. These studies are designed to determine long-term trends in SARs of wild populations.

- The effects of 2005 summer spill on the proportions of “reservoir type” and “ocean-type” fall Chinook relative to the proportions observed in recent years may be observed in the spring of 2006 when reservoir-type fish migrate from the system.

- The larger size of the reservoir-type smolts likely confers a survival advantage over the ocean-type smolts, contributing to their higher representation among returning adults. The reservoir-type life history suggests that, for fall Chinook juveniles, getting to the estuary as fast as possible may reduce the chances of surviving. Emigrating at a slower rate, feeding, and reaching the estuary/ocean at a larger size may promote higher survival due to reduced predator vulnerability. Both increasing travel rates due to summer spill and transporting subyearling fall Chinook that might become reservoir-type may be detrimental to continuation of this life history type.

ISAB Recommendations for Additional Research, Monitoring, and Evaluation Studies for Determining the Efficacy of Summer Spill for Protecting and Recovering Snake River fall Chinook

- Replicate the studies of coordinated dam/spill operations for multiple years, to test for effects of spill on Snake River Chinook salmon over a range of variation in flow that occurs among years.

- Substantially augment monitoring of tagged juveniles and adults throughout the system, to allow wider-scale assessments of competing hydrological options, including strategies related to transport of Snake River fall Chinook juveniles.

- Evaluate the consequences of changing the spill regime for upriver movements of adult salmon and other species for which changes in summer spill are relevant, particularly steelhead trout, white sturgeon, and Pacific lamprey.

- Increase the monitoring of reservoir-type fall Chinook, throughout the system, fall through winter, and over years. There is a need for both a better in-river tracking system for these fish and some sense of the extent to which this over-wintering behavior is genetically programmed.

- Study survival of over-wintering reservoir-type Chinook salmon to estimate their mortality rates during reservoir residency and during passage downstream. Given the substantial proportion of returning adults produced by this life history type, an improved understanding of the factors impacting these fish may be critical to the recovery of Snake River fall Chinook salmon.

ISAB Review: Biological Effectiveness of 2005 Summer Spill

I. Background

On October 17, 2005, the Independent Scientific Advisory Board (ISAB) received a request from the Northwest Power and Conservation Council (Council) to review the biological effectiveness of spill operations in 2005 and provide a report by November 30, 2005 (Attachment 1). On October 18, the ISAB's Executive Committee, including Ex Officio members from the Council, National Marine Fisheries Service (NMFS), and the Columbia River Intertribal Fishery Commission (CRITFC), discussed the Council's request. NMFS and CRITFC approved the ISAB assignment with the understanding that the ISAB would consider their additional questions and comments (Attachment 2). The ISAB included those questions and synthesized all questions into the following set:

(1) *What studies were conducted in 2005 that are expected to provide data relevant to evaluate the effects of the Court ordered summer spill on juvenile salmonid survival, travel time (i.e. from Lower Granite Reservoir to the estuary), smolt to adult return rates, and smolt condition (i.e. physiological condition and disease)?*

(2) *What is the status of data from such studies, are they adequate for analyses of the effects of spill, and which analyses are completed, ongoing, or still need to be undertaken?*

(3) *How are each of the survival and passage metrics derived and are they statistically sound?*

(4) *What are the potential effects of the 2005 summer spill on the fall Chinook "reservoir type" juveniles?*

(5) *What additional studies and monitoring would need to be implemented to provide the region with a more thorough evaluation of the potential benefits of summer spill in recovering listed Snake River fall Chinook?*

II. Responses to Questions Posed by the Council, NMFS, and CRITFC

Questions 1 and 2. Studies Relevant to 2005 Spill Operations, Status of Data, and Data Analyses

The ISAB found several studies relevant to the effect of the 2005 Court ordered spill on juvenile subyearling salmon survival, travel time, dam passage, and smolt to adult return rates (SARs). For each study we give some background, objectives, results, and status of data and analyses.

NMFS/USFWS PIT-tag Studies

Study Design

The NMFS and U.S. Fish and Wildlife Service (USFWS) conducted a joint PIT-tag study (Marsh and Connor 2005) to compare smolt to adult return rates (SARs) of Snake River fall Chinook salmon under alternate transport and dam operational strategies. The three primary objectives for the study were to: (1) compare SARS of PIT-tagged wild and surrogate-sized (hatchery fall Chinook subyearlings reared to a size to match wild subyearlings) hatchery subyearling Chinook transported from Snake River dams to below Bonneville Dam with the SARs of PIT-tagged wild and surrogate hatchery subyearlings remaining in the river; (2) compare post-release performance of wild fall Chinook salmon subyearlings from the Snake and Clearwater rivers to hatchery fall Chinook subyearlings released in these rivers as surrogates for natural fish in transportation studies; and (3) in future years compare SARs of PIT-tagged production-sized hatchery-reared subyearling Chinook salmon transported from Snake River dams to below Bonneville Dam, with the SARs of PIT-tagged production hatchery-reared subyearling Chinook remaining in the river.

Status of Data and Data Analysis

- No reports regarding this study were available for review by the ISAB.
- Only information labeled as preliminary or draft has been reviewed by the ISAB via presentations (Dec. 7 power point presentation by Connor and Smith).
- Objectives (1) and (3) require SARs before results can be evaluated, and thus will not be addressed for several years.
- Reach survival estimates for the lower Snake and to McNary Dam were calculated as the joint probability of migrating as a subyearling and surviving.
- Draft results for Objective (2) were given for Snake River groups but data from Clearwater groups were not yet available, at time of reporting.
- The post-release performance (i.e. passage timing, spill exposure history, travel rate, and joint probability of migrating and surviving) of wild subyearlings and hatchery-reared surrogate subyearlings from Lyons Ferry were similar.
- Compared with either wild or surrogate subyearlings, production subyearlings emigrated much earlier, experienced almost no spill, and had faster travel rates and higher survival.

Adequacy of Data for Evaluating Effectiveness of 2005 Spill

- Current information from this study does not enable evaluation of the effectiveness of 2005 spill, because it is necessary to monitor the returning adults in order to establish SARs for the 2005 cohort. This will require monitoring for another three to five years.
- This study was originally designed to be conducted during alternating spill and non-spill river conditions with 2005 designated as a non-spill year. Detection of juvenile fish at the dams was much lower than anticipated, due to the 2005 spill

regime actually implemented under the court decision. As a consequence, the sample size of tagged fish treatment groups may have been too low for adequate numbers of fish to be collected for the transport treatment group (i.e. because most juveniles passed through the spillways and were unable to be collected for transport).

- Also, in-river detections were probably too low for precise reach survival estimates (again because the great majority of fish passed via the spillways, where they are not detected).
- The available data provide some preliminary indication of how wild subyearlings compared with surrogate and production hatchery subyearlings, but sample sizes were low, relative to the precision needed for Objective (2) above.
- The survival estimates from this and all other analyses presented represent the **joint** probability of subyearling emigration and survival through the reach. Thus, differences among years in this estimate of survival could be due to a change in the proportion of juveniles emigrating as subyearlings vs. over-wintering yearlings, differences in survival, or a combination of the emigration and survival.

Fish Passage Center - Preliminary Survival Analysis for Subyearling Chinook Originating Above Lower Granite Reservoir

Design of Analysis

The Fish Passage Center (FPC) used data from all PIT-tagged wild, surrogate, and hatchery production smolts to estimate reach survival (from Lower Granite Dam tailrace to McNary Dam tailrace) and travel time. Two groups of PIT-tagged fish, the wild Clearwater River fish (n = 858) and hatchery surrogate Clearwater fish (n = 19,268) were not used, because of their late marking and migration timing. All other fish detected and returned to the river at Lower Granite Dam were used in the analysis.

Three different preliminary analyses have been presented by the FPC in different forums (including a presentation to the ISAB on December 7, 2005) and documented in memos dated September 12, October 25, and December 13, 2005. In the October 25, 2005 analysis, subyearling migrants were separated into two groups to assess survival prior to (May 20-June 12) and after implementation (June 17-July 15) of the court-ordered summer spill in 2005. Similar groupings by date were created for each year, 2001 through 2004, to allow comparisons among years. The December 7, 2005 analysis (power point presentation by Filardo and McCann) expanded the survival estimates to include the years 1998-2000, and the within year analysis comparison groups were expanded from two groups to four groups, each with a smaller time interval. The FPC subdivided the intervals, because shorter time intervals exhibit more consistent environmental conditions allowing finer distinctions in survival and travel time among river conditions (FPC memo dated December 13, 2005).

Status of Data and Data Analysis

- No published reports were available for the ISAB to review for this evaluation.
- As noted above, three different preliminary analyses have been presented in different forums and this is a strong indicator of the preliminary nature of the data analyses to date.
- The final analysis will be completed and included in the FPC's 2005 Annual Report due out in the spring of 2006.
- Preliminary analysis yielded the following conclusions: (1) the 2005 point estimate for subyearling Chinook survival during the summer spill period was the highest recorded in recent years (1998-2004) in the reach from Lower Granite Dam to McNary Dam, and (2) travel time estimates of subyearling Chinook through the reach was the second fastest in recent years (2001-2004).

Adequacy of Data Analysis for Evaluating Effectiveness of 2005 Spill

- A majority of hatchery or production subyearling Chinook passed through the lower Snake River prior to initiation of the summer spill. Therefore the effect of the spill on this group was negligible.
- The 2005 reach survival estimate may be a good indicator of a potential benefit of the 2005 summer spill for subyearling Chinook, but actual benefit cannot be determined until SARs can be estimated.
- Most of the preliminary analyses focus on among year comparisons of survival estimates. These comparisons may be of limited utility because of major variations in hydrosystem spill operations among years (power point presentation by Skalski, December 7, 2005) and in view of considerable annual variation in migration timing and passage behavior of subyearling Chinook.
- Travel time estimates may be adequate for the entire population of juvenile salmon but inadequate for wild fish and other specific sub-groups of migrants (e.g. Clearwater fish).
- The latest, December 7 analysis, which used four rather than two groupings of fish further reduced an already small sample size and increased variability/error of the survival estimates.

Radio-tag Studies

The U.S. Geological Survey (USGS) and the NMFS were funded by the US Army Corps of Engineers (COE) to conduct radio-tag passage behavior and survival studies at the following hydroelectric dams during the 2005 summer spill season: Lower Granite, Little Goose, Lower Monumental, Ice Harbor dams on the Lower Snake River, and McNary Dam on the mainstem Columbia River. Evaluations of removable spillway weirs (RSW) at Lower Granite and Ice Harbor dams were also conducted during the court-ordered spill (Peters 2005). Different study designs, as well as passage and survival metrics, were used at each dam, so a brief summary of study design and preliminary results follows for each dam.

Lower Granite – The study was conducted by the USGS from June 20 –July 22, 2005 (Perry et al. 2005) and was designed to compare passage and survival of radio-tagged subyearling Chinook (run of the river fish) through a removable spillway weir (RSW) and the conventional spillbays. They used a randomized-block design. Two single-day treatments (either RSW on or RSW off/conventional spillbays) were randomized within sixteen 2-day blocks during the court ordered spill. The Paired-Release Recapture Model was used to estimate survival probabilities for passage through the RSW and conventional spillbays.

- Dam survival was higher when the RSW was deployed (93.9% Standard Error (SE) = 4.3%) than when it was not (89.5% SE = 4.3%).
- Fish Passage Efficiency (FPE), which is the percentage of fish passing the dam through non-turbine routes, was 97.5% with the RSW deployed and 98% when it was not.
- Estimated survival of fish passing through the RSW was 94.5% (SE = 2.5%) and was 90.2% (SE = 3.4%) through conventional spillbays.

Little Goose – The study was conducted by the USGS from June 17 through August 1, 2005 (Perry et al. 2005) and was designed to estimate survival probabilities of radio-tagged subyearling Chinook (run of the river fish) passing through the spillway by use of the Single-Release Recapture Model.

- Dam survival was estimated to be 91.6% (SE = 2.1%).
- Fish passage efficiency was 97%.
- Estimated spillway survival was 92.0% (SE = 2.2%).

Lower Monumental – The study was conducted by the NMFS from July 6-16, 2005 (Absolon et al. 2005) and was designed to estimate survival probabilities of radio-tagged subyearling Chinook (run of the river fish) passing through the spillway by use of a Paired-Release-Recapture design.

- Dam survival was estimated to be 86.2% (Confidence Interval (CI) = 75.2-98.8).
- Fish passage efficiency was 96%.
- Estimated spillway survival was 90.5% (CI = 76.0-107.7)

Ice Harbor – The study was conducted by the NMFS from June 10 –July 16, 2005 (Ogden et al. 2005) and was designed to compare passage and survival of subyearling Chinook (run of the river fish) through a removable spillway weir (RSW) with that through the conventional spillbays. They used a randomized-block design with treatments (either RSW deployed or RSW not deployed/conventional spillbays) for 20 days during the court-ordered spill. The Paired-Release Recapture design was used to estimate survival probabilities for passage through both the RSW and through conventional spillbays.

- Dam survival was slightly higher when the RSW was not deployed (99.6% CI = 97.1-102.1) than when the RSW was deployed (98.0% CI = 95.3-100.7).
- Fish passage efficiency was also slightly higher when the RSW was not deployed (99%) than when it was deployed (98%).

- Estimated spillway survival was higher when the RSW was not deployed (99.8% CI = 97.3-102.2) than when the RSW was deployed (95.9% CI = 91.2-100.5).

McNary – The study was conducted by the USGS from July 1-August 10, 2005 (Perry et al. 2005) and was designed to estimate survival probabilities of radio-tagged subyearling Chinook (run of the river fish) passing through various passage routes of the dam by use of the Route-Specific Survival Model.

- Dam survival was estimated to be 96.3% (SE = 1.4%).
- Fish passage efficiency was 81%, which was low relative to Snake River dam FPEs, but high compared to other lower Columbia River dams.
- Estimated spillway passage survival was 102% (SE = 1.3%).
- Estimated turbine passage survival was 86% (SE = 3.8%).
- Estimated juvenile bypass survival was 86% (SE = 2.9%).

Status of Data and Data Analysis

- No published reports regarding these studies were available for review by the ISAB.
- Only information labeled as preliminary or draft has been reviewed by the ISAB via presentations (the Anadromous Fish Evaluation Program (AFEP) Annual Review November 14-17, 2005 and the December 7, 2005 power point presentations by Perry and Hockersmith).
- While survival and passage estimates are not finalized in technical reports or peer reviewed documents, statements at the 2005 AFEP Review and in the Federal Columbia River Power System After-Action Report (October 2005) indicated that any final adjustments in the estimates would probably be slight.

Adequacy of Data for Evaluating Effectiveness of 2005 Spill

- Data are very useful for evaluating overall spill passage survival at specific dams but not for reach or system-wide survival.[1]
- Data indicated that when provided with significant levels of summer spill subyearling fall Chinook juveniles will readily pass through spillways at lower Snake River dams with high efficiency (96 to 99 % FPE) and with high rates of survival (90.2 to 99.8%).
- Data also indicated that RSWs tested at Lower Granite and Ice Harbor dams were efficient in passing a large proportion of the subyearling Chinook with high survival rates.
- Except for the on/off RSW tests, only one primary spill condition was tested, spill on for 24 hr/day. Controlled tests, varying amounts and duration of spill would have given a better evaluation of spill effects on passage behavior and survival.

[1] Confidence limits for survival percentages that are above 100% should be interpreted as "not statistically distinguishable from 100% at the upper end." The limited inference is due to inadequate sample sizes.

Question 3. How are the survival and passage metrics derived?

Models

PIT-Tag Studies - The Cormack-Jolly-Seber (CJS) release-recapture model (Burnham et al. 1987) was used to estimate survival from release above Lower Granite Dam to downstream detection sites and between series of dams. The CJS method is based on mark release-recapture theory in which the subsequent detection histories on a known number of marked fish re-released at a particular dam is used to estimate the number of fish that pass that particular dam that are alive but undetected.

Radio Tag Studies - Three major models are being used to estimate survival of downriver migrating smolts, the Single Release Model (SRM), the Paired Release Model (PRM), and the Route Specific Survival Model (RSSM). There are more elaborate models, such as the triple release model, but they are rarely used in such studies. All of the methods and metrics used are the regional standards for the field (Peven et al. 2005).

The ISAB has examined the resulting estimates and sampling protocols. The caveats/limitations listed in this report represent reservations about limited sample sizes and detection of smolts passing through the spillways, not criticisms of the statistical models.

Estimates

The model employed depends on the design of the study and the particular question being addressed. Some of the typical applications for these models are:

System-Wide Estimates – Obtainable from Single Release Model studies, with measurement from release point (above the first dam) and the final detection point at or below the final dam. It is also possible to use a long series of Paired Release Model studies to estimate the survival from each dam and reach, combining into a system-wide estimate at the end.

Project/Dam Estimates – Project survival is measured from below an upstream (1^{st}) dam to detection stations downriver from the next (2^{nd}) dam. With a detector in the forebay of the 2nd dam, it is possible to separate project survival into *pool* and *dam* survival components, respectively, using an augmented Paired Release Model treatment.

Route Specific Survival Estimates – The Route Specific Survival Model is typically used to subdivide survival and passage efficiency among passage routes for a single project. The study design usually entails the placement of detection arrays in the forebay, above the mixing zones in the tailraces of different passage routes through the dam, and further downstream. Fish detected below the dam are compared with the fish above the dam, and parceled out to various routes of passage through the project.

Passage Metrics

- Spill Passage Efficiency – % of fish passing through the spillbays.
- Fish Passage Efficiency – % of fish passing through non-turbine routes.
- Spill Effectiveness – % of fish passing through the spillbays, divided by the % of water through the spillbays.
- Fish Guidance Efficiency – % of fish successfully routed around the turbines to the bypass system by the screens.

Sample Sizes and Error Terms

The variances for estimates of survival fractions depend on the numbers of fish released (R) and on the detection probability (P_D). A graphic analysis is provided in Figure 12 of Peven et al. (2005), as a joint function of R and P_D. It is well understood that large sample sizes are required to document meaningful differences in survival rates. If the initial releases are divided among multiple categories, or if multiple routes of passage are to be evaluated, sample sizes must be quite a bit larger. The numbers of tagged fish released for Summer Spill 2005 studies would have been adequate for the original purposes, but were too small (in retrospect) to obtain the necessary precision for comparisons of multiple passage routes and alternative spill regimes. Time allowance for some advanced planning, along with some advance studies of the statistical power of the design chosen, will ensure adequate (larger) sample sizes and greater precision.

Question 4. Potential Effects of 2005 Spill Operations on Fall Chinook "Reservoir Type" Juveniles

Background on Chinook life history patterns

Until recently, most Snake River fall Chinook were assumed to exhibit an "ocean-type" life history, entering the estuary during the summer. Connor et al. (2002, 2005), using scale analysis, identified another life history type displayed by Snake River fall Chinook. These fish, termed "reservoir-type" Chinook, over-winter in the lower Snake River reservoirs and possibly the lower Columbia River reservoirs, migrating to the estuary the following spring. The rate of expression of reservoir type life history is inversely proportional to water temperature and growth during rearing (Connor et al. 2002). Cooler temperatures resulting from cold water released from the Dworshak Dam and reduced food supply may increase the proportion of Snake River fall Chinook that exhibit the reservoir-type life history. (See Appendix A. for more detailed information on Chinook life history patterns.)

The reservoir-type fall Chinook make an important contribution to returning fall Chinook salmon in the Snake River. In recent years, PIT-tagged reservoir-type Chinook have accounted for a larger percent of returning adults, especially females, than "ocean-type" Chinook (Connor 2005). High food availability in the reservoirs where these fish overwinter enable rapid growth, and reservoir-type Chinook smolts are much larger at the

time of entry into the ocean than ocean-type smolts (Tiffan and Connor 2005). (See Appendix A. for food habits information on juvenile fall Chinook).

Potential Effects of the summer spill on reservoir-type Chinook

Stimulation of migration from different flow patterns during spill - The migratory behavior of ocean-type subyearling Chinook through the Columbia River reservoirs has been described by several authors and is summarized by Coutant and Whitney (2005). The migratory routes are complex and include diurnal shifts in distribution to open water at night to shallow shoreline habitat in the daytime. The latter habitat was thought to be important for feeding. Most of fish were caught in the upper 3.6 m, with 80% in the upper 1.8 m. Curet (1993) concluded that the subyearlings did not pass through Lower Granite Reservoir and Little Goose reservoir quickly, using the shorelines and open water areas of the reservoirs for rearing. This is consistent with observations of Chinook feeding in large lakes such as Shuswap Lake on the Fraser River system (e.g. Graham and Russell 1979.).

However, detailed data on the vertical and horizontal distribution and migratory behavior of large Chinook (e.g. > 200 mm) such as reservoir-type Chinook are not available for late summer, autumn, and winter. It is also not known whether reservoir-type Chinook are relatively more or less entrained in water moving downstream during a spill event, in comparison with other operational modes. As discussed in detail in Coutant and Whitney (2005), movement of salmonids through the reservoirs is not a simple function of water velocity or flow patterns. Factors such as fish size, temperature, and physiological state are involved and can influence current-mediated migration in the surface waters of the dam forebay.

The larger size of the reservoir-type smolts likely confers a survival advantage over the ocean-type smolts, contributing to their higher representation among returning adults. The reservoir-type life history suggests that for fall Chinook juveniles getting to the estuary as fast as possible may not be the best for chances of surviving. Emigrating at a slower rate, feeding, and reaching the estuary/ocean at a larger size may increase the probability of survival due to reduced predator vulnerability. However, until detailed in-reservoir studies are conducted, it is uncertain if attaining a larger size in the reservoir *per se* confers significant survival benefits to reservoir-type smolts. Predation on other life history types of Chinook smolts by northern pike minnow (Shively et al. 1996) in the Clearwater River and by birds in the mid-river (Antolos et al. 2005) and estuary of the Columbia (Lyons et al. 2005) has been shown to be size and species specific. Physiological factors such as osmoregulatory ability are also involved. For example Beckman et al. (1999) investigated the possible role of a variety of factors on survival of hatchery-reared Chinook smolts on the Deschutes River OR. Spring growth rate, gill ATPase activity, and plasma IGF-I concentration showed significant relationships to SAR.

Are data available to determine if the 2005 spill caused significant changes in residency and number of subyearling wild and hatchery Chinook holding over in the upper river reservoirs and emigrating as yearlings in 2006? - No publications or data sets were found that provided a time series of population or residency estimates for overwintering Chinook in the reservoirs. Winter is a difficult season for sampling in the reservoirs because of ice conditions and possible changes in Chinook behavior due to low water temperatures. However, data were obtained during winter 2004-2005 (Tiffan et al. 2005), which might be compared with results of radio-tagging for winter 2005-2006, underway at present (see Appendix A). Winter 2004-2005 results showed residency times of up to 150 days but residency decreased in the spring, as fish resumed emigration.

Change in food supply for reservoir-type - Effects of spills on ecosystem processes and food species dynamics in Columbia River reservoirs have yet to be documented, so effects on the food supply for reservoir-type Chinook are unknown. It is likely that some of the likely potential prey species for reservoir-type Chinook, such as zooplankton and larval fishes, might be expected to be flushed into downstream reservoirs during spill events, which tend to take water off of the upper surface layers of the reservoir. Earlier studies showed that phytoplankton was flushed from the Columbia impoundments to estuarine habitats (Sherwood et al. 1990), but the likely impact of such flushing on production in the system has not yet been evaluated.

Question 5. What additional studies and monitoring would need to be implemented to provide the region with a more thorough evaluation of the potential benefits of summer spill in recovering listed Snake River fall Chinook?

1) Experimental studies involving controlled and coordinated dam/spill operations for multiple years, to address the effects of spill over some reasonable range of variation in flow among years, are required to conclusively address to the effectiveness of spill on Snake River Chinook salmon. A single-year study will not be sufficient to evaluate the juvenile phase of the Chinook life cycle, and the spill regimes for the various dams in 2005 were quite different, both relative to the timing of Snake River fall Chinook passage and in the physical conditions at each dam.

A 2004 summer spill study, comparing survival of radio-tagged subyearling Chinook salmon under two different 24 hour spill operations at Bonneville Dam (Counihan et al. 2005, and Evans et al. 2005) is instructive for the design of studies of summer spill passage and survival in the lower Snake. The ISRP in their review of the proposal for this study[2] stated that, "Summer spill is currently a key issue, and this study starts to address some of the questions of the benefit of summer spill by providing real data, which provides rationale to move forward with this project. However, a primary issue the ISRP has identified in the review of the Anadromous Fish Evaluation Program (ISRP 2004-8)

[2] ISRP 2004-5: Review of Summer Spill Study Proposal: Estimating the survival of sub-yearling Chinook salmon through Bonneville Dam during two spill operation scenarios using radio-telemetry. April 6, 2004.

is the need for a long-term plan for fish studies related to the hydrosystem with proposals developed as far in advance of implementation as feasible to allow for adequate planning, proposal development, and review."

2) Substantially augmented monitoring of tagged juveniles and adults throughout the system to allow wider-scale assessments of competing hydrological options, including strategies related to transport of Snake River fall Chinook juveniles. Consequently, the region's assessments will need to be highly reliable (increased numbers of tagged fish), if the region is to have any hope of contrasting divergent hydrological options, in terms of the mandate to protect and recover listed Snake River fall Chinook stocks.

3) It is important to determine the connection between changes in the hydrological regime and those in life history strategy. It remains unclear whether the reservoir-type fall Chinook is better viewed as an evolutionary response to a major change in the hydrological regime of the Columbia Basin or as a developmentally plastic response to variable hydrological conditions. Regardless, it is almost surely responsive to a changing summer spill regime. The Basin will ultimately require both a better in-river tracking system for these fish and some indication of the extent to which the over-wintering behavior is genetically programmed, as opposed to environmentally responsive and plastic. Perhaps the recent paper by Brannon et al. (2004) is relevant. They surmise that Chinook life history genetics are conditioned by temperature (i.e. life history types are arrayed on a temperature continuum).

The ISAB has emphasized that to resolve the very large uncertainties about the actual migration survival rates and the relative contributions of the two distinct life history types to the effective production of wild fall Chinook will require new data to be collected using a new study design. It will be especially important to collect scales from returning adults as they pass Lower Granite Dam to secure a large enough sample size to determine frequencies of the two life history types at that stage (ISAB 2004-2).

4) Survival of over-wintering reservoir-type Chinook salmon is an area that deserves further research. Estimates of mortality rates of fall Chinook exhibiting this life history during reservoir residency and during passage downstream have been difficult to obtain. To date, relatively small sample sizes have precluded any accurate calculations of survival rates. (See Appendix A for details of ongoing winter migration and distribution study updates.)

5) Data on fall and winter distribution of salmonids in other reservoirs, the tidal freshwater river and the upper estuary are also required to understand the ecology of reservoir-type Chinook. In this regard the monitoring of juvenile Chinook in the upper estuary by Bottom et al. (2005) could be expanded further upriver to the extensive tidal freshwater reaches below Bonneville Dam.

6) Any change in spill regime can be expected to alter the migrational dynamics of various other salmonid and non-salmonid species of interest. Quite apart from the necessity to manage the hydrosystem for several competing human needs, there are

multiple fish species that need to be accommodated. The effect of spill on Pacific lamprey and white sturgeon, species that have been documented to have passage problems in the hydrosystem, clearly needs additional study.

7) It will also be important to determine the consequences of changing the spill regime for upriver movements of adult salmon and any other species for which changes in summer spill timing and volume are relevant. There is anecdotal information (NMFS Hydro Division) that adult passage counts decreased at Little Goose Dam during the summer spill and increased when spill was reduced from 70% of daily average flow to 40% of average flow. Additional data/studies on adult salmon and steelhead passage behavior at lower Snake dams are needed to determine if there are any significant effects of summer spill on passage delay, fall-back, straying rates, and pre-spawn mortality of these migrants.

III. Conclusions

The ISAB found no studies **specifically** designed to evaluate the effectiveness of the court ordered spill on juvenile salmonid survival, travel time, smolt to adult return rates, or smolt condition. Some of the studies implemented on the river in 2005 may provide some information on the response of juvenile salmon to the increased spill. However, these results will not be complete until adult salmon from the 2005 cohort return. The data in hand suggest:

PIT-tag Studies

- NMFS/USFWS - It will be necessary to monitor the returning adults to establish SARs for the 2005 cohort, in order for this study to provide information relevant to the effectiveness of the 2005 spill. Adults from the 2005 cohort will return in three to five years. Reach survival estimates for juvenile migrants will be available in the spring of 2006. Draft post-release performance results of reach survivals were presented to the ISAB for Snake River groups, but data from Clearwater groups were not yet available. Nor do these estimates account for reservoir-type fall Chinook. The post-release performance (i.e. passage timing, spill exposure history, travel rate, and joint probability of migrating and surviving) of wild subyearlings and Lyons Ferry hatchery surrogate subyearlings were similar. Compared with either wild or surrogate subyearlings, production subyearlings emigrated much earlier, experienced almost no spill, and had higher travel rates and survival.

- FPC Analysis - The 2005 reach survival estimate may be a good indicator of a potential benefit of the 2005 summer spill for subyearling Chinook, but until SARs can be estimated it is only a potential benefit. Most of the preliminary analyses focus on survival estimates among years. These comparisons are of limited utility, given major variations in river hydrosystem spill operations among years and considerable annual variation in migration timing and passage behavior of subyearling Chinook from year to year. Travel time estimates may be adequate for the entire population of

migrating smolts but are inadequate for estimating travel times for wild fish and specific sub-groups of migrants (e.g. Clearwater fish).

- The survival estimates presented represent the joint probability of migrating as a subyearling and surviving through the reach of interest. Any changes in survival estimates observed among years could be due to a change in survival or a change in the proportion of fish migrating as subyearlings as opposed to yearlings.

Radio-tag Studies

- Radio-tag studies provided very useful data to determine passage behavior and survival estimates of subyearling Chinook at each of the lower Snake River dams and McNary dam during the court ordered spill. Data indicated that when provided with significant levels of summer spill subyearling fall Chinook juveniles passed through spillways at lower Snake River dams with little delay and high efficiency (96 to 99 % FPE).

- Data also indicate that the removable spillway weirs (RSW) tested at Lower Granite and Ice Harbor dams were efficient in passing a large proportion of the subyearling Chinook with high survival rates. Except for the on/off RSW tests, only one primary spill condition was tested; spill on for 24 hr/day. Controlled tests, varying amounts and duration of spill, would have given a better evaluation of spill effects on passage behavior and survival.

- Radio-tag data are very useful for evaluating overall spill passage behavior and survival at specific dams but not for multi-reservoir reach survival estimates (e.g. Lower Granite Dam to McNary Dam), system-wide survival estimates, or SARs because of relatively short-lived tag duration.

Subyearling fall Chinook Reservoir Type

- PIT-tag data on wild subyearling Chinook are not useful for evaluating immediate effects of summer spill. These studies are designed to determine long-term trends in SARs of wild populations.

- The effects of 2005 summer spill on the proportions of reservoir-type and ocean-type fall Chinook relative to the proptions observed in recent years may be observed in the spring of 2006 when reservoir-type fish migrate from the system.

Recommended Research Studies

- Replicate the studies of coordinated dam/spill operations for multiple years, to reflect some reasonable range of variation in flow among years, particularly as it impacts the effectiveness of spill on Snake River Chinook salmon.

- Substantially augment monitoring of tagged juveniles and adults throughout the entire system, to allow wider-scale assessments of competing hydrological options (i.e. transport vs. in-river strategies).

- Monitor the autumn and winter distribution of salmonids in other reservoirs, the tidal freshwater river, and in the upper estuary, extending all the way to Bonneville Dam.

- Evaluate the consequences of changing the spill regime for upriver movements of adult salmon, steelhead, and other species for which changes in summer spill are relevant (e.g. white sturgeon, Pacific lamprey, and American shad).

- Increase the monitoring of reservoir-type fall Chinook, throughout the system and over years. We will ultimately require both a better in-river tracking system for these fish and some sense of the extent to which this behavior is genetically programmed.

- Estimate survival of over-wintering reservoir-type Chinook salmon. In particular, estimates of mortality rates during reservoir residency and during passage downstream are needed.

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Appendix A. Background Life History Information on Juvenile Fall Chinook

Food Habits

The diet of Chinook subyearlings in reservoirs (lentic environment) is different than rivers and streams (lotic environment). In lotic environments (e.g. Hanford Reach on the Columbia River) subyearling Chinook (55-97 mm length) primarily ate aquatic insects, and in the lentic environment (reservoir Lake Wallula) switched to zooplankton, amphipods, and terrestrial insects (Rondorf et al. 1990). The corophiid amphipod *Corophium salmonis* is now abundant in Lower Granite reservoir and is also potentially available as food for reservoir-type Chinook (Nightengale and Bennett 1996 in Return to the River (2000 draft). However, as far as known subyearling Chinook do not feed on the amphipod (Curet 1993, cited in Coutant et al. (2005) (see also below)). The caloric benefit of the amphipod relative to zooplankton and insects has not been established (Chapter 5 (nwcouncil.org/library/return/ch5.pdf). However, aquatic insects, especially their larvae and pupae are known to have more fatty acids (Higgs et al. 1995) compared to amphipods.

As mentioned above the only data on juvenile Chinook feeding in Lower Granite reservoir indicates that larger fish (> 86 mm) fed mainly on larval fish while smaller fish (< 86 mm) fed on ephemeropterans (mayflies), cladocerans (water fleas), and dipterans (midges) (Curet 1993). Age 0 reservoir-type Chinook passing Lower Granite or Little Goose dams in spring 1997 were larger (112-139 mm, Connor et al. 2005) than the fish that Curet (1993) studied and therefore might be expected to feed on larval fish and possibly amphipods or mysids. Age 1 reservoir-type Chinook were larger again (222-224 mm; Connor et al. 2005).

Overwinter Movements and Distribution

In order to understand the effects of the 2005 spill on reservoir-type Chinook, data on SARs are required. There are good baseline data available on the sex ratio of returning reservoir-type Chinook for several years (Connor Dec 7, 2005 presentation to ISAB). The USGS is currently tagging and radio-tracking 2005 limited numbers of fall Chinook holdovers, which is a good start on an in-season assessment of reservoir-type Chinook which should tie with the SAR data when those become available. The following studies are in progress for the winter 2005-2006 (Tiffan pers. comm. to Tom Poe, Dec 14, 2005):

- Collection and radio tagging of reservoir-type Chinook in Lower Granite reservoir. 25 juveniles were collected and tagged on 11/02/2005, 23 juveniles on 12/06/05. It is hoped that another 25 can be tagged in January 2006.

- From Lower Granite Reservoir beach seine sampling 25 juveniles were collected, tagged, and released 25 juveniles on 11/02/05, and 23 juveniles on 12/06/05. It is hoped to collect, tag and release another 25 juveniles early in Jan 2006.

- Radio-telemetry antenna arrays kept in place from the summer studies for detections of smolts (and maybe some mobile tracking) are now being used to collect data on over-winter movement and distribution history, as was done in 2004. The tags being used have an estimated life of 139 days, but past history has shown that some have lasted over 150 days.

- If efforts can be expanded by collecting and tagging more fish, it should be possible to conduct a meaningful study of overwinter survival for tagged fish.

The ISAB looks forward to the results of these studies. Although the research planned is limited by budget concerns, the winter 2005-2006 data will be very useful to help assess survival status of reservoir-type Chinook, pending later SAR results.

Winter passage survival of over-wintering juvenile fall Chinook at lower Snake River dams is also deserving of further research. Mortality resulting from turbine passage routes could result in significant decreases in detections of radio tagged fish. To date, limitations based on relatively small sample sizes have precluded meaningful estimates of survival probabilities for over-wintering fish that passed through turbines in dams on the lower Snake River.

Lower River and Estuarine Distribution

Data on autumn and winter distribution of salmonids in other reservoirs, the tidal freshwater river and the upper estuary are also required to understand the ecology of reservoir-type Chinook. In this regard, the monitoring of juvenile Chinook in the upper estuary by Bottom et al. (2005) could profitably be expanded upriver to the extensive tidal freshwater reaches below Bonneville Dam. Results from the upper estuary habitats show Chinook are present during winter (Figure 1). If these fish remained in the habitats over the winter they would develop a freshwater check similar to reservoir-type Chinook, and therefore might be indistinguishable in returning adults. Long-term ecosystem studies in the reservoirs are also needed to understand the feeding ecology of reservoir-type Chinook and its effects on their survival.

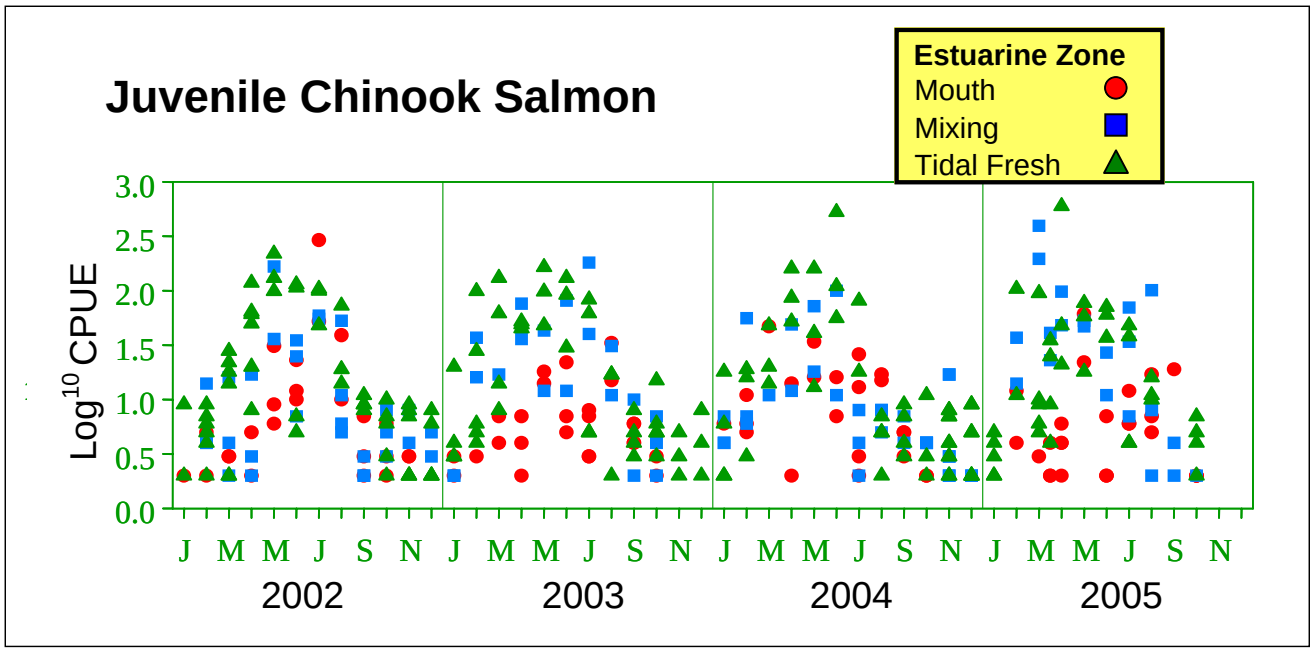

Fig 1. Results of beach seine sampling for juvenile Chinook in three zones of the Columbia River estuary (graphic courtesy of Dr. Dan Bottom, NOAA Fisheries, Newport; OR. presented at the AFEP Annual Review Nov15 2005).

Attachment 1. Memorandum from the Northwest Power and Conservation Council, October 14, 2005 (letterhead removed)

TO: **ISAB Executive Committee and Administrative Oversight Panel**

FROM: **Melinda Eden, Council Chair**

SUBJECT: **Request for ISAB Review of 2005 Spill Effectiveness**

At its October 12, 2005 meeting, the Council agreed to request the Independent Scientific Advisory Board (ISAB) to review the biological effectiveness of spill operations in 2005. The Council's 2003 mainstem amendments call for NOAA Fisheries, the federal operating agencies, and salmon managers to implement tests to examine the benefits of the current summer spill program for outmigrating juvenile fall Chinook, and to determine whether the biological benefits can be achieved in a more effective and less costly manner. The 2005 operations amounted to an experiment beyond the envisioned spill program, of which the Council is highly interested in the results.

Specifically, the Council asks that the ISAB consider the full migration and spill season and address the following questions:

1. What was the effect of the spill operations, including the net effect of the court-ordered spill, for juvenile survival over the various passage routes including the standard spillways, the removable spillway weirs, and other bypass routes?

2. How does or should the fall Chinook reservoir life-history type factor into an analysis of the effectiveness of the 2005 operations?

In answering these questions, the Council understands that the ISAB will examine data collected and analyses conducted by Columbia River Basin fish and wildlife agencies such as the National Marine Fisheries Service, the Fish Passage Center, and others. The Council asks that the ISAB review these data and analyses for their scientific soundness and where appropriate, suggest ways in which the analyses may be improved; e.g. were a broad enough range of years or factors such as temperature adequately considered? The ISAB should also highlight uncertainties that affect the analyses.

The Council values the fact that the ISAB serves not only the Council but also the National Marine Fisheries Service (NOAA Fisheries) and the Columbia River Basin Tribes. Consequently, the Council encourages NOAA Fisheries and the tribes to review, refine, and add questions to the Council's request and to provide information necessary to ensure a thorough review.

To be of greatest value, the Council requests that the ISAB complete the review by November 30, 2005.

Attachment 2. NMFS (NOAA Fisheries) and CRITFC Questions

NMFS Questions

1. Do sufficient data exist and do the analyses conducted to date provide an adequate evaluation of the effect of the 2005 summer spill program on:
    a. Juvenile survival and travel time?
    b. Smolt-to-Adult return rates?

2. What are the potential affects of the summer spill program on fish of the "reservoir-type" life history compared to fish that migrate as subyearlings?

3. Are studies currently in place or planned adequate to address these questions?

CRITFC Questions

1. Can the ISAB provide comparisons of estimates of route-specific survival and passage rates (i.e. for turbines, RSW, bulk spill, screens and bypass system) by project and reach?

2. Which stocks were likely to be most affected by the 2005 spill operations?

3. What additional monitoring would be appropriate and desirable to discern other useful biological knowledge related to spill and other dam passage routes (e.g., physical monitoring metrics such as temperature in the migration corridor and in transportation facilities; physiological status of juveniles as they move downstream)?

4. Can the ISAB relate the data available for interim analysis in the context of achieving recovery metrics for Snake River fall Chinook (e.g., meeting biological diversity, spatial structure and abundance)?