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ISAB Findings from the Reservoir Operations / Flow Survival Symposium

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I. Executive Summary

On November 9th and 10th, 2004, the Northwest Power and Conservation Council and NOAA Fisheries sponsored a reservoir-operations/flow-survival symposium. The ISAB was asked to provide scientific feedback on the Council's proposed operations of Hungry Horse and Libby hydroelectric projects, as described in the Council's Mainstem Amendments, and NOAA Fisheries' questions about Montana's subsequent System Operations Request (SOR, referred to below as the Montana proposal). At issue is the potential trade-off between the probable detrimental biological effects on the resident fishes in reservoirs and rivers at Hungry Horse and Libby dams under flow management with existing BiOp operations and the unquantified potential detriment to anadromous fishes in the lower Columbia River under the Council's 2003 Mainstem Amendment and Montana Systems Operations Request. There is also interest in determining the proper design of an experiment(s) to provide this quantification. The anadromous fish of most concern are ESA-listed Snake River fall Chinook salmon because they are believed to migrate during the August-September period when flows have been augmented by releases from Hungry Horse and Libby dams.

The ISAB found the relevant science to be in flux, providing no unambiguous answers at this time. Flow-survival debates have been prominent in the region since the first Fish and Wildlife Program and its water budget (1982). The current amendment and Montana's proposal have focused attention on one particular manifestation of the issue. Although the likely detrimental effects of current operations on the gross biological productivity (i.e., production through all levels of the ecosystem, including plants, invertebrates, and fish) of the Hungry Horse and Libby reservoirs and downstream rivers are easy to envision and are probably of a substantial magnitude, the way in which current operations will affect the species of greatest concern (sturgeon and bull trout) is actually unknown. The physical changes in flow in the Columbia River below Chief Joseph Dam (the uppermost limit of anadromous fish in the Columbia River) that would result from the Montana proposal are affected by so many factors that predictions remain too uncertain for fine-scaled biological analyses. Little attention has been paid to measuring the physical features of "flow" important to fish migration and survival, such as water velocity or within-day variations due to load following (power peaking). Reliance on broad averages and sweeping generalizations of flow-survival relationships are not adequate for resolving this specific issue. In addition, the effects of altered temperatures on salmon require reevaluation for their relationships to flow, in spite of new thermal modeling efforts.

Although summer-migrating juvenile fall Chinook salmon from the Snake River have been the main concern for downstream effects of the Montana proposal, there is new information about this stock's life history. Some juveniles are holding over their first winter in fresh water and emigrating as yearlings in the spring (termed the "reservoir" life history, also referred to as the holdover life history). Importantly, a disproportionately large percentage of returning adults are originating from these holdovers. This new information leaves us with major unresolved implications for management because populations adopting the holdover life history will not respond to flow changes in the same way that the "ocean-type" summer-migrating fall Chinook normally do. Juvenile fall Chinook salmon have a complex life history, much more so than juvenile spring/summer Chinook salmon, with observations of juvenile fall Chinook salmon emigrating in the Snake and Columbia Rivers throughout most of the year. The intent of flow augmentation is to reduce mortality of smolts by speeding their migration to the ocean. With the recent findings of the large adult contribution from migrants exhibiting the reservoir life history, and also for PIT-tagged late fall migrants (NOAA Fisheries, unpublished data), the strategy of using flow augmentation to speed migration should be reassessed.

In addition, estimates of survival of in-river migrants have included holdovers as an unknown part of the "mortality" experienced during emigration, i.e., a portion of those estimated to have died may actually have survived, but did not pass a tag detection facility downstream during their first year. Resolving the very large uncertainties about actual outmigration survival rates and the contributions of the two distinct life history patterns to the effective production of wild fall Chinook will require new data collected using a new study design. In particular, it will be important to obtain scales from returning adults as they pass Lower Granite Dam to secure a large enough statistical sample for determining frequencies of the two life history types at that stage. This task should be implemented in conjunction with continued studies of PIT-tagged smolts released above Lower Granite Dam, and the exploration of various options for radio tagging migrating smolts to determine their life history behavior, as well as the overwintering locations and mortality patterns for the reservoir type. The importance of these data collection issues for the Snake River fall Chinook goes far beyond the narrow questions concerning the Montana System Operations Request. For example, transporting Snake River fall Chinook salmon subyearling smolts to below Bonneville Dam likely affects the proportion of smolts utilizing the reservoir life history strategy, as well as their size and time of arrival to the ocean. This aspect of transportation needs evaluation.

Traditional flow-survival analyses are currently benefiting from detailed statistical analyses, with the result that different functional mechanisms for fish survival appear to be operating at different flows. There is good physiological evidence supporting delayed effects of hydrosystem passage that are likely expressed in survival in the estuary and ocean. Because adults respond negatively to flow increases, the effects of these increases on them, not just on juveniles, need to be considered as well. No existing models seem adequate for evaluating the flow effects from the Montana proposal.

All indications are that the down-river effects of the shifts in flow associated with the Council's Mainstem Amendments of 2003 will be small. There is some uncertainty whether the effect is positive or negative because flows under the Montana proposal will be slightly greater than BiOp flows at times and slightly less at other times. As a result, the Council's hypothesis that the effects on survival of salmonids in the lower Columbia River will be indiscernible is probably reasonable. Nonetheless, there is reasonable concern for potential cumulative effects of even such small changes.

No "passive" design for measuring downstream effects of the proposed change is likely to be effective in a reasonable period of time. Deliberate experimental flow manipulations of an amplitude considerably larger than flows that will result from the Amendments probably would allow empirical quantification of flow effects. Whether or not present institutional constraints would allow such manipulations, however, is an open question. An experimental trial of Montana's proposed flow regime is unlikely to reveal incremental biological effects within a modest number of years because annual variability in flow and salmon survival due to other causes is much larger than the expected effect of the Montana proposal.

II. Introduction

On November 9th and 10th, 2004, the Northwest Power and Conservation Council and NOAA Fisheries jointly sponsored a reservoir operations / flow survival symposium. The ISAB was asked to participate in the symposium and provide scientific feedback on the Council's Fish and Wildlife Program's hypothesis for the proposed operations of Hungry Horse and Libby hydroelectric projects, as described in the Mainstem Amendments, and NOAA Fisheries' questions related to those proposed operations. The ISAB was well prepared for the assignment, having reviewed and released numerous reports on the issues of flow augmentation and Montana operations over the past several years (ISAB 1997, 2001, 2002, 2003; ISG 1995, 2000; ISRP 2004). The fact that in each of the ISAB, ISG, and ISRP reports new and important insights emerged and many previously identified issues lingered is a reflection of the state of uncertainty and science on this issue. The symposium continued this trend.

The symposium was organized in response to the Council's Mainstem Amendments of 2003 that directed the region to test, implement, and evaluate an interim summer operation that employs new drafting limits at Hungry Horse and Libby dams. Summer drafting for flow augmentation in the lower river system would be limited to 10 feet from full pool by the end of September (elevations 3550 and 2449, respectively) in all years except the lowest 20th percentile water supply (drought years) when the draft could be increased to 20 feet from full pool by the end of September. Basically, the proposed Montana SOR operation would alter summer flow operations at storage reservoirs in Montana from the current strategy identified in NOAA Fisheries' 2000 Biological Opinion to a strategy that would shift elevated August flows and water releases more into September. Details can be found in the Council's Mainstem Amendments and in the System Operations Request filed by the State of Montana (2004-MT-2).

This ISAB report responds to a Council request (November 5, 2004) to examine the Council's hypothesis that the proposed Montana operations "will significantly benefit listed and non-listed resident fish in the reservoirs and in the portions of the rivers below the reservoirs without discernible effects on the survival of juvenile and adult anadromous fish [in the Columbia River mainstem] when compared to ordinary operations under the biological opinions" (p.26, Council 2003). In addition, in a July 19, 2004 letter from Bob Lohn, NOAA Fisheries Regional Administrator, to Judi Danielson, Council Chair, NOAA Fisheries posed four sets of questions that they felt were important in weighing the benefits and risks associated with the proposed action:

1. What is the "state of the science"? What information is available and applicable to this question? On which points is there consensus, and on which is there widespread disagreement?

2. Which of the attributes that are currently unknown or in general dispute are most important to decision making about hydro operations? What kinds of further research would be needed to resolve them?

3. Is there an experimental design practical and feasible for implementation in the next water year that would allow meaningful testing of the Council's hypothesis? If so, how would the experiment be structured?

4. In modeling projected effects of flow on listed and non-listed fish -- especially in instances where empirical measurements are not available or not practical or feasible -- what are the relative strengths and weaknesses of the available models? Is there credible scientific information that certain models (and modeling assumptions) are likely to be more reliable than others?

These NOAA questions pertain largely to potential changes in anadromous fish migration (especially ESA-listed Snake River stocks) in the Lower Columbia River from McNary Dam to downstream of Bonneville Dam that result from the modified drafting strategy at Libby and Hungry Horse Dams, two of the primary water storage facilities in the Federal Columbia River Power System. They also pertain to effects on anadromous fish migrations in the mid-Columbia River from Chief Joseph Dam, which blocks further anadromous fish migration, to McNary Dam. (Both Hungry Horse and Libby dams are on rivers that feed into the upper Columbia River in Canada and pass through intervening rivers, lakes and reservoirs in the U.S. and Canada.)

Early in 2004 the ISRP, including several members of the ISAB subcommittee, reviewed Montana Fish Wildlife and Park's *Proposal to Evaluate the Biological Effects of the Northwest Power and Conservation Council's Mainstem Amendments on the Fisheries Upstream and Downstream of Hungry Horse and Libby Dams, Montana* (ISRP 2004). Although the ISRP found that the proposal would provide useful information on upriver physical and biological effects on resident fish in the reservoirs and downstream from the dams resulting from the Council's proposed changes in dam operations, the ISRP added qualifications intended to improve the modeling effort and to focus the study on key indicators of trends in biological responses. The ISRP emphasized that the proposed study was but part of a broader question. The overarching issue is the tradeoff between the costs and benefits to resident fish and fisheries in Montana/upper Idaho and the costs and benefits to anadromous fish in the lower Columbia River. Although brief presentations were provided on resident fish issues in Montana, the November 9-10, 2004 symposium was focused on providing the most current information on the lower river part of the equation. Presentations were made by leading experts in the field, with facilitation by Dr. Willis McConnaha.

Presentations covered the following topics:
1) the Council's proposed operation, including upriver biological effects;
2) translating changes in flow to changes in velocity and temperature;
3) the status and presence of affected anadromous stocks;
4) biological responses to river conditions and flow augmentation, including reservoir-type chinook life histories, delayed effects, effects on adult passage, and modeling; and
5) research needs and experimental feasibility, focused on anadromous fish in the lower river.

The symposium and presentations were well organized, thought provoking, and provided sufficient background information for the ISAB to expeditiously generate some findings that we hope will move forward the regional understanding of the issue. The section below addresses the NOAA questions and concludes with observations on the Council's hypothesis.

III. Responses to NOAA Fisheries' Questions

What is the "state of science"?

The state of relevant science is in flux. Scientific understanding of flow survival relationships for juvenile and adult salmonids has progressed over two decades from simplifying assumptions, regression analyses of broadly averaged variables, and sweeping generalizations of results toward a synthesis of issue-specific, detailed data. This shift does not denigrate previous work; it simply reflects a growing sophistication of our understanding of the consequences of hydrosystem operations on fish survival. Many questions remain unanswered. New technologies and the data they provide are showing that the earlier assumptions and generalizations are inadequate or inappropriate for current needs. Change is being forced by the analytical demands of important issues ranging from development of Biological Opinions on hydrosystem operation to specific issues like the present Mainstem Amendments and the Montana System Operation Request.

This report is not the place for an in-depth scientific review. A few highlights from the informative symposium of November 9-10, however, will illustrate important points. The highlights are presented following the order of the agenda.

Refinement of the issue

The current issue (i.e., the Montana proposal) has been refined. It has progressed from a general upriver-downriver competition for water and its timing to more specific, data-driven issues. The main issue is one of reconciling potentially competing protections for biological productivity of ESA-listed bull trout, Kootenai River white sturgeon, and other important species in the Hungry Horse and Libby environs in summer against the needs of lower river ESA-listed anadromous migrants and other stocks for water in August and September. The issues include balancing social/economic as well as biological changes. Because resource managers must make decisions about the Montana proposal, it is increasingly apparent that a clear focus for the issue is necessary for science to provide useful answers. Although the probable effects of the Montana proposal in Montana and Idaho are fairly apparent, there are questions about the data and models used there that can stand refinement, as the Montana biologists have proposed and Council has recommended for funding. The questions for science are not just about what changes in flows would do in a general sense, but more specifically concern justifying the existing BiOp flow patterns versus the specific proposed changes in flows in August and September, how these flows affect the Hungry Horse and Libby environs both upstream and downstream, how the flows are routed downstream as waves and water particles (which are different), and the specific biological effects anticipated from these flow changes in downstream reaches. More focused questions can yield more focused scientific study (even of existing data) and better answers.

Physical effects of water flow and velocity

The water routing models seem inadequate to the task at hand, which is predicting changed flows for fish in the mid-Columbia and lower Columbia in August and September, either in formulation or application. The Council has made general estimates of volumes and travel times in the lower river (some of which are based on simulated 50-year averages that may inappropriately represent current variability or future conditions) that are informative but insufficient. The 14-step water model (monthly except twice-monthly for April and August) does not adequately depict the details of a water budget that can be translated to components of "flow" that are relevant to biological resources downstream of Chief Joseph Dam—quantity, velocity, timing, temperature, etc. Square-wave temporal targets, in which flow or other criteria change instantaneously with calendar date, are environmentally artificial no matter how convenient they are operationally. It was unclear to our team of mostly biologists whether the water models are technologically incapable of realistically determining downstream flow patterns from alternative Hungry Horse and Libby operations within a specific year (probably because of the effects of intervening facilities and their operations in the US and Canada) or if the calculations just included too many simplifying assumptions. If intelligent estimates of biological effects are desired, the hydrological aspects must be better developed and made more specific to the questions at hand.

It is dismaying that so little attention has been placed on measuring river and reservoir water velocities when so much of the traditional lore of flow-survival relationships in the mainstem depends on calculated differences in these velocities (travel times). Velocity measurements have largely, but not exclusively, been restricted to dam forebays and tailraces where other issues were addressed (e.g., bypass attraction and bypass outfall location). Hydrodynamic models have been developed and calibrated with cross-sectional velocity measurements for a number of forebays and tailraces in the mid-Columbia and lower Columbia and Snake River dams. These models are sensitive to changes in flow and may offer some means for detecting small changes in near-dam flow effects. This modeling approach needs to be extended to entire reaches and reservoirs.

Pertinent details of factors that affect velocities experienced by juveniles and adults (as well as resident fish) in reservoirs—reservoir morphology, daily and hourly load-following, potential seiches (reservoir "sloshing")—are blurred by simple calculations based on average river discharge and average reservoir volumes. These details likely contribute strongly to the large scatter in estimates of both travel time and survival information now available. Without a grounding in actual measurements that involve these factors, it is difficult to see how operational changes at Hungry Horse and Libby in August and September can be translated into functionally significant changes in salmon migrations, especially fall Chinook salmon migrations in the lower river, or in any other downstream species.

Relating flow to temperature

The well-understood relationships of salmonids to temperature are often misperceived and misapplied in Columbia River Basin practice. First, temperatures of the discharges from Hungry Horse and Libby dams do not easily translate to downriver temperatures because of long intervening distances containing rivers and reservoirs. Water temperatures could change downstream mainly as a function of the water particle movement, not the downstream-moving flow pulse, which is actually a wave phenomenon. As the well-developed field of thermal modeling recognizes, it is the balance between local heat fluxes, temperatures of inflows, and the volumes of water in local reaches, as well as flow rates that determine reach temperatures. In contrast, the discharges from Dworshak Reservoir, especially in summer, *are* relevant, because the short travel distance in the Clearwater River retains the cold discharge temperatures well into the Snake River through the lower Snake River reservoirs. "Flow Augmentation" in the Snake River is often inappropriately equated largely with Dworshak flow. The temperature of these cold-water releases, as well as their volume, is most likely the dominant operational factor affecting salmon survival. The misunderstanding of this relationship has led to scientifically untenable suggestions to further augment the Snake River flows to benefit fish using flows from Brownlee Reservoir that are *warmer* (and so would negate some of the survival benefit from Dworshak releases). Ironically, the Action Agencies proposal to purchase extra Snake River flow in summer 2004 as an offset for reducing spill could have added to *mortality*, not survival (based on thermal requirements of the fish).

Although temperature models are now being developed for the Columbia River that advance efforts started there in the 1960s, these efforts lag behind models in other river systems. The EPA model is one-dimensional, even though it would be more relevant for salmon survival to have multi-dimensional models that better reflect rearing and migration habitats, especially in the low flows and high ambient temperatures of reservoirs in July, August, and September. It is encouraging that multi-dimensional modeling is being done in Lower Granite Reservoir, where the vertical and horizontal patterns of cold water from the Clearwater River (Dworshak Dam) can be related to salmon survival and life histories such as the newly recognized reservoir-type life history pattern for fall Chinook.

Status and presence of affected anadromous stocks

It was heartening to see the realistic portrayal of the status and presence of various stocks of salmon and lamprey in the reaches of the lower river potentially affected by operational changes in Hungry Horse and Libby flows. Years of monitoring are yielding tangible benefits for understanding the timing and abundances of relevant native stocks. It was clear, however, that lamprey carry out most of their migration in the pertinent time period, yet have received little attention for evaluating effects. It would have been helpful to have heard some comment as well on the potential effects of the Montana System Operations Request on the extensive community of resident and non-native fishes in the lower river.

Prevailing views of the life history of Snake River fall Chinook salmon have been shaken by credible data demonstrating that a portion of the underyearlings halt their summer migration, overwinter in reservoirs, resume migration to the ocean in the spring, and return as adults – the so-called "reservoir" life history. Although other populations of fall Chinook salmon are known to include a significant component that remains in the river over the winter and migrates the following spring as yearlings (Wydoski and Whitney 2003), data have only recently been accumulated that demonstrate it to be a significant element in the life history of the Snake River stock. Furthermore, these holdover fish have been shown to experience a higher per capita rate of return as adults than the subyearling emigrants.

This scientific revelation raises questions about the estimates of smolt survival previously made for Snake River fall Chinook salmon; smolt mortality may have been overestimated and aggregate ocean mortality probably underestimated. Because the percentage of holdovers is not known, the magnitudes of the various misestimates also are not known. This lack of information adds considerable uncertainty when assessing the implications of the Montana proposal, the current BiOp flows from Hungry Horse and Libby that are intended to aid August-migrating underyearlings, and the current transportation program for fall Chinook. Given the apparent higher SAR of the reservoir life history, it becomes important to determine what conditions encourage smolts to select this life history option, and whether or not the Montana System Operations Request could bear on this selection process. If the original justification for an August flow augmentation from Hungry Horse and Libby is confounded by a change to a different migration strategy for fall Chinook originating in the Lower Snake River (and the survival deficit long believed to exist is, in part, actually retention of survivors), there is a new management reality to be faced. Clearly then, there is an urgent need to further understand and quantify the "reservoir" life history pattern of Snake River fall Chinook.

Biological responses

Flow-survival analyses

Our understanding of the complexity of relationships among flow, travel time, and survival is being aided by increasingly sophisticated statistical treatments, more data from additional years coupled with additional sampling within years, and increasing recognition of the factors that cause data scatter. These analyses cry out for fewer simplifying assumptions and more environment-specific information, as noted above. Flow thresholds for fish travel time and survival, seen as abrupt changes in slopes in many data sets, point to different functional mechanisms operating over different flow ranges. That is, different fish responses probably occur with different environmental conditions. The influence of load following that dominates discharge predominantly at low river flows is one example. These differences in functional mechanisms can be further explored and likely offer alternative ways to adjust hydrosystem operations to benefit fish. The ISAB has previously recommended such research. Whereas the incremental effect of flow changes from the Montana proposal on smolt survival as predicted from continuous models has been given most of the attention, a more pertinent question may be whether any of these functional thresholds for effects on survival will be crossed.

Delayed effects

Physiological research is demonstrating the plausibility of delayed effects from hydrosystem passage. Whether the information is applied to issues of transportation, flow in general, or the specific Montana proposal, it is now clear that migrating juveniles go through physiological changes beyond just smoltification. Energy reserves stored in lipids and proteins change through migration. Different migration timing, temperatures, and the metabolic costs of feeding and predator avoidance affect these reserves and likely affect subsequent performance and survival in the river and estuary. Physiological indicators of nutrition and stress can help define energetically deficient or stressful reaches of the hydrosystem, leading to more specifically beneficial measures. For example, a correctable migration delay at one dam may cause greater physiological detriment than the incremental change in river travel times resulting from the Montana proposal.

Adults

Recent telemetry data indicate that upstream-migrating adults respond differently to increased flow than juveniles in that adults' migration is slower at higher river velocities, perhaps to their detriment. The Montana proposal might shift some flows to later in the season when more adult fall Chinook are in the river. New data show that warm temperature in summer is an important detriment for adult migrations, i.e., slower migration speeds at higher temperatures, delays while fish seek cool refuges, and the rapid use of energy reserves needed for the remainder of migration and the spawning process. Incremental benefits or costs to juveniles need to be evaluated in the context of generally opposite effects on adults, which are individually more valuable to the population than individual juveniles. The incremental effect on fall Chinook adults of the Montana proposal is unclear because of unknown details of the effect on temperatures.

Models

The degree to which science is in a state of flux was demonstrated by work with two models, CRiSP and SIMPAS, both of which have been, and might be used further in the future, in attempts to assess the downstream effects of the Montana proposal. CRiSP is being modified to include a novel, but unproven, predator-prey hypothesis that smolt survival depends on travel time and distance. The theoretical construct, however, requires testing and validation. CRiSP is also evolving in other ways (to accommodate new data) that warrant scrutiny before the model is applied uncritically. The model SIMPAS, which was used to formulate BiOp flow requirements and could be used to evaluate the Montana proposal, appears flawed because it subsumes effects of temperature (and all other variables) in ”flow.” When the effect of temperature goes from being a net benefit to being a detriment above about 20 C, it is scientifically untenable to assume that more warm flow is advantageous. SIMPAS may be inadequate not only for evaluating effects of the Montana proposal, but also for its fundamental use in determining BiOp flows.

Climate change

The regional fixation on flow-survival relationships generally ignores the broader issues of temperature and precipitation change from global warming and the effects of human population increase on water demand that could significantly impact water quality and quantity. These points were brought home by a National Research Council review of water withdrawals.

Cumulative risks

Notwithstanding those broad effects, the NRC Panel warned of the cumulative risks of many relatively minor changes with individually small effects. This is clearly the potential of the Montana proposal—small changes and small effects in the lower river that might accumulate with other influences (like more water withdrawals) to yield significant, long-term changes. The incremental effects of the Montana System Operations Request on the mid-Columbia and lower Columbia, however, are likely to be beneficial at certain times as well as detrimental at others because of the shifting of flows between months, rather than any consistently one-sided net change.

Which attributes are most critical?

Better definition of the physical changes in flow and its corollary attributes at various points in the hydrosystem from Hungry Horse and Libby to Chief Joseph Dam and from there to the estuary is essential to be able to make reasonable estimates of the likely biological effects of the Montana proposal. Stable operations through the Canadian portion of the system are apparently not guaranteed. Daily average flows are not adequate to describe flow changes throughout the hydropower system relevant for fish because of hourly load following, especially at low flows of August and September. Experience in the Hanford Reach has demonstrated detrimental effects on fall Chinook salmon from hourly fluctuations in flow. Gross approximations of flow changes provided by the water models cannot suffice when biologists are asked to estimate fine-scale effects.

Among the biological questions, the life-history status of the ESA-listed Snake River fall Chinook requires the highest priority attention. This is the stock of primary concern in passage through the lower Snake River and the lower Columbia River. Our current understanding is limited because of the newly discovered importance of holdover fish (the "reservoir" life history that migrates to sea in spring) and the high return rate of adults from these fish that do not emigrate in the relevant time frame of August and September. Where they are retained in the Snake and Columbia rivers in fall and winter is central to the issue. If they remain in the Snake through the normal August-September migration period, they are outside the influence of proposed flow changes from Hungry Horse and Libby; if they migrate into the lower Columbia in summer before holding, then they could be affected by the Montana proposal. A portion of the fish does remain in the Snake River to overwinter. Connor's research includes samples of holdover juveniles caught in beach seines above Lower Granite Dam and others caught at the PIT tag detector at Little Goose Dam. Most likely, a variable portion of the fish remains behind in each reservoir on the way downstream. Speculations about retention location in the period when PIT-tag operations stop in the fall and resume in the spring need to be tested with more complete annual (winter) sampling.

Using present estimates of both hydrology and biology, we conclude that the effects of the Mainstem Amendment and the Montana System Operations Request on salmonids downstream in the Columbia River are likely to be small. They may be significant only as they contribute in a small incremental way to accumulating effects of many other small changes, negative and positive, such as water withdrawals or other hydrosystem operational decisions. Science cannot currently define whether the incremental effect of the proposal is significant in this broader picture, but efforts in this direction seem warranted.

Is there a practical and feasible experimental design to test the Council's hypothesis?

Although there is no experimental design that would immediately compensate for the lack of detailed flow information and our lack of understanding of the most important stock's life history, some directed experiments could provide that information over time. There are improvements in the analysis of existing and accumulating data on flow and survival of many stocks that can perhaps be used to further identify small effects when they occur within the context of historical and existing flows.

Finding a practical and feasible experimental design is difficult because the effects of the Montana proposal are likely to be small, both in terms of water amounts delivered and the resulting effects, if any, on survival. Considering the scientific uncertainties discussed above, any attempt to identify with precision what a "small" change in survival means is nearly futile. The range of estimates now available, however, suggests a numerically low change in overall salmon survival, with uncertainty over direction.

For example, in late 2002, the Council staff compared estimates of fish survival derived from SIMPAS (version 9) and CRiSP (Council memoranda dated November 6 and December 2 from Bruce Suzumoto to Council members). For SIMPAS, 11 populations of listed and unlisted stocks were examined; six for CRiSP; High, medium, and low flow regimes were evaluated. Using SIMPAS, the estimated percentage change in survival for Montana operations compared to the BiOp flows were 0, 0.3, 0.2 (high summer flow), -0.7, 0.5, 0 (medium summer flow), and 0, 0.2, and -0.5 (low summer flow) for Snake River fall Chinook, Lower Columbia Chinook, and Hanford Reach fall Chinook, respectively; all less than 1%. The most comparable results from CRiSP showed in-river survivals of 0.035 and 0.021 (high flow), -0.068 and -0.050 (medium flow), and -0.083 and -0.049 (low flow) for Hanford Reach fall Chinook and Snake River subyearling Chinook, respectively; again, all estimates substantially less than 1%. Furthermore, "small" in this analysis ranges from an estimated loss of 7 fish in 1,000 to a gain of 5 fish in 1,000 using SIMPAS, whereas using CRiSP, there is an estimated loss of about 8 fish in 10,000 (less than 1 in 1,000) to a gain of 3.5 fish in 10,000 (less than 1 in 1,000). Although we are reluctant to place high confidence in either of these models, the estimated changes in survival are quantitatively low and of inconsistent sign.

As another example, several graphs were shown at the workshop relating flow to salmon survival in the Columbia River, which can be used to estimate the anticipated survival change due to the Montana proposal. Council staff estimated the 50-year-average change in flow at McNary Dam to be diminished by 8.3 kcfs in July and 5.6 kcfs in August, but increased by 0.9 kcfs in September. The largest of these estimates (-8.3 kcfs) would yield an estimated change in survival from McNary to John Day of 0.01 percent (1 fish in 10,000) using graphical analysis of the plot shown by Steve Smith of NOAA Fisheries. Using the regression equation of underyearling survival from Rock Island Dam to McNary provided by the Fish Passage Center (Berggren and Filardo), and the Council's estimated July McNary flows, the change in survival for a decline of 8.3 kcfs would be 0.0098 percent (less than 1 fish in 10,000). Use of these regressions assumes that factors operate similarly in all river reaches, which is probably not entirely valid. Again, the estimated change in survival is tiny and can be obscured by other factors. The clear caveat, however, is that the 50-year average flow changes due to the Montana proposal may not adequately reflect flow extremes caused by exceptionally wet or dry years, which could be important for population survival.

It could be argued that the wide variability among data points used to develop the Smith and Fish Passage Center flow-survival curves indicates in each case that the percentage changes in survival from the Montana proposal would be statistically undetectable (i.e., the data would not meet the scientific standard for rejection of no effect). However, because the comparative analysis in each case uses the same data set with the same variability, the predicted effects can be quantified legitimately. We conclude that the effects would be small.

It was pointed out in the symposium that experimental designs developed by federal researchers and others have been stymied by lack of cooperation by other agencies. Permission has not been granted for use of fish, taking of scales, tagging, and other data collection. If lack of cooperation is indeed a factor, then the best experimental designs will require more effective interagency cooperation.

The “easiest” experiment may already have been initiated (and is still underway), with detailed flow records and passage and survival data on juveniles and adults from PIT-tagged individuals awaiting collection and further analysis. This conclusion presumes the existence of appropriately detailed flow and other environmental records, including year-around detection of smolts passing downstream.

What are the strengths and weaknesses of available models?

No present model is capable of an accurate, precise analysis of the effects of the Montana proposal. The two process models we examined, CRiSP and SIMPAS, contain unrealistic or untested assumptions. The models include an *a priori* effect of flow on survival based on simplified conditions, which to some extent predetermines the result. Nonetheless, both models suggest that the effect of the Montana System Operations Request will be small. The regression models we saw often contain so much data scatter that model fitting is itself uncertain. Because the regression models use the same data with the same scatter, however, comparisons can be made among flow conditions. The results to date from the Fish Passage Center and NOAA Fisheries regression models suggest the Montana System Operations Request would result only in small changes.

IV. Overall Council Hypothesis

The Council hypothesized in its Mainstem Amendments that certain modifications to current operations at Hungry Horse and Libby dams would significantly benefit resident fish without discernable adverse effects on the survival of juvenile and adult anadromous fish in the lower Columbia River. We conclude the following:

1. Resident fish and fisheries influenced locally by the Hungry Horse and Libby water-release situations may receive important biological benefits from the flow modifications, assuming they are carried out as planned. It is almost certain that the general productivity in the Montana reservoirs and in the immediate downstream reaches will benefit considerably. What are uncertain are the effects on the species of greatest concern (sturgeon and bull trout) when the increased productivity propagates through the community of predators, prey, and competitors. If the effects on these species are very large, they may be detected by future monitoring, but attribution of cause may still be confounded unless the experimental design alternates to provide years when the Montana System Operations Request is implemented and years when it is not.

2. Effects of the Council’s Mainstem Amendment and resulting Montana operations proposal on the survival of juvenile and adult anadromous fish in the Columbia River below Chief Joseph Dam will probably be very small. The available data and analytical tools do not allow us to say whether the net effect will be positive

or negative for fish present in the river in the August-September period. Other time periods were not addressed in the symposium. Based on the best information now available, the Council was likely justified in its hypothesis that the flow modifications at Hungry Horse and Libby dams outlined in its Mainstem Amendments would lead to effects on survival of juvenile salmonids in the mainstem Columbia River that will be too small to measure practically against both the measurement error itself and real background variation due to other causes.

3. Recognition of the holdover or "reservoir" life history pattern of one of the foremost stocks of concern, the ESA-listed Snake River fall Chinook, complicates assessment of this stock in relation to the flow proposal. Because further research on this life history pattern is so critically needed, it is important to implement monitoring systems that will make it possible to quantify the magnitude of holdover behavior and how that affects estimates of smolt survival and SAR, as well as to reveal what factors affect holdover behavior and overwintering survival in freshwater.

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