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RE: CRITFC Comments on Four Draft Technical Memoranda

Dear Mr. Stein,

The following are comments of the Columbia River Inter-Tribal Fish Commission on the four draft technical memoranda, or "white papers," released by NOAA Fisheries' Northwest Fisheries Science Center in late December, 2003. As you are aware, the Columbia River Inter-Tribal Fish Commission (Commission) provides technical support on behalf of the four interior Columbia basin treaty tribes with reserved fishing rights in the region – the Confederated Tribes of the Warm Springs Reservation of Oregon, the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes and Bands of the Yakama Indian Nation, and the Nez Perce Tribe. These comments are submitted at the direction and on behalf of the Commission's member tribes.

The Science Center developed the draft white papers to provide updated data and information for the FCRPS biological opinion revision that was judicially mandated in National Wildlife Federation v. NMFS. As we are sure you are aware, the issue of co-manager coordination is presently being discussed in this litigation. Under this context, a process is being developed to better allow for collaboration among co-managers on technical issues, including those covered by the four draft white papers. The first step of this process is a "scoping" which will allow NOAA to share the approach it is taking and to allow co-managers to identify issues for collaboration.

Consistent with the collaborative process agreed upon, the comments the Commission now submits on the draft white papers are preliminary scoping comments that are intended to help identify issues where collaboration is necessary in issuing a new biological opinion. The Commission has focused on identifying areas where assumptions underlying the white papers discussions may not have been explained or where alternative science may not have been addressed or is at odds with the conclusions. In addition, the comments identify issues or factors that were not considered in the white paper analyses. The comments submitted here should not be considered our final comments, but a starting point for collaboration. We hope that these comments will allow for more efficient and effective collaboration on the development of these papers.

General Comments:

We agree with the Fish and Wildlife Services' comments about the general structure and content of the white papers. With regard to the FCRPS Effects paper, the USFWS stated:

Overall, the document suffers from the lack of any decision framework guiding the presentation and interpretation of analysis and evidence of FCRPS impacts on salmon and steelhead. Burden of proof is applied inconsistently among the various hypotheses. Insufficient attention is devoted to detailing alternative hypotheses for the cause of particular impacts, e.g. stress and disease related reasons for low post-Bonneville survival of transported fish. Inappropriate metrics are sometimes used. Historical information is applied selectively, sometimes leading to inaccurate statements or misleading graphics. Much relevant literature, published either in the peer-reviewed journals or as technical documents of involved agencies, is omitted (some are referenced at the end of these comments). Scant attention is given to several of the impacts from construction and operation of the FCRPS on the physical, and hence the ecological, environment of Columbia and Snake Rivers. An example is the effect of impoundment and water management on water temperature [for a review of temperature effects, see McCullough (1999)].

In summary, the document is poorly organized. There are no clear problem statements and the methods, results, and discussion do not logically flow from one another. We could not consistently trace a problem statement to a method and then to the corresponding result and discussion. Then finally, it is difficult to review a document that does not contain a summary or conclusion section.

Similar inefficiencies are found in all of the white papers, limiting their utility and the ability for effective review.

Another overarching weakness of the papers is what they fail to address. The most obvious omission from the suite of white papers is a paper describing NOAA Fisheries' biological rationale for concluding that habitat improvement will recover listed stocks above Bonneville Dam. Because habitat improvement is the chosen means by which NOAAF intends to restore listed Columbia Basin salmon stocks, to completely ignore it seems a glaring oversight. There is a considerable amount of evidence aimed at the feasibility of habitat restoration as a means of rebuilding Columbia Basin salmon stocks that should be presented. We have attached a feasibility study prepared for the Commission in this regard entitled An Analysis of "All-H" actions for Snake River spring/summer chinook stocks using the PATH Life-Cycle Model, and a Preliminary Feasibility Analysis of those Actions (Attachment A).

Non-listed Fish: Lamprey and Sturgeon

Also missing from the white papers is any substantive discussion of the effects of the system on non-listed fish. While the Passage White Paper gives some mention to lamprey (pp. 101 and 123), such discussion is brief and uninformative. Sturgeon are given even less time; they are listed in a heading at page 123 of the Passage White Paper, but the discussion that follows then fails to even mention them. The effects of the FCRPS on both lamprey and sturgeon should be considered simultaneously with that of anadromous fish, both in the context of fish passage as well as the effect of the hydrosystem on populations in general.

Pacific lamprey are highly regarded culturally and religiously by Native American tribes. Former lamprey abundance provided both tribal and non-Indian fishing opportunities throughout Columbia River Basin tributaries. For example, significant lamprey collection at Willamette Falls for fish food processing in 1913 was documented at 27 tons (CRITFC 1999). Commercial fishermen in the 1940's harvested 40 to 185 tons annually (100,000 to 500,000 adults) at Willamette Falls for use as vitamin oil, protein food for livestock, poultry, and fish meal.

Along the Pacific coast, Pacific lampreys are believed to migrate into freshwater and move upstream to spawn from May to September, overwinter, and spawn in early spring the following year (Beamish 1980, Beamish and Levings 1991). In the Columbia River Basin, data from trapping efforts by NOAA Fisheries at Bonneville Dam suggest Pacific lampreys move upstream to spawn from May to October, with the run peaking in mid-July (Vella et al. 2001, Ocker et al. 2001). While NOAA's research has shown that hydroelectric projects can pose significant passage constraints for Pacific lampreys (Vella et al. 2001, Ocker et al. 2001), details about migration behavior and timing in the CRB are still nearly unknown, including rate of movement through the mainstem Columbia River, timing of movement into tributaries, rate of movement in tributaries and habitat preferences during migration.

Although adult lamprey counting at mainstem Columbia and Snake River dams is not standardized, population trends indicate precipitous declines (Table 1). Based on 1997 fish ladder passage estimates, there was a 65% drop in Pacific lamprey abundance between Bonneville (Columbia River km 235) and The Dalles (Columbia River km 308) dams, with another large drop (72%) between John Day (Columbia River km 347) and McNary Dam (Columbia River km 470) counts. Passage over upriver dams in the Snake and Columbia rivers in 1997 was low. Only 3% of the Pacific lamprey that crossed Bonneville Dam were counted at Lower Granite Dam (Snake River km 173) and approximately 6% crossed Wells Dam (Columbia River km 830).

Table 1. Comparison of Historic and Recent Passage Counts of Adult Pacific Lamprey at Columbia and Snake River Dams (from CRITFC 1999)

Dam	Former Counts	1997 Counts
Bonneville	350,000 in early 60's	22,830
The Dalles	300,000 in early 60's	14,835
John Day	----	14,845
McNary	25,000 in early 60's	4,213
Ice Harbor	50,000 in early 60's	1,454
Lower Monumental	----	217
Little Goose	----	245
Lower Granite	----	1,274
Rock Island	----	2,321
Rocky Reach	17,500 twice in 60's	1,405
Wells	----	773

Current knowledge of habitat use of juvenile Pacific lamprey is mainly limited to tributaries of the Columbia and Snake rivers (Kan 1975; CRITFC 1999). To date, studies of the use of mainstem habitats have been limited to adult and juvenile migration behavior and dam passage effects (e.g., Starke and Dalen 1995, Moursund et al. 1999, 2000). One reason for the paucity of data on juvenile habitat use is that few comprehensive fishery surveys have been conducted with the mainstem Columbia and Snake rivers.

There are a few known documented accounts of juvenile lamprey habitat use in mainstem reaches since the period of hydroelectric development (i.e., 1910 to 1968). These observations occurred when water surface elevations were rapidly lowered via manipulation of base flows by hydroelectric dams. For example, investigators documented several hundred juvenile lamprey emerged from the gravel near river km 566 and approximately 40 near river km 555 during a low flow test involving the Hanford Reach in early April 1976 (Page 1976). The arrival of ammocoetes in the collection system of Little Goose Dam suggests that some rearing (and possibly spawning) of lamprey in the tailraces of mainstem Snake River dams (BPA et al. 1994). This premise was substantiated by the report of Dauble and Geist (1992) that several juvenile lamprey were exposed during the test drawdown of Little Goose and Lower Granite dams in March 1992. Recently, investigators observed juvenile lamprey in a gravel bar downstream of Wanapum Dam (Geoff McMichael, PNNL, personal communication, April 2002). Two common features of mainstem habitats where juvenile lamprey are known to rear include a low gradient shoreline and gravel/sand substrate.

Habitat requirements of Pacific lamprey share several common features with salmonids. Both spawn in areas of relatively high velocity, are nest-builders, and eggs develop in the substrate. One important difference is that juvenile salmon emerge from redds soon after they hatch and rear along the shoreline until they migrate to the ocean during the first or second year of life. In contrast, larval lamprey or ammocoetes burrow into the substrate downstream of the nest after hatching, where they remain and develop for up to 6 years (Scott and Crossman 1973). At transformation, typically at stage 6 or as "young adults," they move out of their burrow and begin their migration downstream to the Pacific Ocean. While substrate composition of salmon and lamprey redds are different, adequate intergravel flow (a characteristic of alluvial habitats) is important for the survival of both taxa during their early life history development period. Thus, lamprey would benefit if additional mainstem riverine habitat were created for fall chinook salmon via manipulation of the current hydropower system.

Wide alluvial floodplains, once common in the Columbia and Snake rivers, are largely eliminated and fragmented because of extensive hydroelectric development. Remaining mainstem riverine habitats are restricted to the Hanford Reach of the Columbia River, Hells Canyon in the Snake River, and short sections ~2-5 km downstream of hydroelectric dams (Battelle and USGS 2000). This change suggests that one factor leading to the decline of Pacific lamprey is loss of mainstem riverine habitats for spawning and/or juvenile rearing.

Juvenile lamprey, or ammocetes, are small enough so that they may pass thorough tributary irrigation diversion screens that would restrict juvenile salmon passage. However, by the time they begin their seaward migration, they can become impinged upon turbine intake screens, particularly extended length submersible fixed bar screens (ESBS), installed during the 1990s at most Corps of Engineers dams with screen bypass systems. This problem was first identified in 1995 when test ESBS screens were lifted out of the turbine slots and dozens of lamprey were found impinged between the screen wedge wires. Subsequent studies by Batelle NW Laboratories (Moursund et al. 2002) indicated that juvenile lamprey are weak swimmers and cannot resist turbine intake velocities, with 70-90% of test fish becoming impinged on the screens at test velocities less that actual field velocities. They also found that juvenile lamprey, ammocetes, had the tendency to use their tails for locomotion and then became permanently wedged in the screens.

Another study at McNary dam indicated that of 700 lamprey released, only five were detected at John Day dam. Until recently, the common operation of the Corps has been to sweep impinged ammocetes from the screens so that they can pass through the turbines. Restrictions on tag size has thus far prevented survival tests for lamprey, although tags are currently being developed for these studies. Recent work by the Corps has resulted in smaller gaps between wire wedges on the screens to reduce ammocete impingement.

Migration and survival studies have been conducted for adult lamprey since 1997. Radio-telemetry techniques have been utilized to track adult passage thorough the Lower Columbia River dams. Vella et al. (2001) noted that of 130 adults detected at the Bonneville Dam tailrace, only 29 were detected at The Dalles and only three successfully passed over John Day. Particular problem passage areas were identified in the adult fishways. They included passage over diffuser gratings, high velocity areas such as junction pools, fish counting windows where lamprey were discouraged from climbing count windows due to restricted visibility necessary for counting, and areas around picketed leads, vertical slots in fishway entrances and cracks in the fishways themselves. The Corps funded research in 2001 and 2002 to attempt to identify structural remedies for problem areas in fishways. Stansell (2002), Moser et al. (2002) and Daigle et al. (2002) devised structural alterations in the Bonneville Dam fishway to facilitate passage, with plate over diffuser areas, modification of head differentials over weirs and wall dividers to adjust pool velocities showing promise.

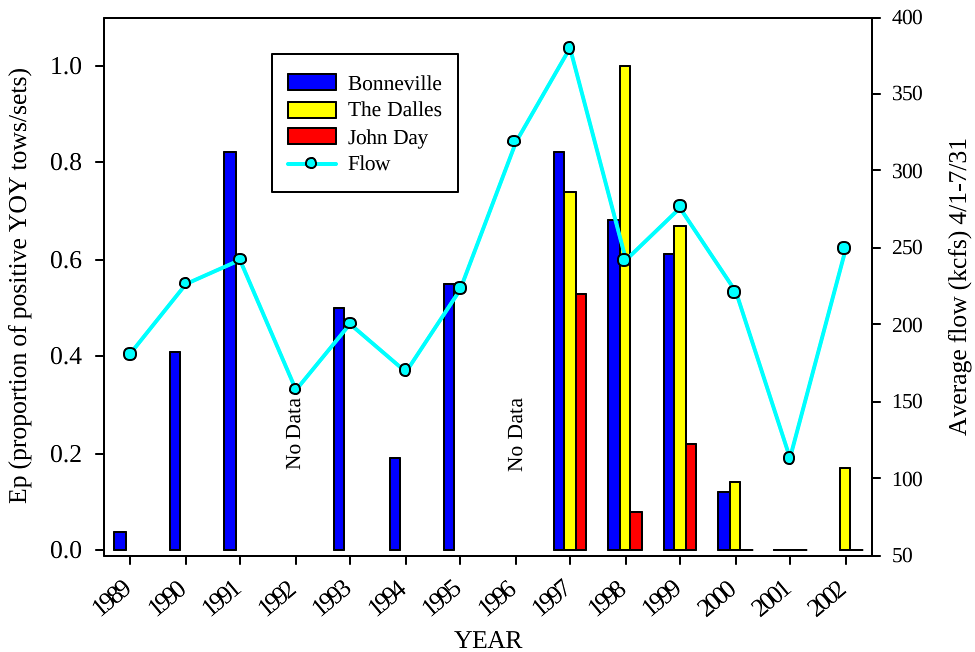
Adult lamprey can also be trapped below floor diffusers during fishway dewatering for maintenance. In November 2002, over 5,000 lamprey were trapped at John Day in this fashion, and of these about 1,200 were lost due to human error. Unfortunately, for 2003, just when adult passage solutions appear at hand, the Corps terminated all research funding for juvenile and adult lamprey passage in their Columbia River Fish Mitigation Program that annually receives about $80-100 million from Congressional appropriations.

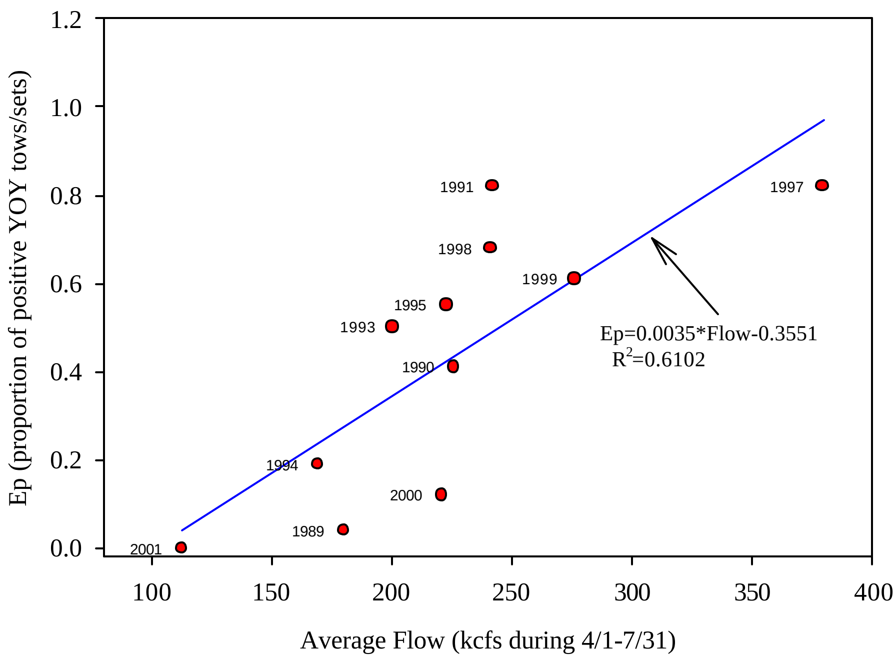
Pacific lamprey are a key indicator of the ecological health of the Columbia Basin and appear to be a choice food for avian and fish predators over salmon smolts (FCO 1959). Lamprey were designated as Category 2 candidate species for ESA listing in 1994 by the USFWS. On January 28, 2003, Pacific lamprey were petitioned for ESA listing by Adult and juvenile lamprey passage research is desperately needed and should be made a collaborative effort of all co-managers. Operations and maintenance procedures have been identified in tribal and agency comments to the Corps' annual fish passage plans that would avoid lamprey kills from dewatering fishways and other operations. The Corps should implement feasibility studies to install promising modifications to adult fishways to facilitate adult passage, and increase juvenile lamprey survival through dams and should evaluate the success of such modifications. Collaborative projects are also needed to develop lamprey supplementation research, methods and programs.

White Sturgeon are also culturally and economically important to the regions' fishing tribes. Reduced productivity of white sturgeon populations in reservoirs has complicated fishery management and affected harvest. Sustainable harvest levels have been reduced by low productivity caused by poor recruitment and slow growth.

Recruitment and growth have been reduced by altered flow regimes and degraded spawning and rearing habitat.

Potential yield of white sturgeon from impounded populations has been reduced by dam construction and operation of the hydropower system and its significant effect on white sturgeon spawning habitat. As can be seen in the figure below, during years of low discharge in spring and summer, the lack of high quality spawning habitat in impounded reaches may preclude successful reproduction. Recruitment to young of the year is poor during these years of low discharge.





Operation of the hydropower system consistent with salmonid recovery maximizes spawning and rearing success of white sturgeon in reservoirs. Spawning conditions are optimized by maintaining minimum discharge of 250 kcfs at McNary Dam during the time period when river temperatures are between 13 and 15 ^{o}C. Flow objectives of the Biological Opinion meet discharge recommendations for optimal spawning conditions for white sturgeon. The journal articles Parsley (1993) and Parsley (1994) provide supporting information.

White sturgeon are anadromous and the dams have eliminated this life history trait for the populations above Bonneville. Lack of passage to the ocean is the single greatest factor in the decline of sturgeon above Bonneville. While sturgeon do occasionally use fish ladders, mark recapture studies conducted by the states and tribes have shown that there is a net downstream movement of sturgeon in each reservoir from McNary to Bonneville. Recruitment to white sturgeon populations in The Dalles and John Day reservoirs has been low since development of the hydropower system. Though development of the hydropower system has reduced availability of habitat for spawning white sturgeon in these reservoirs, it has increased the area suitable for young of the year and juvenile fish. Mitigation efforts to supplement depleted populations of white sturgeon in reservoirs should be employed until changes in configuration and operation of the hydropower system have resulted in restored populations. This could inclued transplantation of naturally-produced juvenile white sturgeon from below Bonneville Dam into The Dalles and John Day reservoirs. Supporting documentation for this can be found in Rein (2002).

White sturgeon populations between Priest Rapids and Grand Coulee dams have little or no natural recruitment (upstream passage) under the current hydropower system and there is little potential for providing flows that allow spawning and recruitment. Initiating hatchery release programs to supplement populations in these areas, as well as others in the Snake basin, would allow establishment or re-establishment of white sturgeon fisheries. Currently, Commission staff is doing work in a research program to determine the best strategies for conducting sturgeon supplementation efforts. Supporting documentation can be found in Ireland (2002).

Monitoring is also needed due to the uncertainties associated with sturgeon populations and the benefits of any mitigation effort. Harvest in reservoirs should be monitored and regulated based on estimated abundance and exploitation rates that provide optimum sustainable yields. Periodic assessments of white sturgeon abundance, growth, recruitment, and age distribution in reservoirs needs to be perfomed. Periodic updates of population status will provide evidence of the success or failure of actions designed to restore white sturgeon populations. Currently the evalauation program has been on a 5 year rotation (i.e. sample each reservoir population every 5th year). Beamesderfer (1994) effectively captures all of the previously listed options for white sturgeon restoration under the Resident Fish heading.

Again, we thank you for allowing the Commission to provide these comments on the four draft white papers to be used in the revision of the FCRPS biological opinion. We look forward to further discussion of the issues identified, and collaboration with NOAA and the other fishery co-managers.

Sincerely,

Olney Patt, Jr.
Executive Director
Columbia River Inter-Tribal Fish Commission

cc: ODFW
WDFW
IDFG
USFWS
Fish Passage Center
NOAA Fisheries Hydro Division
NOAA Fisheries Regional Administrator

Attachments:

Peters, et.al. 2000. An Analysis of "All-H" actions for Snake River spring/summer chinook stocks using the PATH Life-Cycle Model, and a Preliminary Feasibility Analysis of those Actions. [Attachment A]

Letter from Michele Dehart, Fish Passage Center regarding Comments on NMFS white paper entitled "Passage of Juvenile and Adult Salmonids at Columbia and Snake River Dams" (Janurary 30, 2004). [Attachment B]

Letter from the State, Federal, and Tribal Fishery Agencies Joint Technical Staff regarding the proposal to the Corps of Engineers Study Review Work Group (SWRG) to discontinue the 1% peak turbine efficiency turbine operating limits (May 29, 2003). [Attachment C]

<u>References</u> (cover letter comments):

Beamesderfer, R. C. P., and R.A. Farr. 1994. Alternatives for the protection and restoration of sturgeons and their habitat *in* Proceedings of the International Conference on Sturgeon Biodiversity and Conservation. New York City, New York.

Ireland, S. C., P.J. Anders, and J. T. Siple. 2002. Conservation Aquaculture: An adaptive approach to prevent extinction of an Endangered white sturgeon population. Pages 211-222 *in* W.Van Winkle, P.J. Anders, D.H. Secor, and D. A. Dixon, editors. Biology, management, and protection of North American sturgeon. American Fisheries Society, Symposium 28, Bethesda, Maryland.

Parsley, M. J., L.G. Beckman, and G.T. McCabe, Jr. 1993. 1993. Spawning and rearing habitat use by white sturgeons in the Columbia River downstream of McNary Dam. Transactions of the American Fisheries Society 122:217-227.

Parsley, M. J. and L. G. Beckman 1994. White sturgeon spawning and rearing habitat in the Lower Columbia River . North American Journal of Fisheries Management 14:812-827.

Rien, T.A. and J. A. North. 2002. White sturgeon transplants within the Columbia River. Pages 223-236 *in* W.Van Winkle, P.J. Anders, D.H. Secor, and D. A. Dixon, editors. Biology, management, and protection of North American sturgeon. American Fisheries Society, Symposium 28, Bethesda, Maryland.

Passage of Juvenile and Adult Salmonids Past Columbia and Snake River Dams

Overview:

In many instances, the passage white paper fails to review recent data, with most sections written with references to 2000 data. There is a significant body of research that has been completed since 2000. If decisions are to be made on the "best research", it should include more recent studies that evaluated the operational and structural changes that have occurred at the hydroelectric projects since 2000. The paper's failure to evaluate more recent data is especially disappointing given the fact that its purpose is to provide "the most recent data and information on the impacts of the FCRPS" for the BiOp revision (as noted in Usha Varanasi's letter releasing the white papers, December 22, 2003).

The white paper contains no discussion about fish passage impacts during the low water year of 2001. In river migrant survival indicated significant impact from low flows and reduced spill operations at the eight mainstem projects. Steelhead in river survival was less than 10% from Lower Granite to Bonneville, and yearling Chinook survival was in the low 20's. A discussion of the impacts of reduced flow and lack of spill, lack that which occurred in 2001, needs to be added to this paper.

The information presented in the paper does not represent all the pertinent research with regard to fish passage information available in the region. Additional research completed by USGS performing radio tagged evaluations is not mentioned, and the Comparative Survival Evaluation is also not mentioned. Further a great deal of time is spent discussing operations at dams that have little to no impact on the survival of fish passage as they migrate past dams. These sections provide no new information and do nothing to increase the readers understanding of the hydrosystem impacts on juvenile migrants.

We concur with the following USFWS general comments:

While the task of summarizing the vast body of research on juvenile and adult passage is large, the summary presented in "Passage of Juvenile and Adult Salmonids at Columbia and Snake River Dams" is lacking in several respects: content within each of the subsections is not organized in a clear and consistent fashion, there is little attempt to judge the quality of the research studies that have been conducted or the strength of their conclusions; results from small or poorly-designed studies are given equal weight with large, well-designed studies. A qualitative assessment of the validity and strength of conclusions for each study would be very helpful, there is little synthesis of the results from past research and what they mean for current and future management decisions and research. Preliminary data are too often reported and personal communications are too often used as references. Analyses and recommendations by fishery co-managers have not been incorporated into the document. Critical uncertainties of passage related issues in the context of overall salmon survival and productivity have not been identified, which *would greatly aid in directing future research. Several sections need to be updated, as they discuss "future" research that is to take place in 2001.*

We are not surprised by these USFWS comments and encourage the USFWS' participation in the collaborative co-manager process to revise the four white papers and the biological opinion in general.

Lastly, the document provides little context for how passage related impacts for juvenile and adult salmon impact overall life-cycle survival. The passage impact information needs to be integrated into an overall analytical framework to assess the impacts of direct and indirect affects of passage and hydrosystem operations on achieving salmon survival and productivity needed for recovery.

<u>Specific Comments:</u>

Throughout the document:

There needs to be a discussion of the differences between tagging methods, their strengths and their limitations. Are PIT tags providing the same estimates as radio tags? What are the limitations of balloon-tags and when are they appropriate? Which tagging methods lead to robust conclusions and which are largely uninformative? These questions need to be discussed at the onset before conclusions can be drawn based on the many varying tagging studies that have been conducted. The region has held two specific meeting dealing with concerns over the methodologies used in survival and passage studies. The findings and discussions from those meeting should be incorporated into the white paper.

We have also reviewed and concur with the comments prepared by the Fish Passage Center. The Fish Passage Center provides valuable analysis and collection of data with regard to fish passage information and we agree with there comments on the white paper, "Passage of Juvenile and Adult Salmonids at Columbia and Snake River Dams." We have attached the Fish Passage Center comments (Attachment B) and expect them to considered with ours.

Seasonal Spill Timing

There was no rationale provided for the planning dates set for the spill season. We have understood that they are an attempt to provide spill passage for 95% of the migration, however there is no discussion about how these dates where arrived at and for what target species. There was also no discussion about potential importance of the tails of the runs and there genetic contribution to the overall population. This must be addressed.

Forebay Predation

A great deal of discussion is made throughout the paper and references made to predation in both the forebay and tailraces, however there is no updated information about populations of predators. Furthermore there does not seem to be a plan or outline on how to address this issue.

Tailrace Passage

Several paragraphs in this section discuss the impacts of predation on migrants and minimum hydraulic thresholds that reduce predation from Northern Pike Minnows. This section neglects to address predation from any other species or how to address or reduce impacts from them. Several exotic aquatic species are known to prey on juvenile migrants, but there is no discussion about their predatory abilities or impacts on juveniles in the tailrace. Avian predation is a known concern, which is why we have encouraged installation of bird wires at locations were juveniles are more susceptible to avian predation as well as advocating best tailrace egress conditions for juveniles in tailraces to insure best possible passage in the tailraces.

Spill Survival

This entire section needs updating. Tables 1 and 2 only include some of the research through 2000. On page 13, the white paper talks about preliminary analysis from the 1999 data; is this analysis not yet completed? The final research report was received nearly 4 years ago. Numerous spillway survival studies have been completed at many of the hydroelectric projects since 2000. These additional evaluations need to be included to insure that the most recent and best research is included for management decisions. There are also biased sweeping statements such as the following, "Hence survival over spillways with flip lips may be reduced somewhat when spill occurs at lower flow levels." While this may be true at some projects such as Ice Harbor, this does not necessary apply to all projects. Before such sweeping generalizations can be made research should be conducted to evaluate these claims. Without such information such claims should not be included in a technical white paper such as this paper claims to be.

Dissolved Gas Standards

Current discussion among agencies about the applicability of the 115% total dissolved gas level below Bonneville has occurred. The 115% was set as a forebay limit. The river below Bonneville returns to an unimpounded condition with higher velocities thus reducing the time juveniles would spend in higher levels of TDG that were of concern for juveniles migrating in the forebays. The continued management of spill at Bonneville to the 115% level should be investigated and evaluated as a potential management option for the future to improve juvenile survival past the project.

Table 3 in the report indicated that spill levels at Bonneville for the gas cap are 100 -135 kcfs. This is based on old information. End bay deflectors have been added to the spillway and the estimated spill volume to meet the current TDG management target is approximately 130 – 150 kcfs. A similar statement pertaining to the McNary spill volume is also in error. This entire table needs to be updated.

Juvenile Passage Through Mechanical Screen Bypass Systems

Overall this section is so poorly written and organized that there are no overarching conclusions or recommendations on outstanding issues. There is no discussion about the possible effects of multiple bypass or if studies have been conducted to determine its effects. The Commission has continually maintained – based on available PIT tag and other data – that bypass system do not provide adequate passage for full life-cycle survival when compared to spill. However, this paper does not even mention the issue.

Further, there is no discussion about the importance of outfalls and the need to insure that egress conditions at the outfall are optimum under a wide range of project operations. The whole reason that approximately 68 million dollars was allocated from the Columbia River Fish Mitigation budget and used to move the Bonneville Powerhouse II JBS nearly two miles down stream was because of poor performance of migrants at the outfall. Yet this paper does not even discuss outfalls let alone the important factors necessary to insure adequate conditions exist for migrants using the bypass and outfall system.

Fish Guidance Efficiency (FGE)

The document spends a great deal of time discussing guidance efficiency estimates and fyke net estimates. However, there is no discussion about the potential biases and problems with fyke nets and hydroacoustic techniques. A major concern with fyke netting is that capture efficiency degrades over time due to debris building up on the nets and then reducing flow and thus guidance into the gatewell. Hydroacoustic sampling is a more robust method, but has difficulty identifying targets and can easily over or under estimate FGE depending on the accuracy of identification of targets.

Orifice Passage Efficiency (OPE)

The paper discusses the improved OPE achieved through the use of extended bar screens (ESBS), however there is no discussion about the downside of ESBS. Descaling and stress levels of fish bypassed through ESBS gatewells are higher than those of fish passing through STS gatewells. This occurs due to the increased flow up the gatewell that occurs with the deployment of ESBS's. When an orifice is blocked due to debris, fish mortality occurs after only 2-3 hours in ESBS, while migrants in an STS can survival for over 24 hours. The increased flow and turbulence may increase OPE since fish are treated more like neutrally buoyant objects rather than active migrators, however there are other effects that must be discussed.

Separators and Separations Efficiency

This was one of the longer sections of the paper, but has the least to do with fish passage at hydroelectric projects. While numerous years of research have been committed to this work, we have seen little to any benefit from it. Nowhere does this paper discuss the measured benefits in SAR's due to improved separation.

Further the current transport system is incapable of dealing with large scale separation, so even if improvements in separation can be made there are no plans to implement them in the transport side of the equation. Further, SAR's from LWG, which does not employ separation of transported juveniles, consistently has the highest SAR's of any transported juveniles in the system.

Diel Passage and Timing

Under the John Day section this paper mentions that juvenile steelhead generally pass at night regardless of spill discharge at their arrival. Unfortunately the authors did not thoroughly review the research. The study only looked at 30% daytime spill, concluding that higher daytime levels my actually increase overall steelhead passage; this claim can only be made for spill at 30%. Limited information from time periods during large forced spill events indicated the juvenile steelhead will migrate during the day. Further and more disturbing is the author's omission about the size relationship that was observed during this evaluation. Steelhead under a certain length, about 130 mm , were found to migrate during the day. Steelhead over that length were found to delay and pass at night. The smaller steelhead correspond to wild steelhead while the larger steelhead were almost exclusively hatchery steelhead smolts. It is disturbing that the authors failed to mention this fact.

The passage information about Bonneville needs to be updated. Powerhouse priority was changed during the juvenile migration season and has greatly altered the passage numbers of the project. It is troubling that this was not mentioned since a great deal of time and effort has been spent to improve conditions at Bonneville and powerhouse operations changes are critical to these improvements; yet, there was no discussion of these improvements anywhere in this document.

Water Temperature Effects

The paper claims that the upper incipient lethal water temperature for salmonids is defined as 77 degree F. It is our understanding of reviewing temperature information with regard to salmonids that 70 degrees is the conservative start of the lethal zone for salmonids. (Snyder, et al 1966, Brett, 1960, Dawley 1992, McCullough 1999) It seems strange that the paper would only discuss the upper temperature level and not discuss the range especially since different salmonids have differing sensitivities to temperature. Further the paper discusses massive fish mortality that occurred at temperature exceeding 70 degree F.

The paper also discusses the Water Quality Teams attempt to come up with alternatives during high temperature situations at McNary. The state schedule was approval of a plan by 2000. Has this been complete? This is nearly 4 years ago.

Surface Bypass Premises

While this section provides some interesting discussion of hypotheses, there is no discussion or relation of these hypotheses to the actual research discussed. How accurate are these statements? This section needs to be rewritten and summarized with references to actual data.

Surface Bypass Designations

This whole section needs updating. There has been a great deal of change in the system especially with the RSW installation at LWG and the testing in 2004 of the corner collector at Bonneville dam. It is disturbing that so little discussion about these technologies that are cornerstone efforts at these two projects is provided. Much of the information in the entire section is old and outdated; systems that are identified as planned are now built. Other systems that are discussed have been removed or greatly modified, and some have been dropped from discussion.

The section "The Dalles Dam Ice and Trash Sluiceway" (page 83) needs to be updated. There have been several years of survival study since 1997. Further the operation at The Dalles has been changed to 40% spill which was not tested in any of the years of research that this paper referred to.

The permanent collector system at Rocky Reach (discussed at page 84) has been completed for nearly two years. The System has not achieved the estimated levels of passage that were hypothesized and used to justify the current design.

Juvenile Passage Through Turbines

We greatly disagree with most of this section and its findings. We find it curious that this is the only section of the white paper that used updated research while many of the other sections only used research from 2000 and prior. The use of balloon tags to estimate turbine passage has been argued strongly in the region. Currently no scientific consensus exists on the topic and the use of such data is subject to much speculation.

The paper discusses at length the Skalski et al. (2002) publication dealing with turbine operations juvenile survival. Based in large part on the Skalski et al. 2002 publication, the paper goes on to conclude on page 96 that a "statistically valid relationship between turbine operation efficiency and fish survival does not appear to exist." The white paper's conclusion section on page 98 then states emphatically, " Statistical relationship between fish survival and Kaplan turbine unit efficiency for Snake and Columbia River dams does not exist." However, the Skalski et al 2002 publication that is the basis of this statement, states, when discussing the four sites used in the analysis, "However, at three sites, maximum survival was within the 1% peak efficiency operating rule." We believe that tubines should be operated to the 1% range until a more thorough evaluation can be completed to determine what the peak survival operating point of a turbine is. The Corps of Engineers has a turbine survival program with an objective to address survival and turbine passage. However, there is no mention of this Corps work or hypothesis about operating ranges. It would seem prudent to use information from this source when discussing turbine passage.

The fish managers responded to Skalski et al. 2002 in a letter dated May 29, 2003. Please find this letter attached (Attachment C).

At page 96, the paper states that, "The physical conditions fish experience passing through turbines is less than through spillway stilling basins." This statement is not entirely true. The conditions of the spillway and turbine are dam and project operation specific. Therefore it may be true that under certain circumstances spillway stilling basins may provide poorer physical conditions for fish than turbines, it is also true that fish survival through spillway stilling basins is higher that turbines. To date no project survival study has indicated that test fish that used turbine passage survived better than spillway. While the converse has been demonstrated in numerous studies (Galbreaten, 1993), this statement should be altered to reflect our comments and discuss the difference of fish passing through a spillway stilling basin and a turbine and draft tube.

The paper also discusses the travel time through turbines and that of spillway stilling basins. While this is interesting trivia, it is meaningless. A more meaningful comparison would be to juvenile passage under the spill gates to turbines, or the spillway stilling basin travel time compared to turbine and draft tube boil exit. This would be more suitable comparison since the turbines are only the beginning of the passage route for juvenile migrants.

Adult Passage

Page 101: Paragraph 1 "…but none have been confirmed with empirically-derived data to actually cause extra mortality". Proving causation is difficult if not impossible in dealing with complex ecological systems such as the Columbia Basin. Decisions can be reasonably made using a preponderance of scientific evidence however.

Paragraph 3. The first sentence is simply not true. There is no uncertainty that the hydrosystem causes extra mortality. NMFS has found that the federal hydrosystem does cause jeopardy to listed species. There may be some uncertainty about the whether other factors aggravate or in part mitigate for this extra mortality, but the existence of the mortality cannot be reasonably denied.

Page 101-02: Lamprey passage. The last sentence on page 101 suggests that the hydro-system effects on juvenile lamprey are not known. This sentence is misleading. As discussed in the Commission's cover letter to this and the other three white papers, while the full effects on lamprey are not completely understood, there are known effects. They do find real dead ammocoetes impinged on screens. Screens do kill some juvenile lamprey. The possible effects on juvenile lamprey especially in the absence of spill might be quite severe. Current information appears to indicate that juvenile lamprey do not actively avoid screens or turbines or anything as they appear to migrate completely passively just as a leaf floats in the current. Because juvenile lamprey either can not or at least do not appear to be able to swim against the current, it appears that any lamprey that contact screens will become impinged. It may be that the debris brush sweep may mask total numbers of ammocoetes impinged on the screens. Such an occurrence took place at John Day in 1998 where the screen cleaner became jammed in placed for several days. When the extended fish screen was removed for repairs hundreds of juvenile lamprey were found to be impinged on the screen. This would indicate that a large percent of juvenile lamprey come into contact with fish screens and are removed by the brush screen cleaning system. It is highly unlikely that this removal process is benign. To date no research has been conducted to quantify this effect.

Page 103-4: Paragraphs 2-4: Unfunded maintenance and inadequate facilities. There should be a higher priority on getting these issues fixed. It sounds like the Corps of Engineers generally knows what needs to be accomplished but does not have the funds to do it. The paper does not make any recommendations for dealing with this issue.

Page 104: Migration Behavior. This section should discuss more/ mention the potential for PIT tags to be used to evaluate some of the questions for which radio tags are currently used. Also, the paper needs to incorporate more recent data. There are much better PIT tag data available from Bonneville and Lower Granite for the past couple years (as well as some other places). There are several apparently conflicting statements made regarding migration timing. The paper states that, "there was no evidence that radio-tagging affected chinook passage rates...," but in the end of that sentence the paper says that radio tagged fish migrate significantly faster that PIT tagged fish. This actually suggests that there may be effects (not clear if positive or negative or neutral) of radio tagging fish.

Page105: Paragraph 2. Last sentence – "Under rare high flow……upstream movement can slow…until the event subsides." It seem plausible that it is the change rather than the higher flow it self that slows migration. The way this sentence is worded suggests that flow or high spill will "permanently" slow migration and therefore is not a good thing. It seems more likely that rapid increases in flow and subsequent drop in flows adversely affects migration timing not the total amount of flow.

Entry time into ladders. There is an implication that high flow and/or spill increases the time required to enter fish ladders. It may be more complicated than simply flow or spill; there may be temperature, turbine operation, ladder design issues, etc., that may impact timing or that might be used to address any concern.

Page 107: Last two paragraphs. The paper compares historic migration speed estimates with radio tag estimates. Historic steelhead migration speeds are said to be spring 11.3-16.0 km/day and fall 8-9.7km/day. Then the paper states that radio tag summer speeds are 10.7-16-7 km/day and late fall migration rates are 0.5 km/day. This seems like an apple and orange comparison. With the apparent seasonal changes in migration speed, it is probably not possible to compare spring with summer. Also, since it was stated previously that radio tagged fish migrate faster than PIT tagged fish, using radio tags at all to measure migration speed seems to introduce a bias in comparing to untagged fish. Discussions of migration timing should probably utilize recent PIT tag data and should relate the migration speeds to environmental conditions.

Page 108: Paragraph 2. The last sentence says that Bjornn estimated that the median time for salmon to pass the lower Snake was the same or less than without the dams. This may be an inaccurate statement given that the paper also says that radio tagged fish migrate faster than PIT tagged fish.

The paper asserts that there is little or no difference in migration times whether the fish pass over the dams and through the reservoirs or in tributaries. This statement ignores impacts to adults spending longer times in poor water quality than under historically cleaner conditions. The FCRPS exhibits higher water temperatures for extended periods of time, whereas the historical system was flashier with regards to temperature (Karr et al., 1998). Historically, there was a rapid temperature increase followed by a rapid cooling. This peak usually took place at the end of July and into the middle of August. Historically, adult runs were timed to avoid that time period. Few if any adults were in the river system at the times of these peak temperatures. By altering the shape of the temperature regime, we have increased the exposure of adults to water quality-challenged water.

Further this compares travel times of adults in the mainstem to that of tributaries. This is a weak comparison since adult behavior in a tributary will likely differ than that of main stem migration. Adults, upon entry to a tributary, may begin spawning rituals such as red digging and sparing for mates. A better comparison would be to compare adults migration through a non-impounded section of a mainstem migration route with that of the passage time through an impounded section.

Paragraph 3. The paper states that PIT tagged Spring Chinook migrated at 28.0 km/day which is longer that the historic value of 17-24 km/day stated on page 107. The paper also fails to use 2001 or 2002 data.

Paragraph 5 (extends onto page 109). This information contradicts the information on page 104.

Page 109: Paragraph 2. The paper states that a substantial percentage of salmon fall back under certain conditions. It should state the percentage and indicate if the "certain conditions" are only when uncontrolled high spill volumes occur or if there are other situations as well. Assuming the paper is talking primarily about spill, then it appears to be stating that even if spill does increase fall back, few fish are injured or killed because of it. This position need clarification and support.

For discussions of fall back, the paper should incorporate analysis of PIT tag data, which would either corroborate or contradict the radio tag data. It may be that the radio tag data is biased in some manner because of the tag's effect on the fish. If there is indeed some level of fall back at any time, then maintaining at least some spill would be essential to ensure that fish that fall back do so over the spillway where presumably they have better survival. While, as asserted, fall back may bias window counts high, other factors like lack of night and/or winter season counts may bias some counts low. For instance at Lower Granite, from 1997-2002 an average of 22% of the total sockeye counts were made from nighttime video counts, which were discontinued in 2003. Typically night counts, if available, are not included in published dam counts.

Page 110: Paragraph 2. The discussion of fall back at Lower Granite and the number of Lyons Ferry fish going to Granite is not very applicable to the present. In recent years there has been some fall back, but it has not been as high as 16% according to recent run reconstructions (Norma Sands, NOAA). Also, the fact that 80% of LFH fall chinook reached Little Goose before going back the hatchery should not be a surprise given the way the hatchery entrance is situated and the short distance to Little Goose.

Page 111: Paragraph continued from page 110. In the final sentence, the first part is accurate, but the second part is no longer accurate given the number of new PIT tag detection sites installed in the last couple years.

Passage survival estimates

These several paragraphs are not well written. So many different survival percentages are presented that it is difficult to understand what point if any the authors are trying to make. Are they saying that it is impossible to know the exact survival because of all the different types of estimates? Or are they saying that survival varies for different reasons? What is the main point? One point worth mentioning is that adult passage loss corrected for estimated harvest impacts is generally higher than the harvest impacts for any species in any season.

Page 112: Paragraph 4. This paragraph has some interesting details. An estimate of 8% mortality of sockeye that fell back at Bonneville is intriguing given the near extinction of Snake River sockeye; the paper, however, fails to state what the estimated fall back rate is. Apparently for fall chinook, the mortality due to fall back nearly doubled with lack of spill because fish went through the turbines. Further more current radio tagged studies at Bonneville indicate that spill rate has little to do with fallback numbers. After changing the powerhouse operations there has been no significant statistical difference in fallback rates between the current spill level and higher spill levels. Bonneville fallback has more to do with which ladder adults use. Further, there seems to be a background level of fallback that occurs regardless of spill operations. The paper should address these issues.

Page 113: Water Temperature: The paper fails to present it very clearly, but it seems to be provide evidence that warm water is indeed bad for at least fall chinook and sockeye, but may not be as much of an issue for steelhead as long as they can seek cool water refuges since they spawn the next spring. This needs clarification.

Page 117: Head burn. The question should be asked, "Has headburn been noted in basins without dams that fish pass." If Headburn does not exist except in systems where fish pass dams, then it is almost certainly related to the dams, whether or not it is GBD or trauma in the ladders.

Page 119, Table 11. This table makes absolutely no sense. What are these numbers? Why are they not properly labeled to insure understanding from the reader?

Page 121. Key Uncertainties. The paper should mention the potential of PIT tags to help address continued uncertainty.

Page 123: Lamprey and Sturgeon Passage. The paper forgot to provide any discussion on sturgeon. As noted in the Commission's cover letter for this and the other three white papers, sturgeon have been greatly affected by the hydropower system. To a great extent, these effects are the result of lack of upstream passage for sturgeon, however other adverse effects have resulted as well. We refer you to those general comments for this discussion her.

Lamprey were also discussed in our cover letter comments, and we refer you to those comments as well. Regarding the discussion at page 123, it is not clear if the statement regarding, "…50% passed over successfully…." Can be interpreted as a 50% passage survival or not. Assuming it is close to the actual single project survival rate then lamprey destined for above Lower Granite have a 0.39% survival rate (0.5^8). This may help explain why only 282 lamprey were counted passing Lower Granite in 2003. Yet the paper bizarrely ends the section by stating that, "Ongoing studies are needed to address whether the hydropower system is impacting lamprey recruitment, homing, and life histories." Equally as strange is that there is a relatively easy technical fix available that would be relatively inexpensive compared to other passage projects. A smooth surface such as even glazed ceramic tiles could be built into the ladders. Lamprey pass quite easily using smooth surfaces.

Page 124: Adult count accuracy. The COE has reduced the counting schedule at many projects. This adversely impacts the precision of window counts and adversely effects fishery management.

Flow:

In general, there is little mention in the white paper of the flow-survival relationship for salmon. This is an important factor that should be included in the analysis of the effects of the hydrosystem, as flow is controversial operational factor.

The Section "Adult Passage-Water Temperature" (page 114) ignores the Idaho-Nez Perce Tribe Management Plan for Dworshak (IDWR 2000). This Plan was approved by the Idaho legislature in December 2000 and has the effective force of law. The ID-NPT Plan calls for 200 KaF of Biological Opinion designated July-August water to be used for late Clearwater juvenile and adult migration in September. The NPT and Idaho want draft limits of 1535 feet (August 31) and 1520 feet (September 30). This plan, as advocated in the Commission's annual River Operations Plan (CRITFC 2003), was mostly implemented for 2002 and 2003 and the results should be evaluated by NMFS. Chris Perry of the UI gave a presentation on the effects of the 2002 NPT-ID operation to the TMT (Perry et.al. 2003) that should be cited. The Perry reference in the draft gives a defunct website link.

The Water Temperature section also fails to mention the warm temperatures in the Hells Canyon Complex during summer. It is imperative that Upper Snake summer flow augmentation be released during July, while holding back Dworshak water for as long as possible, then ramping up Dworshak flows in early August while Hells Canyon flows are ramped down, as specified in the Commission's annual River Operation Plan (CRITFC 2003). NOAA should collaboration with the Commission about this operation plan.

In the section entitled "Key Uncertainties" (p. 121), the draft white paper states, "Flood control has altered the estuarine hydrograph and may be resulting in delay and/or increased mortality in the estuary." While noting this, there is no mention of returning the FCRPS to a natural peaking-normative river system or a basin-wide eco-system approach to recovery. This is one area that co-manager collaboration is needed, whether in conjunction with this white paper or otherwise.

Technical staff (Transboundary Conference 2002, LRF 2003) strongly recommends a holistic ecosystem approach to managing water and salmon resources in the Columbia, yet the Federal Action Agencies and NOAA continue to resist. Current flood control operations and the subsequent amount of increased system-storage have muted the peak of the annual hydrograph over the last 50 years—resulting in migration delays. Spring flow targets were not met in the medium-and-low years of 2000-2002 (see Table 1).

Table 1. Spring Flow Targets.

Spring	LWG		MCN		PRD	
(kcfs)	4-10/6-20		4-20/6-30		4-10/6-30	
	Target	Observed	Target	Observed	Target	Observed
1995	96.3	100.9	249.2	253.0	135	
1996	100	138.3	258	357.1	135	
1997	100	162.5	260	454.8	135	
1998	90.3	115.6	220	287.8	135	153.9
1999	100	117.0	260	303.6	135	169.6
2000	97	85.1	246.4	243.4	135	158.1
	4-03/6-20		4-10/6-30		4-10/6-30	
	Target	Observed	Target	Observed	Target	Observed
2001	85	47.5	220	123.9	135	76.7
2002	97	83.4	246	269.3	135	180.6
2003	89.1	90.0	220	231.4	135	141.4
Hits:		6 of 9 yrs.		7 of 9 yrs.		5 of 6 yrs.

NOAA continues to insist on flat flow targets instead of moving toward a natural peaking-normative river operation (Bunn and Arthington 2002) that would benefit salmon (Williams et.al. 1996). GENESYS hydro studies conducted by Commission staff (Martin 2003) show that 8 MaF (million acre-feet), on average, from the Columbia-Snake River can be annually reclaimed from Altered Flood Control (AFC) operations without significantly increasing flood risk to Vancouver and Portland with significant benefits to salmon. AFC operations use modified upper rule curves for Grand Coulee, Brownlee, Dworshak, Arrow and Mica dams (British Columbia), plus modified VAR-Q operations at Hungry Horse and Libby dams. Current flood control operations wastes 8 MaF, on average, annually that could be used for anadromous fish passage.

NOAA should request that the Corps of Engineers cease overly conservative flood control operations that manage the Columbia at The Dalles to 300-350 kcfs each spring, or 100 kcfs less than bank-full conditions, or 200 kcfs less than flood-flow conditions at Vancouver or Portland. An independent academic and/or engineering review should be conducted on the feasibility and the consequences of altering flood control operations to achieve an intelligent use of spring water.

For the past four years, the Commission has submitted River Operation Plans that fully utilize altered flood control and earlier reservoir refill that could have been ideally suited for implementation in medium (2000, 2002) and low (2001, 2003) water years. FCRPS managers ignored/rejected such plans, even though the risk of flooding would be negligible. The COE needs to test altered flood control operations for low and medium water years (i.e., TDA January-July WSF < 105 MaF).

The 427 KaF Snake flow augmentation continues to be inadequate. Summer flow targets were not met in most years of 1995-2003 (see Table 2). The Commission advocates an additional 500 KaF from Brownlee (short-term) plus 1 MaF from the Upper Snake (long-term), in addition to the current 427 KaF. On the Columbia, the Commission advocates 500 KaF from Canadian Non-Treaty Storage and 250 KaF from Banks Lake (short-term) and double those totals for the long-term.

The draft paper fails to mention using advanced weather and climate forecast tools to help decision makers. The UW-Climate Impacts Group now offers one-year forecasts for the Columbia at The Dalles using ENSO/PDO signals into mainstem flow models (Hamlet and Lettenmaier 2003; Hamlet et.al. 2003). A comprehensive package of climate forecast tools is needed to better manage all Columbia basin reservoirs, instead of continued reliance on outdated procedures because it is “comfortable.” Nichols (1999) suggests that policy-makers and resources managers are unable, or unwilling, to utilize weather and climate forecasts in the decision-making process.

Table 2. Summer Flow Targets.

Summer	LWG 6-21/8-31 Target	Observed	MCN 7-01/8-31 Target	Observed
1995	51.3	55.3	200	165.0
1996	52.5	52.7	200	214.5
1997	55	66.3	200	236.5
1998	50.6	53.2	200	169.7
1999	54.3	56.0	200	228.2
2000	51.3	33.7	200	153.6
2001	50	25.4	200	90.9
2002	51.3	41.0	200	189.1
2003	50.5	32.3	200	135.5
Hits:	5 of 9 yrs.		3 of 9 yrs.	

Kelt survival (pp. 117-120):

Overall the draft white paper summarizes the issue surrounding kelt steelhead passage survival reasonably well, however it does state that "specific effects of the hydropower system on the survival and reproductive success of Columbia Basin kelts are poorly understood." This is incorrect.

It is well known that kelt steelhead survival through the hydrosystem is very low. This is based on radio tagging work contained in Hatch et al., 2003a, and Evans, 2002. These studies found kelt survival between Lower Granite and Bonneville dam to be 13.3% (28/210) in 2002 and 3.8% (8/212) in 2001. These are studies conducted by staff at the Commission and should be considered in the context of co-manager collaboration. While the mechanism causing the kelt mortality is not precisely known, these studies provide data on the effect of the hydrosystem on kelt steelhead. Moreover, that the hydrosystem is a significant source of kelt mortality is obvious. The white paper, on page 118, cites work by the Corps of Engineers (2000) that shows that 60.5% of their test kelts passed through the Bonneville Dam powerhouses and most of these (80%) passed directly through the turbine units. As the paper notes at page 122, turbine mortality rates can be very high for adult fish.

Study results suggest that despite the thousands of kelts that arrive at Lower Granite Dam every year, very few successfully navigate the Columbia Basin hydrosystem. The effect of the hydrosystem on kelts and the subsequent loss of kelt contribution to future steelhead runs is an important aspect of steelhead recovery and should be more thoroughly considered both in this white paper and in the revised biological opinion. If kelts are to contribute to future steelhead runs by spawning multiple times, methods are needed to improve passage success of kelts in the Snake and Columbia rivers, particularly during low flow years. Co-manager collaboration is vital for this issue.

Commission staff has been investigating reconditioning kelt steelhead and evaluation of reproductive success of reconditioned kelts is underway in ongoing research. Previous year research has been reported in Hatch et al. 2002 and 2003b. Results from this work could provide avenues to compensate for the high mortality caused by the hydrosystem.

References:

Bunn, S.E. and A.H. Arthington. 2002. Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity. Environmental Management, v. 30 (4), pp. 492-507.

CRITFC (Columbia River Inter-Tribal Fish Commission). 2003. 2003 River Operations Plan. Presentation given at the Technical Management Team, March 19, 2003, Portland, Oregon. (http://www.nwd-wc.usace.army.mil/tmt/agendas/2003/0319.html)

Evans, A.F. 2002. Steelhead (*Oncorhynchus mykiss*) kelt outmigration from Lower Granite Dam to Bonneville Dam: Abundance, downstream conversion rates, routes of passage, and travel times. Annual Report to U.S. Army Corps of Engineers, Walla Walla District, for Contract No. DACW68-01-0016. Prepared by the Columbia River Inter-Tribal Fish Commission, Portland, OR.

Hamlet, A., and D. Lettenmaier. 2003. 1-Year Lead Time Experimental Streamflow Forecasts for the Columbia River at The Dalles. University of Washington Climate Impacts Group, Seattle, Washington. (http://www.ce.washington.edu/~hamleaf/DallesForecast.html)

Hamlet, A., Wood, A., Babu, S., McGuire, M., and D. Lettenmaier. 2003. New Tools and Resources for Streamflow Forecasting Applications. Conference: Climate and Water Resource Forecasts for the 2004 Water Year. Kelso, Washington. (http://www.jisao.washington.edu/PNWimpacts/Workshops/Kelso2003/Hamlet_Tools&Resources_Kelso03.pdf)

Hatch, D.R., P.J. Anders, A.F. Evans, J. Blodgett, B. Bosch, D. Fast, and T. Newsome. 2002. Kelt reconditioning: a research project to enhance iteroparity in Columbia Basin steelhead *(Oncorhynchus mykiss)*. Project 2000-017-00. Columbia River Inter-Tribal Fish Commission Report to the U.S. Department of Energy, Bonneville Power Administration, Portland, Oregon.

Hatch, D.R., R. Branstetter, and S. Narum. 2003a. Evaluate steelhead (Oncorhynchus mykiss) kelt outmigration from Lower Granite Dam to Bonneville Dam and test the use of transportation to increase returns of repeat spawners. Contract No. DACW68-00-C-0027. Columbia River Inter-Tribal Fish Commission Report to the U.S. Army Corps of Engineers Walla Walla District, Washington.

Hatch, D.R., R. Branstetter, J. Blodgett, B. Bosch, D. Fast, and T. Newsome. 2003b. Kelt reconditioning: a research project to enhance iteroparity in Columbia Basin steelhead *(Oncorhynchus mykiss)*. Project 2000-017-00. Columbia River Inter-Tribal Fish Commission Report to the U.S. Department of Energy, Bonneville Power Administration, Portland, Oregon.

IDWR (Idaho Department of Water Resources). 2000. Dworshak Operation Plan. (http://www.nwd-wc.usace.army.mil/tmt/agendas/2003/0709DOP.pdf)

LRF (Lake Roosevelt Forum). 2003. 2003 Spring Conference. Spokane, Washington. (http://lrf.org/conf/index.html)

Martin, K. 2003. Altered Flood Control, Climate Change, and Rebuilding Pacific Northwest Salmon Stocks. Presentation given at the Lake Roosevelt Forum, Spokane, Washington. (http://www.critfc.org/text/floodcontrol.pdf)

McCullough, D.A. 1999. A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, with Special Reference to Chinook Salmon. Prepared for the U.S. Environmental Protection Agency (EPA), Region 10, Seattle, Washington. Published as EPA 910-R-99-010. July 1999. 291 pp.

Nicholls, N. 1999. Cognitive Illusions, Heuristics, and Climate Prediction. Bulletin of the American Meteorological Society, v. 80 (7), pp. 1385-1397.

Perry, C., Keefer, M., and T. Reischel. 2003. Effects of Dworshak Water on Passage of Adult Salmon and Steelhead: 2002 September Releases. Presentation given at the Technical Management Team, January 22, 2003, Portland, Oregon. (http://www.nwd-wc.usace.army.mil/tmt/agendas/2003/0122dwrfish.pdf)

Transboundary Conference. 2002. Toward Ecosystem Management: Breaking Down the Barriers in the Columbia River Basin and Beyond. Spokane, Washington. (http://www.sff.bc.ca/2002.html).

Williams, R. and eleven co-authors. 1996. Return to the River. Northwest Power Planning Council. Portland, Oregon. (http://www.nwcouncil.org/library/1996/96-6/default.htm)

Effects of the Federal Columbia River Power System on Salmon Populations

The FCRPS Effects paper, in general, is a useful summary of data and analysis as they pertain to the survival of salmon stocks transiting the FCRPS. Unfortunately the "Conclusions" section of the review draft contained no text. In the absence of this important section, this review must be based on inferences gleaned from the text of the paper.

Delayed Mortality:

The cursory treatment of delayed mortality of both transported and non-transported fish is perhaps the greatest concern with the FCRPS paper. In particular, the statement at page 51 that "non-transported fish [do] not experience delayed mortality (or have very little)" is unaccompanied by any analysis and is in contrast with published information. Published values indicate substantial levels of delayed mortality could be occurring in wild Snake River spring/summer chinook inriver migrants. This issue is one area where co-manager collaboration is crucial.

Similarly, the white paper seems to ignore delayed mortality beyond that estimated in "D" values as is evident from the following two statements. First the paper states at page 54 that "survival of yearling Snake River chinook salmon through the present 8 dams of the mainstem FCRPS recently matched or exceeded those estimated to have occurred when FCRPS had only 4 dams." Second, it states at page 56 that "…overall effective survival of fish downstream of Bonneville Dam meets or exceeds estimated values from the 1960s." These statements are unaccompanied by analysis and, to be true, would need to be based on data that does not exist. For calculations to be consistent with these statements, current levels of delayed mortality must have been left out. Also, although it is true that data exist only back to 1964 (page 56), data from the years 1964 through 1967, when only three dams were in place, indicate SARs were considerably higher than those seen in the 1990's. NOAAF should work collaboratively with co-managers to resolve these issues.

The following language on page 57 is confusing: "…where we have long constant periods within years with relatively steady flows, we found little relationship between migration rates and flow." Any discussion of the relationship between flow and survival should be clearly presented and documented.

The discussions of size and timing on survival are interesting but do not seem to point to useful management advice. It would be helpful for the authors to explain how this information may lead to better management.

The Karieva et al. study cited on page 60 did not seek to explain the effects of anthropogenic activities on fish. They looked at model sensitivities to changes in mortality without regard to whether the sources of mortality were anthropogenic or natural. To date it appears that NOAAF has attempted no feasibility analysis for listed stocks. We urge NOAAF to enter collaborative feasibility analyses that will better define the potential efficacy of proposed management actions.

NOAAF does provide a candid discussion of transportation and its effectiveness for various stocks. From this it appears that for stocks in which good estimates of "D" and other information are available, that transportation is marginally effective at best. NOAAF should provide co-managers with specific plans for hydro management prior to the release of the next BIOP including future plans for transportation. If transportation is either halted or curtailed, co-managers should be involved in the assessment of management alternatives.

The Role of the Estuary in the Recovery of Columbia Basin Salmon and Steelhead

Fresh et al., the authors of "The Role of the Estuary in the recovery of Columbia River Basin Salmon and Steelhead: An Evaluation of Limiting Factors" have done a good job of assembling available and applicable information on salmon in the Columbia estuary. They also suggest a tentative framework for evaluating the limiting factors. However, while we recognize that their effort is still in its early stages, there are pieces of available information that could help to better put the role of the estuary into perspective.

The authors do a good job of describing the historical role of the estuary and the effects of human development. Apparently, prior to hydropower development (both run-of-the-river dams and storage dams) yearling (stream type) chinook were literally swept out to sea in swollen, silt laden spring freshet. Feeding was probably impossible but so probably was being fed upon. Somewhere along the continuum of fresh to salt water, as the water became more saline and less turbid, the fish faced the tenuous task of learning to seek new sources of food while avoiding new types of predators. Mortality was undoubtedly high but was of a natural, not anthropogenic, nature.

Today's estuary, on the other hand, has been subjected to a number of anthropogenic factors. Most notable of these is the development of the hydropower system that has had two deleterious effects. First, storage reservoirs have reduced the flow volume of the plume. Second, both storage and run-of-the-river dams have acted as settling basins to reduce the turbidity of the plume. These hydropower effects have no doubt increased the already high mortality in the estuary. The white paper needs to recognize this.

The white paper states, at page 50, that the focus of paper was on the "effects of estuarine factors on population viability, not on the relative importance of the estuary." It is irrational/ erroneous to try to separate these issues: in the big picture, the relative importance of the estuary cannot be excluded from the analysis. For example, assumption 2 used in the analysis (as described on page 52) states that the "main effect of flow reductions is to affect amount of habitat available to fish." This fails to recognize that flow reductions also have affected the *role* of the estuary in the species' life strategy.

Along the same vein, the authors need to recognize that, because of the hydrosystem, the estuary plays a varying role in the life strategy of different stocks of the same species. The authors describe and quantify the loss of habitat structure in the estuary and conclude that some life history types will be more affected by such loss than others. Some life history types have clearly been affected already – pinks for example. However, for this document to be useful in the development of the imminent BIOP, it will be necessary to avoid discussing stocks in the abstract and focus on particular listed stocks, especially those affected by the FCRPS. It would also seem useful to draw on available information on those stocks.

Fall chinook arguably spent time rearing in the estuary in historic times, however these fish have been significantly affected by the hydrosystem. Snake River fall chinook now spend considerable amounts of time feeding in Snake and Columbia River reservoirs. Seemingly, slack water is a cue to begin feeding. By the time they get to the estuary, the original role of the estuary may be moot. Fall chinook from lower in the system (Hanford Reach and Warm Springs River) may be more reliant on the estuary than their Snake River counterparts. Even if this is the case, the authors should acknowledge that the lower river fall chinook stocks, stocks that would seem to be most dependent on the estuary, happen to be the stocks that are most productive and are not listed under ESA.

Likewise, spring chinook lower in the system, such as those from the John Day River, transit the estuary also but have not undergone the sudden and abrupt declines as their Snake River counterparts. Both these examples draw into question the degree to which the estuary is a limiting factor for specific stocks listed under the ESA, particularly those affected by the FCRPS. While, in the abstract, there may have been dramatic reductions in the habitat of some stocks – i.e., chums and pinks – these are coastal stocks and are not listed under the ESA. Thus they have no bearing on the upcoming BIOP.

It is also worth noting that there is no singular event or set of events that occurred in the estuary that coincides with the steep decline of the listed stocks. While this does not mean that there are no habitat problems in the estuary, it indicates that the bottleneck lies elsewhere and that habitat in the estuary is not the over-riding limitation.

Finally, piscivorous birds may be a limiting factor to some extent but this is a recent phenomenon. Only in the mid to late 1990's did the bird populations begin to flourish. Thus they are not responsible for the declines that created ESA listings to begin with.

In short, because all salmon stocks pass through the estuary, but not all are listed, and because there was no calamitous event in the estuary that explains the rapid declines in the listed stocks in the 1970's, the extent to which the conditions in the estuary limit efforts to recover listed stock is limited. We encourage NOAA Fisheries to embrace a collaborative effort that will focus attention on listed stocks and the degree to which habitat restoration in the estuary will restore the listed stocks.

A Review of the Relative Fitness of Hatchery and Natural Salmon

Commission staff have reviewed this document, and find it to be a helpful, significant step in the synthesis of our understanding of the role of artificial propagation in conservation and restoration efforts. We have the following comments to contribute.

At the bottom of page 4, the paper states:

> We emphasize that we are reviewing studies of the relative fitness of hatchery and natural fish in the natural environment. In some cases, **hatchery fish could have high relative fitness but still contribute to the decline of a natural population**. For example, in cases where a hatchery population and a natural population are linked by high levels of genetic exchange it would be surprising to find large genetic differences in relative fitness between the two groups. **However, both the hatchery and natural populations could potentially have reduced absolute fitness in the wild due to hatchery-induced genetic change.** We do not address these types of long-term consequences of hatchery production in this paper, nor do we attempt to summarize information on genetic versus environmental causes for differences in relative fitness. Our goal is simply to provide narrower ranges of relative fitness values than are currently assumed for hatchery fish, which will improve estimates of ?.

The above statements (in bold) are theoretical and no supporting evidence is presented. This subject is still contentious and the NOAA Fisheries' management position on this issue will greatly affect the outcome of the information presented in this white paper. We commend the authors for recognizing the variety of factors that influence the relative fitness of hatchery fish compared to their naturally produced counterparts and outlining the effects of the different artificial production techniques (the four broodstock management scenarios). However, these efforts are ineffective unless the issue of genetic change and the potential for negative impacts of hatchery origin fish are addressed. Without resolution on these issues, the value of naturally spawning hatchery fish will continue to be a controversial, and the NOAA Fisheries position will greatly effect how naturally spawning hatchery fish are managed.

Review of empirical studies:

Scenario 1: Non-local, domesticated stocks

We generally agree with scenario 1 although there is an over reliance on data from steelhead studies. Artificially produced steelhead are often directly selected for early run timing and experience accelerated growth so the juveniles smolt in one year. None of the other Pacific salmon species experience this drastic life-history change through artificial production. Therefore, it's difficult to generalize all scenario 1 Pacific salmon programs based on steelhead data alone. Although the coho example only represents a portion of lifecycle, hatchery adults did experience 50-82% the reproductive success of natural coho (Fleming and Gross 1993), which is much higher than the steelhead examples presented. Therefore, summarizing the relative fitness of Scenario 1 fish from 0.06 to 0.35 may not be representative of all Pacific salmonid species. In addition, relative adult to adult steelhead survival studies rarely account for selective fisheries for hatchery (adipose clipped) fish which can confound adult hatchery return data.

Scenario 1 should be used to establish a lower limit on the range of relative fitness of hatchery fish. Since none of the studies reviewed by NOAA Fisheries observed relative fitness of 0 for hatchery fish it is apparent the range (0 to 100%) used by McClure (2000) was inappropriate.

The authors discuss the very important Bouin (2003) paper only very briefly. The paper should include a discussion on the results of the hybrid crosses as well as state the difference between local and non-local recruitment success as a demonstration of the affect of using a non-local stock. In fact, some of the hybrid crosses demonstrate fitness above the local, natural stock, indicating some hybrid vigor. Similar results (albeit at a lower scale) are observed in the crosses between the non-native stock and the natural stock. We are also a bit surprised that the reviewers conclude that the causes of the differences are confounded between genetic and environmental sources, whereas the observed results of Reisenbichler and McIntyre (1977) is said to be of genetic causes. The experimental design and interpretation of the later paper are far more ambiguous than those of Blouin (2003)'s pedigree analysis. In general, we find that the paper is very uneven in its interpretation of the results.

Although a series of papers by Clarke (Withler et al. 1987, Clarke et al 1002, Clarke et al 1994) were not designed as a test of hatchery vs. wild productivity, the paper discusses issues of direct importance to the understanding of local/non-local effects and consequences. In general, the papers on the subject ignore a large dataset from quantitative genetic research.

Scenario 2: Local, natural broodstock

This section is missing a summary. Granted there is only one example presented, but it seems likely that these types of programs would produce fish with fitness similar to natural origin fish.

The Umatilla River steelhead supplementation program could be used to strengthen the review of the scenario. Data for the Umatilla could be obtained for the Umatilla Tribe or from Phillips et al. (2000).

Scenario 3: Local, multi-generational stocks

Since estimates for lifetime relative fitness were not found for this category the authors chose to include studies that only test a portion of the lifecycle. Highly variable results found in scenario 3 are partly due to specific studies that have major study design flaws that confound their results. Therefore the results and conclusions of these studies should be viewed with skepticism. Additionally since the authors choose to review only one study in Scenario 2 due to their criteria for that section, to be consistent they should apply the criteria to Scenario 3 with the same rigor thus most of reviewed studies would not be included.

Reisenbichler and McIntyre (1977) compared performance of wild, hatchery, and wild x hatchery steelhead, using the Deschutes River steelhead stock. Although their end result indicated that wild fish out-performed hatchery fish, wild fish were not always superior to hatchery fish. Growth differences were generally insignificant, and in half the cases the highest survival was shown among the hybrids (H x W). The fact that this occurred without blind tests and with traps that were not operated during certain periods of the year leaves a major uncertainty about the conclusion that hatchery fish performance was poorer than wild fish. One can conclude, for example, that when 27,000 eggs are planted in each of two streams and only 245 hatchery verses 253 wild and 344 hatchery verses 369 wild fingerlings respectively are recovered in the traps, the numbers don't represent biologically meaningful differences,

The conclusions of the Reisenbichler and Rubin (1999) review are extremely overstated. The authors failed to provide any evidence that traits experimentally tested were genetically inherited, fitness related, caused a decline in a natural population, or that the hatchery environment genetically selected for these traits. A negative genetic effect of hatchery fish on the natural populations was never demonstrated in any of the studies, only that hatchery-bred fish may have poorer performance values under specific conditions. Even though Reisenbichler and Rubin (1999) acknowledged that all of the studies presented in their review had shortcomings and don't provide conclusive evidence supporting their hypothesis, they still conclude that taken collectively they somehow offer support for their view.

The goal of the Chinook salmon study from Reisenbichler and Rubin (1999) and Rubin, USGS, (pers. Com.) was to test for genetic differences in survival and growth between experimental groups. The methods used consistently confound the results including; conducting the experiment in the Little White Salmon River rather than the native Warm Springs River, not using standardizing breeding protocols for each experimental group (number of parents, factorial breeding design), different rearing environments, not accounting for emigration in the experimental stream, non-standardized recapture methods, and inconsistent data reporting (pooling of some data sets and not others).

Scenario 4: Captive and farmed stocks

No major problems with scenario 4.

<u>Inferences based on species and life history strategies</u>

We generally agree that length of time in captivity is a contributing factor in the fitness of artificially produced salmonids, but would disagree that it is reasonable to extrapolate this hypothesis to all species. Differing from steelhead, coho and stream type Chinook salmon still maintain similar freshwater life histories even in the hatchery facilities. The Ford et al. coho experiment demonstrates that fitness can be maintained in species where the freshwater life history is maintained in the artificial environment. It seems likely that the same would apply to stream type Chinook.

Importance of Competition

The authors should review Weber and Fausch (2003) for discussion on competitive interactions for hatchery and wild salmonids, and the difficulties in measuring competitive ability without appropriate controls.

General Comments

Not all studies included in this review address lifetime fitness (adult to adult recruitment), therefore the inclusion of studies that demonstrate differences between hatchery and natural fish at various life-history stages may not be adequate to determine overall fitness. Since the authors chose to include non-lifetime fitness studies they easily could have included a more comprehensive list of experiments that may change the resulting scenario summaries. Examples of additional studies that could be used in this review include the following:

Lofy et al. (1997) showed that non-local steelhead out-planted in the Lookingglass Creek had a spawner-to-spawner return rate similar to local wild stocks. Rhodes and Quinn (1999) showed that hatchery-reared fish released from a conventional program grew and survived as well as their wild counterparts. Mullan et al. (1992) found no difference between wild and hatchery smolt success in the mid-Columbia. Fuss (1998, 2002) demonstrated that coho and chinook salmon raised in hatcheries can spawn successfully and do well under natural conditions, Phillips et al. 2000 adult to adult returns were similar for hatchery and natural steelhead, and Berejikian et al. (2003) has shown hatchery steelhead spawning naturally in the Hamma Hamma River on Hood Canal have egg viability and egg to fry survival rates comparable to wild steelhead. It is noteworthy that Lannan (2002) using several years of comparative data on Oregon coastal coho, found no difference in productivity of natural spawners between river basins with and without hatchery programs.

Blouin (2003) states in their conclusion that the use of local stock in artificial propagation "appears to have added a demographic boost to the population without having obvious negative genetic consequences – at least in regards the effects of domestication selection and mutation accumulation that should occur in the hatchery." This is a significant finding that merits much discussion, but is not mentioned in the review.

TABLE 1:

The environmental effects interpreted as "genetic" in Reisenbichler and McIntyre (1977), Reisenbichler and Rubin (1999) and Rubin (unpublished) are NOT genetic. At the most, they are confounded. It is also arguable in some of these studies whether the experimental design allows conclusive results to be cited (see above).

There is little discussion of experimental variance and reproductive variance (error variance and biological variance) and their interaction. Most of the studies suffer to some degree from inability to track all animals, confounded population determinations, straying, etc. On the other hand, natural variation in reproductive success within stock is not addressed. Under declining populations, predictions of variance in reproductive success are much different than those for healthy populations. Many assumptions of the effect of hatcheries on long-term reproductive success assume a healthy natural population, which is not the case in most instances (after all, that is why the stock are listed). There is a general need to discuss this subject matter thoroughly.

In 2002, the Commission shared a white paper with the NOAA for the purpose of beginning a dialogue on the development of a guidance document for the use of artificial propagation in the recovery of species (Whiteaker and Talbot 2002). The results of this white paper ought to have informed this review. We would hope that a second draft of the white paper would include some elements of that review.

Although working collaboratively on a guidance document for the use of artificial propagation would be a daunting task, the Commission believes that input from the managers of the conservation programs is needed and would reduce reliance in old studies of little current relevance and update the information database necessary to make such decision. The Commission, in its monitoring program for supplementation hatcheries, is in a good position to assist in the development of the information database for the present exercise. As such, the white paper would integrate a broader data source and include studies more relevant to the development of a guidance document.

References:

Berejikian, B, 2003. Hamma Hamma River Steelhead Supplementation. Hatchery Scientific Review Group research review. Puget Sound and Coastal Washington Hatchery Reform Projects. January 13, 2003, Olympia, Washington.

Clarke, W.C., R.E. Withler, J.E. Shelbourn. 1992. Genetic control of juvenile life history pattern in chinook salmon (*Oncorhynchus tshawytscha)*. Can. J. Fish. Aquat. Sci. 49:2300-2306.

Clarke, W.C., R.E. Withler, J.E. Shelbourn. 1994. Inheritance of smolting phenotypes in backcrosses of hybrid stream-type x ocean-type chinook salmon (*Oncorhynchus tshawytscha)*. Estuaries 17(1A):13-25.

Fuss, H.J. 1998. Hatcheries are a tool: they are as good or as bad as the management goals that guide them. Pages 19-28 *in* E.L. Brannon and W.C. Kinsel, editors.

Proceedings of the Columbia River anadromous salmonid rehabilitation and passage symposium, Aquaculture Research Institute, University of Idaho.

Fuss, H.J. 2002. What needs to be reformed, the objectives, technology or the fish? *in* Hatchery Reform: the Science and the Practice. International Congress on the Biology of Fish, Congress 2002: Vancouver Canada.

Lannan, J. E. 2002. Abundance and productivity of natrually spawning Oregon coastal coho salmon *(Oncorhynchus kisutch)* in rivers with and without hatchery stocks. *in* Hatchery Reform: the Science and the Practice. International Congress on the Biology of Fish, Congress 2002: Vancouver Canada.

Lofy, P.T., M.L. McLean, R.W. Carmichael. 1997. Performance of hatchery chinook salmon (*O. t.)* in the natural environment. American Fisheries Society Symposium, September 1997, Monterey, CA.

Mullan, J.W., K.R. Williams, G. Rhodus, T.W. Hillman, J.D. McIntyre. 1992. Production and habitat of salmonids in mid Columbia River tributary streams. U.S. Fisheries and Wildlife Service Monograph I:1-489.

Phillips, J.L., J. Ory and A.J. Talbot. 2000. Anadromous Salmonid Recovery in the Umatilla River Basin, Oregon: A Case Study. p. 1287-1308 in "*Watershed management for endangered species*". Journal of the American Water Resources Association. Vol. 36(6).

Rhodes, J.S. and T.P. Quinn. 1999. Comparative performance of genetically similar hatchery and naturally reared juvenile coho salmon in streams. North American Journal of Fisheries Management 19: 670-677.

Webber, E.D. and K.D. Fausch. 2003. Interactions between hatchery and wild salmonids in streams: differences in biology and evidence for competition. CJFAS 60:1018-1036.

Whitler, R.E., W.C. Clarke, B.E. Riddell, and H. Kreiberg. 1987. Genetic variation in freshwater survival and growth of chinook salmon (*Oncorhynchus tshawytscha*). Aquaculture, 64:85-96.

An Analysis of "All-H" actions for Snake River spring/summer chinook stocks using the PATH Life-Cycle Model, and a Preliminary Feasibility Analysis of those Actions

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Executive Summary

ES.1 Objectives

The draft Biological Opinion on Operation of the Federal Columbia River Power System (BiOp) released by NMFS on July 27, 2000 calls for improvements in hydropower conditions for salmon. Recognizing that these improvements would be insufficient to avoid jeopardizing the survival or recovery of listed salmon stocks, NMFS included off-site mitigation measures in the BiOp . These measure require the action agencies to address Harvest, Habitat, and Hatchery, in addition to Hydro conditions (i.e. an "All-H" alternative) to prevent extinction of Snake River spring/summer and fall chinook (NMFS 2000a). This proposal was based on analyses of overall and life stage-specific population growth rates by the Cumulative Risk Initiative.

The objective of this analysis was to use the PATH life cycle model (Bayesian Simulation model, or BSM) to assess the performance and feasibility of "All-H" alternatives for seven index stocks of Snake River spring/summer chinook. The BSM was used in an extensive series of PATH analyses from 1995 to 1999 to address the relative performance of various alternative strategies for recovery of the index stocks.

ES.2 Methods

The PATH life-cycle model was updated to use more recent recruit data for lower Columbia and Snake River index stocks of spring and summer chinook through brood year 1994, spawner estimates through BY 1999, and revised conversion (up-river survival) rates. Wild and hatchery spawners were accounted for separately, to allow for multiple hypotheses about the spawning effectiveness of hatchery adults that spawn in index streams. The analysis also incorporated the most recent information on D values[1] (PIT-tag data from 1994-1996 transport studies), which suggested that recent D values have averaged around 0.58. This value was applied both retrospectively and prospectively, based on analyses of SARs of transported fish that suggest that D values haven't changed substantially in recent years. The net result of these changes was that the projected number of spawners for the index stocks were less than in previous PATH analyses, but still projected spawner abundances that were generally higher than observed escapements in the last few years. We explored various reasons for this in Appendix C.

The BSM model estimates posterior distributions of model parameters (Ricker *a*, Ricker *b*, extra mortality, and common year effects), then draws from the distributions in future simulations. The model runs 4000 prospective simulations to ensure that the uncertainty in parameter estimates is fully represented in the outputs. In addition, the BSM is embedded in a decision analysis framework that permits scientists to include different hypotheses about three uncertainties:

[1] D is the ratio of the survival rate of transported fish to inriver fish <u>after</u> they have arrived below Bonneville Dam.

a) magnitude of direct passage mortality – this uncertainty was represented by two passage models (CRiSP and FLUSH)

b) the causes of extra mortality[2] – alternative hypotheses were the "Hydro" hypothesis, which attributed extra mortality to passage through the hydrosystem; the "Hatchery" attributed it to interactions between wild and hatchery fish; the "Regime Shift" hypothesis attributed it to environmental conditions; and the "Hybrid" hypothesis allocated 0.5 of the extra mortality to the hydrosystem, 0.3 to hatcheries, and 0.2 to environmental conditions

c) the spawning effectiveness of hatchery fish – we included two hypotheses, 20% effective (relative to natural spawners), and 80%, which are similar to NMFS assumptions in the BiOp. [3]

The modeling framework incorporates two kinds of uncertainty: uncertainty in model parameter estimates, and uncertainty in other key assumptions about life-cycle mortality and responses to management actions. The inclusion of these uncertainties allowed us to assess how they affect the performance and ranking of alternative management actions. In all modeling efforts, it is the relative performance of alternative actions which matters more than the projected absolute levels of escapement or recruitment. Models of fish populations simply cannot predict biological responses over decadal time scales with absolute accuracy. It is, however, justifiable to compare the relative performance of alternative actions under a range of hypotheses for key uncertainties. This is the primary focus of this report.

We modeled four different overall actions, combining actions in each of the four H's (Hydro, Habitat, Harvest, Hatchery; Table ES-1). A1+ and A3+ actions included non-hydro mitigation efforts, while A1 and A3 did not. We made the following assumptions about each of the actions:

Hydro: A1 represented operation of the hydropower and smolt transportation system according to the 1995 BiOp, and assumed that operating improvements proposed in the 1995 BiOp were implemented in full in every year and were successful. Although the assumed survival improvements may have not been realized in recent years (see Appendix C), A1 was the closest of the scenarios that had already been defined and run by the passage models to the operating conditions prescribed in the 2000 BiOp. A3 assumes breaching of the four lower Snake River dams (natural river drawdown). We used the FLUSH and CRiSP passage models to estimate the direct survival of juvenile fish under the A1 and A3 actions.

[2] Extra mortality is the difference between the total mortality experienced by the Snake River spring/summer chinook stocks (which migrate past 8 mainstem projects) andthat experienced by six downstream stocks (which migrate through 1, 2, or 3 projects), after accounting for differences in passage mortality, differences in intrinsic stock productivity, and year to year variations in survival experienced by both Snake River and downstream stocks.

[3] We did not prepare an analysis of the effect of supplementation efforts on the index stocks. See appendix F for a discussion of this issue.

Habitat: We analyzed a habitat action similar to the "Preferred" Option (#2) in the ICBEMP reports. This scenario was developed by the multi-agency PATH habitat sub-group, which specified probabilities of an increase in the productivity (Ricker *a*) of each index stock that was expected to result from the habitat restoration actions. These probabilities were based on the current condition of the habitat in each tributary, as well as the susceptibility of the tributary to natural disturbances. This habitat action was a component of the A1+ and A3+ actions (Table ES-1). In the A1 and A3 actions, Ricker *a* parameters were assumed to be unchanged.

Harvest: We simulated a harvest scenario where harvest rates were capped at current levels of around 5% (summer chinook) or 8% (spring chinook) in the mainstem, and 0% in the tributaries. The capped harvest rates were assumed to be in place for the full 100-year simulation period, and was a component of the A1+ and A3+ actions. Actions A1 and A3 used the tiered harvest schedule developed under the Columbia River Fisheries Management Plan. We also considered an alternative sliding scale harvest schedule prepared by CRITFC. The results of our analysis of the CRITFC alternative harvest schedule are discussed more fully in Appendix G.

Hatchery: We implemented a generic hatchery action that was assumed to reduce the portion of extra mortality attributed to hatcheries by 25%, where the reduction takes effect after 5 years to account for delays in implementation.. The absolute value of the reduction in extra mortality depended on the extra mortality hypothesis, because each hypothesis attributed a different proportion of the total extra mortality to hatcheries. Implementing the generic hatchery action had no effect with the hydro and regime shift hypotheses because under these hypotheses all of the extra mortality was attributed either to dam and reservoir passage or to environmental conditions. With the "hybrid" extra mortality hypothesis, only the 0.3 portion of the extra mortality assigned to hatchery effects was reduced by 25% under the generic hatchery action (i.e., extra mortality was reduced by around 8% overall). The hatchery hypothesis attributed all extra mortality to hatcheries, so the reduction in extra mortality caused by the generic hatchery action in that case was 25%.

Table ES-1. Summary of actions, uncertainties, and performance measures.

<table>
<tr><th colspan="5">Actions</th><th colspan="2" rowspan="2">Uncertainties
(16 combinations)</th><th rowspan="2">Performance Measures</th></tr>
<tr><th></th><th>Hydro</th><th>Habitat</th><th>Harvest</th><th>Hatchery</th></tr>
<tr><td>A1</td><td>1995 BiOp operations</td><td>None (no change in productivity)</td><td>FMP Tiered Schedule</td><td>No action</td><td rowspan="4">Passage Models

Extra Mortality

Hatchery effectiveness</td><td rowspan="4">FLUSH
CRiSP

Hydro
Hatchery
Regime Shift
Hybrid

20%
80%</td><td rowspan="4">1995 BiOp Jeopardy Standards

Pr(<2 spawners,5 years)

Distribution of projected spawners in each year</td></tr>
<tr><td>A1+</td><td>1995 BiOp operations</td><td>Action similar to ICBEMP option 2</td><td>Capped at current rates</td><td>Generic hatchery action</td></tr>
<tr><td>A3</td><td>Breach 4 Snake River dams</td><td>None (no change in productivity)</td><td>FMP Tiered Schedule</td><td>No action</td></tr>
<tr><td>A3+</td><td>Breach 4 Snake River dams</td><td>Action similar to ICBEMP option 2</td><td>Capped at current rates</td><td>Generic hatchery action</td></tr>
</table>

ES.3 Results

For all seven index stocks of Snake River spring/summer chinook, A3+ (breaching plus hatchery, habitat, and harvest actions) produced the largest projected increase in spawners under all hypotheses, and A1 (current hydro operations alone) produced the smallest projected increase. For six out of seven stocks, A3 (breaching alone) provided a larger increase in spawners than A1+ (current hydro operations plus hatchery, habitat, and harvest actions). For the exception, Bear Valley, A1+ and A3 provided similar increases in projected spawners because, unlike the other stocks, Bear Valley currently has large areas with poor habitat conditions and therefore has potentially more to gain from habitat improvements. For all stocks, there was a smaller range of potential outcomes (resulting from uncertainty in estimated model parameters) for A3 than A1+ outcomes, and less uncertainty in A1 and A3 than in A1+ and A3+. A risk-averse approach would favor actions with smaller ranges of outcomes because this implies that actions have lower probabilities of producing extremely low projected escapements.

We explored several possible reasons why A1 produced higher numbers of spawners that what has been observed recently, even though this action assumed no change in extra mortality from historical levels, and there were no survival improvements due to habitat or harvest actions. The only survival improvement with the A1 action was an increase in the direct component of passage survival rates of Snake River smolts due to the assumption that all components of the 1995 BiOp are successfully implemented. We found that this improvement in direct passage survival accounted for a substantial proportion of the increase in projected spawners under action A1 (Appendix C). However, a larger proportion of the increase was accounted for by the historical period from which common year effects and total mortality factors were selected in the simulations. In BSM, common year effects were selected from brood years 1952-1995, which included above average ocean survival years, particularly in the 1952-1975 period. Total mortality factors were selected from brood years 1975-1995, a period which included some years from 1975 – 1983 when total mortality was quite low. Our model results thus assume better future climate and mortality conditions than what would be expected if we had used only the most recent estimates. When we altered the model to select common year effects and total mortality factors from only the brood year 1984-1995 period, the projected spawning escapement six of the seven index stocks decreased to fewer than 10 spawners (the seventh stock decreased to fewer than 20 spawners). See Appendix C for more details.

We used the 1995 BiOp jeopardy standards as the primary performance measure in this analysis. The standards are based on two spawner thresholds for each stock: a survival threshold (either 150 or 300 spawners) and a recovery threshold (this value ranges from 350 to 1150 spawners, depending on the historical abundance of the stock). The jeopardy standards integrate uncertainties in estimated model parameters by calculating the probability of exceeding these thresholds over the 4000 simulations. Higher probabilities indicate that an action produces an increase in spawners that exceeds the thresholds under a wide range of estimates of model parameters and is thus less sensitive (more "robust") to uncertainty in those parameters. In the 1995 BiOp, NMFS provided yardsticks for measuring the success of actions by specifying minimum levels for these probabilities: 0.7 for the survival probabilities and 0.5 for the recovery standards (i.e., for an action to meet the survival standard 0.7 of the 4000 simulations must produce an increase in spawners that exceeds the survival threshold). NMFS also specified that six out of the seven stocks must achieve these minimum levels, so we present results for the 6th best stock.

The rank order of actions in terms of their projected probabilities of exceeding survival and recovery exceeding thresholds was generally the same as for the projected increase in spawners: A3+ with the highest probabilities, followed by A3, A1+ and lastly A1 (Table ES-2 shows average probabilities for each action and extra mortality, averaged over results for the combinations of passage models and hatchery spawning effectiveness). An exception to this general result was when one assumed that all of the extra mortality was related to hatcheries: in this case, A1+ produced probabilities of exceeding survival and recovery thresholds that were slightly higher than A3, but still lower than the A3+ action.

Table ES-2. Average probabilities of exceeding survival and recovery thresholds for the Sulphur stock. Results shown are for each of the extra mortality hypotheses, and are averaged over the passage models and hatchery effectiveness hypotheses (i.e., combinations 1, 5, 9, and 13 for the Hydro hypothesis; 2, 6, 10, and 14 for the Hatchery; 3, 7, 11, and 15 for Regime Shift, and 4, 8, 12, and 16 for Hybrid). Values that exceed the NMFS standards of 0.7 for survival measures and 0.5 for recovery measures are in **bold**

Performance Measure	Extra Mortality	Actions			
		A1	A1+	A3	A3+
Likelihood of exceeding survival threshold, 24 years	Hybrid	0.42	0.47	0.48	0.52
	Hatchery	0.40	0.51	0.42	0.51
	Hydro	0.39	0.40	0.49	0.51
	Regime Shift	0.54	0.56	0.55	0.56
Likelihood of exceeding survival threshold,	Hybrid	0.57	0.64	**0.75**	**0.78**
	Hatchery	0.53	**0.71**	0.63	**0.74**

100 years	Hydro	0.51	0.53	**0.77**	**0.78**
	Regime Shift	0.68	**0.70**	**0.74**	**0.74**
Likelihood of exceeding recovery threshold, 48 years	Hybrid	0.20	0.38	**0.65**	**0.78**
	Hatchery	0.18	**0.59**	0.40	**0.71**
	Hydro	0.17	0.24	**0.78**	**0.83**
	Regime Shift	0.25	0.35	0.43	**0.51**

Embedding the BSM in a decision analysis framework allowed us to examine the robustness of the four actions with respect to uncertainty about extra mortality, passage models, and hatchery spawning effectiveness. We did this by examining frequency distributions of the outcomes across all possible combinations of these hypotheses (i.e., all 16 combinations of assumptions in Table 2-2). For example, Figure ES-1 shows frequency distributions of the likelihood of exceeding the recovery threshold for the Sulphur stock (results for this stock were typical of all the other index stocks except Bear Valley; results for Bear Valley are discussed below). In this figure, the horizontal length of each bar shows the proportion of the 16 combinations that produced a particular likelihood. For example, 0.25 of the 16 combinations (i.e., 4 out of 16) for Action A1 resulted in a likelihood of exceeding the recovery threshold of 0.1 to 0.15. A robust action is one where there is a high proportion of the 16 combinations resulting in a high likelihood of exceeding the threshold. The figure also shows the overall mean and median likelihoods over all 16 combinations, and the proportion of the 16 combinations that resulted in a likelihood that equaled or exceeded NMFS standard of 0.5. For example, none of the combinations for A1 resulted in a likelihood that met the 0.5 standard, whereas results of 0.94 of the 16 (15 out of 16) combinations for A3+ met the standard.

Figure ES-1 shows that the A3+ action was the most robust action in terms of meeting the NMFS 1995 BIOP recovery standard, meeting this standard in 15 of the 16 (0.94) possible combinations of assumptions. Breaching alone (A3) met the standard in 8 of the 16 cases (0.5), and A1+ met the standard in only 4 of 16 cases (0.25). A1 alone did not meet the standard with any of the combinations. Because the impact of the hypotheses is clearly an important part of a decision analysis such as this, an important aspect of assessing the feasibility of these actions is to document and provide evidence for assumptions about the underlying hypotheses by which the actions lead to survival and recovery.

For Imnaha, Minam, Marsh, Sulphur, Poverty, and Johnson stocks, hatchery and harvest actions had a greater effect on spawner projections than habitat actions. This was because most of these stocks are either already in generally good habitat conditions or are subject to periodic to declines in habitat quality because of natural conditions or past disturbances. With these stocks, the projected increase in spawners resulting from the A1+ action was generally not as large as the projected increase from breaching of the 4 lower Snake River dams alone (A3). This conclusion was true for all extra mortality hypotheses except the hatchery hypothesis. If one assumed that all of extra mortality were due to hatcheries, then implementing A1+ produced results that were similar to breaching. Dam breaching plus harvest, habitat, and hatchery actions (A3+) produced the largest increase in projected spawners.

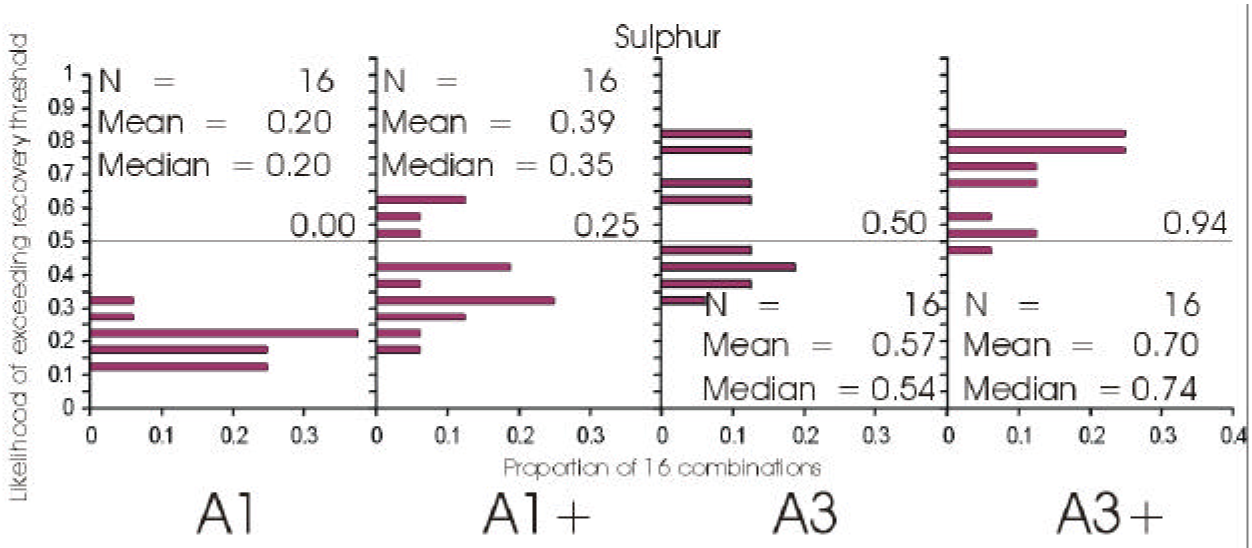


Figure ES-1. Distributions of 48-year recovery probabilities over all combinations of passage models, extra mortality, and hatchery effectiveness hypotheses for Sulphur stock. The "+" actions include habitat, hatchery, and harvest improvements. Overall mean and median probabilities (calculated over the 16 combinations of passage model, hatchery spawner effectiveness, and extra mortality hypotheses) are also shown, along with the proportion of the 16 combinations that exceed the 0.5 recovery standard. For example, for action A1+ the mean and median probability of exceeding the recovery threshold over 48 years were 0.39 and 0.35 respectively, and 0.25 combinations (4 out of 16) produced a probability of exceeding the recovery threshold of 0.5 or greater.

Results were somewhat different for the Bear Valley stock (Fig. ES-2). Habitat actions for this stock had a substantial benefit because habitat conditions in large areas of Bear Valley creek are currently poor. For this stock only, projected spawners and probabilities of exceeding recovery thresholds, were almost as high under the A1+ action as with breaching alone (A3). However, the positive effects of habitat improvements on Bear Valley at low spawner abundance, and therefore on the ability of habitat actions to recover this stock, may be overstated because there are pockets of good habitat conditions where fish currently spawn. Therefore, assumed productivity increases associated with habitat restoration may not be realized until escapements are large and actively spawning in areas where habitat is currently poor and has most to gain from restoration activity. Because our implementation of the habitat action assumes that all Bear Valley fish (even those that spawn in the good habitat that currently exists) realize productivity increases from habitat restoration, we may be overestimating the efficacy of habitat restoration for increasing abundance of the Bear Valley stock from its currently low levels to levels approaching its recovery threshold. Like the other stocks, the greatest improvement for Bear Valley was achieved with dam breaching plus harvest, habitat, and hatchery actions (A3+).

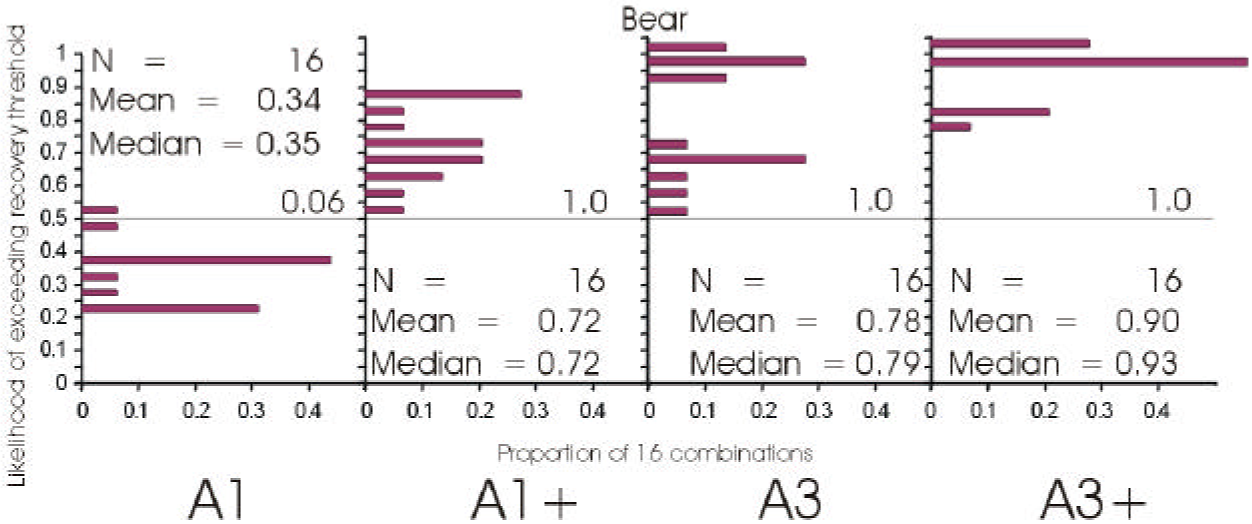


Figure ES-2. Distributions of 48-year recovery probabilities over all combinations of passage models, extra mortality, and hatchery effectiveness hypotheses for Bear Valley stock. The BiOp standard is 0.5; the figure shows the proportion of the 16 runs that exceed this standard. The "+" actions include habitat, hatchery, and harvest improvements. Mean and median probabilities (calculated over the 16 combinations of passage model, hatchery spawner effectiveness, and extra mortality hypotheses) are also shown, along with the proportion of the 16 combinations that exceed the 0.5 recovery standard.

ES.4 Feasibility of Implementation and Achieving Assumed Survival Improvements

Many of the actions NMFS has proposed may benefit listed Snake River stocks, if implemented as planned. However, for any model to project what those benefits might be requires assumptions about:

a) whether and to what extent the action can be feasibly implemented, and
b) the effects of the action on the survival rate of Snake River spring/summer chinook index stocks (including direct survival and extra mortality)

We examined the assumptions that we made in our assessments described in this report. These assumptions are particularly tenuous for non-hydro mitigation efforts because NMFS and the action agencies have yet to work out the details about implementing non – hydro management actions and their expected survival improvements.

ES.4.1 Evaluation of feasibility and assumptions related to Habitat actions

Efforts to improve freshwater and estuary habitat face a number of practical hurdles. Moreover, relationships between population productivity and habitat condition or actions which affect habitat condition are difficult to quantify. While few would disagree that habitat can be a critical limiting factor in freshwater rearing, or that changes in land use can affect habitat quality and survival, the effects of any given habitat action on stock productivity are difficult to predict.

Qualitatively, the fact that there are stocks such as Marsh Creek and Sulphur Creek that are in pristine or designated wilderness areas, but are in immediate risk of extirpation strongly indicates that improving habitat quality and quantity is insufficient to recover Snake River spring/summer chinook. To perform quantitative analyses, one must rely on (often confounded) analyses that relate survival to habitat actions. NMFS has used the Feist et al. (in prep.) analysis as the basis for its quantitative assessments. We have based our assessments of the impacts of habitat actions on a set of assumptions developed by the multi-agency PATH Habitat sub-group. These assumptions involved the probability of changes in stock productivity, where the range of plausible changes was bounded by the range in stock-recruitment parameters among index populations from habitats of varying condition. Probabilities of changes in productivity reflected current habitat conditions as well as possible effects of future habitat scenarios. As a result, the productivity of stocks that either currently experience gradual or periodic declines in habitat quality because of natural events or past management (such as Poverty and Johnson), or are already in pristine habitat conditions (such as Minam, Imnaha, Sulphur, and to a lesser extent Marsh), had a significant probability of no change. Bear Valley, which currently has large areas of poor habitat, was the only stock with a significant probability of improvement from habitat restoration actions.

ES.4.2 Evaluation of feasibility and assumptions related to Harvest actions

The alternative considered in this analysis is similar to the harvest rates that NMFS has recently approved in biological opinions on Columbia River mainstem fisheries. (NMFS 2000b). According to NMFS' 2000 Harvest BiOp,

> Even with zero harvest the analysis indicates that all of the index populations will continue to decline unless conditions affecting survival in other sectors are improved…. Elimination of harvest cannot change that result. Growth rates decline with increasing harvest, but the effect on the growth rate is relatively small – on the order of one or two percentage points. p.57

Harvest rates on Snake River spring/summer chinook have dropped significantly since the 1960s in response to declining adult returns. Appendix G of this report compares alternative harvest schedules from the now expired Columbia River Fish Management Plan, the NMFS Harvest BiOp, and an alternative prepared by CRITFC.

ES.4.3 Evaluation of feasibility and assumptions related to Hatchery actions

Concerns that hatchery fish may be having a negative impact on wild stocks in the Columbia basin have focussed on two types of interactions. The first concern is that hatchery fish compete with wild fish for resources in natal streams. Qualitatively, it would seem that if hatchery fish could result in severe declines, it would have been evident among lower river stocks where substantially higher densities of hatchery fish were released decades before the Snake River hatcheries were built. Also, Middle Fork Salmon River stocks such as Marsh and Sulphur Creek stocks have had no history of hatchery plantings but have still experienced declines.

Second, NMFS and others have hypothesized that spring/summer chinook are negatively impacted by their interaction with larger steelhead in bypass and holding systems and in barges used for transportation (e.g. Williams et al. 1998; Paulsen and Hinrichsen 1998). Previous PATH analyses have explored three types of relationships between these hatchery effects and survival (Table ES-3). Because these analyses were based on tenuous assumptions, their quantitative results do not form a strong basis for predicting the effects of hatchery actions. However, they demonstrate potential approaches one could use to quantify hatchery effects.

Table ES -3. Analyses used to derive bounds on assumed effects of hatchery actions on survival rates.

Analysis	Relationships Explored	Reference
1	productivity (i.e., ln(R/S)) of wild fish **vs.** hatchery-related variables	Wilson (1996)
2	hatchery steelhead releases **vs.** total mortality of Snake River spring/summer chinook	Peters et al. (2000); Williams et al. (1998); Paulsen and Hinrichsen (1998)
3	hatchery steelhead abundance **vs.** wild smolt to adult survival rates	Appendix D of Peters et al. 2000b

These analyses bounded the range of potential responses of Snake River fish to hatchery influences. The lower bound (no effect) is based on analyses 1 and 3, which suggested no relationship between steelhead hatchery releases and survival rates. Analysis #2, which showed a positive relationship between hatchery steelhead releases and total mortality of Snake River fish (i.e. more releases = higher mortality), suggested that our assumption of a 25% reduction in extra mortality is consistent with a 50% reduction in hatchery steelhead production, assuming that the regression relationship represents a causal effect. Without strong scientific and public support, large reductions in hatchery programs may not be acceptable, and considerable delays in implementing hatchery reforms (i.e., delays longer than the 5 years we have assumed in our simulations) might be anticipated.

ES.4.4 Evaluation of feasibility and assumptions related to Hydro actions

Our analysis incorporated three major assumptions about the response of chinook populations to operation of the hydropower and transportation system.

1. Hydrosystem Effects on Direct Survival Rate of In-river Migrants

We have used CRiSP and FLUSH passage models to estimate hydrosystem effects on direct survival rates of juvenile migrants. We used input values for these models that were developed by the PATH hydro subgroup, which included representatives of NMFS, BPA, and State and Tribal fisheries agencies. CRITFC believes that the survival values assumed to result from 1995 BiOp operations are generally higher than what has recently occurred and may explain why model-predicted increases in populations were not observed in recent years (see Appendix C).

The A3 action assumed that breaching will lead to increases in direct survival of in-river migrants to levels currently observed in free-flowing reaches of the Snake River above Lower Granite dam. That is, we assumed that survival rates will not return to pre-impoundment levels because of shoreline development, effects of introduced species, changes in upstream water regulation, and changes in predator communities. Concerns have been expressed that breaching would have adverse short-term impacts on survival rates because of release of sediments from reservoirs, but a sensitivity analysis in the PATH Weight of Evidence exercise suggested that even a temporary 50% reduction in juvenile survival rates after breaching would not affect probabilities of exceeding the survival and recovery standards. Several studies detail economic costs and benefits of breaching (e.g. US Army Corps of Engineers 1999).

2. Extra Mortality

Evidence for and against the Hydro, Regime Shift, and Hatchery extra mortality hypotheses was summarized in PATH's Weight of Evidence Report. The weights assumed for the "Hybrid" hypothesis (50:30:20 for hydro, hatchery and regime shift, respectively) approximated the average weights applied by the SRP. We felt that it was better not to place too much weight on any one hypothesis to avoid the risks associated with relying too much on any one set of circumstances in an evaluation of recovery actions.

3. The Effectiveness of Transportation

Since the late 1960's NMFS has used transportation studies to compare the smolt-to-adult-returns (SARs) of transport groups to those of controls. These studies produced a transport-to-control ratio or TCR, a relative measure of the survival of transported fish. However, such a relative measure is unimportant if the fish are not surviving at rates high enough to sustain the population. A goal for smolt to adult survival rate (SAR) of two to six percent was established by a PATH hydro sub-group (Toole et al. 1996) as an absolute rather than a relative goal for Snake River spring/summer chinook. Because SARs of transported chinook are currently averaging approximately 0.5%, which is well below even the minimum goal of 2%, it is unlikely that minor refinements to the transportation system will result in increases in overall survival necessary for survival and recovery.

"D values" are an alternative measure for measuring transport effectiveness. D is the ratio of the survival rate of transported fish to inriver fish after they have arrived below Bonneville Dam. We have used a D value of 0.58 for this analysis, based on analyses of the 1994-1996 transportation studies (Bouwes et al. 1999). However, D's, like TCRs, are relative measures used to relate the survival of transported fish to that of inriver fish. A high D value does not provide evidence that the hydrosystem has no effect on mortality, because it just shifts mortality into the "extra" mortality component of overall mortality. Therefore, even if one assumes that D's are reasonably high, populations do not reach survival or recovery levels unless one also assumes that extra mortality is not related to the hydrosystem.

ES.4.5 Feasibility of Recovering Other Listed Stocks

The probabilities of recovering other listed stocks in the Snake River Basin through an All-H approach are more limited. The hydropower system accounts for high direct mortality on fall chinook during the mid and late summer because of high mainstem temperatures and prolonged migration times (Peters et al. 1999). Mainstem spawning habitat for Snake River fall chinook has been reduced by construction of the Lower Snake and Hells Canyon dams, and a panel of experts on regional hydrosystem assessments and mainstem riverine habitat convened by Battelle/USGS recently concluded that reservoir drawdown, dam breaching, and restoration of normative flow conditions is the only viable strategy for restoring mainstem habitat (Batelle and USGS 2000). Ocean harvest rates for fall chinook are higher than for spring/summer chinook, but achieving recovery would require severe reductions among both U.S. and Canadian fisheries in excess of recently negotiated treaties.

Snake River sockeye have abundant good habitat in Redfish Lake, but there are very few sockeye present. Their near absence is more than likely due to unusually high descaling rates for sockeye that encounter bypass screens. Harvest and hatchery actions are unlikely to have major benefits for sockeye, because hatchery impacts have been historically low and sockeye harvest rates are already lower than those for spring/summer chinook.

Introduction

The draft Biological Opinion recently released by NMFS calls for improvements in Harvest, Hydro, Habitat, and Hatchery conditions (i.e. an "All-H" alternative) to prevent extinction of Snake River spring/summer and fall chinook (NMFS 2000a). NMFS postpones breaching in favor of other actions in the areas of harvest, habitat, and hatchery, and continued reliance on the transportation system to mitigate for hydro losses. NMFS' Biological Opinion is based on analyses of overall and life stage-specific population growth rates by the Cumulative Risk Initiative.

The Biological Opinion has stimulated several critical questions: Will the proposed actions actually lead to survival and recovery of listed stocks? Would PATH[4] models (updated with the most recent available data) suggest the same outcomes as the CRI models? How strong is the evidence that the proposed actions are actually feasible to implement?

The objectives of this project were to:

a) update the PATH life-cycle model (Bayesian Simulation Model, or BSM) using the most recent data on spawners and recruitment, conversion rates, and D values.
b) define a set of reasonable assumptions about the possible responses of stocks to harvest, habitat, and hatchery actions
c) assess the performance of "All-H" alternatives using the updated model.
d) evaluate the feasibility of an All-H alternative
e) explore the effects of various factors on model projections

Methods

Bayesian Simulation Model (BSM)

Overview of the BSM

The PATH life-cycle model (Bayesian Simulation Model, or BSM) is based on a generalized Ricker stock-recruit model (Deriso et al. 1996; a technical description of the model is provided in Appendix A). The model runs in two phases. In the retrospective phase, the model uses historical spawner-recruit data, estimates of direct passage survival from the passage models, and assumptions about the relative post-Bonneville survival of transported fish compared to non-transported fish to estimate the following model parameters:

- Ricker *a* parameters for each of the spring/summer chinook index stocks (7 Snake River stocks and 3 lower Columbia stocks)

[4] PATH, the Plan for Analyzing and Testing Hypotheses, was a 4-year collaborative process involving 25 scientists from 6 federal entities (NMFS, USFWS, BPA, CORPS, USGS-BRD, USFS), 3 state fishery agencies (IDFG, ODFW, WDFW), 1 tribal organization (CRITFC), 2 regional entities (CBFWA, NPPC), 3 independent participating scientists (Drs. Randall Peterman, Richard Deriso and Louis Botsford), an independent facilitation team (ESSA), and an arms-length Scientific Review Panel (SRP – Drs. Steve Carpenter, Jeremy Collie, Saul Saila and Carl Walters).

- Ricker *b* parameters for each of the spring/summer chinook index stocks
- Survival factors experienced by both Snake River and lower Columbia spring chinook stocks (Common Year Effects), estimated for brood years 1952 to 1993
- A total mortality factor (estimated for brood years 1975 to 1993), which is combined with passage model estimates of direct passage mortality to derive an "Extra Mortality" factor to account for observed differences in survival between Snake River spring/summer chinook stocks and downstream stocks after 1970

In the prospective phase, the model simulates the trend in recruitment and escapement for the seven Snake River spring and summer chinook index stocks over the next 100 years (starting in year 2000). Each simulation is based on a set of the four parameters listed above drawn from their distributions, passage model estimates of what direct passage survival will be in the future under alternative hydrosystem operations, and assumptions about the relative post-Bonneville survival rate of transported fish compared to non-transported fish. This latter factor is represented by the D value, which is the ratio of the post-Bonneville survival rate of transported fish to the post-Bonneville survival rate of non-transported fish.

Forward projections with the BSM use 4000 100-year prospective Monte Carlo simulations, each using a different set of parameters (Ricker *a* and *b*, common year effects, and total mortality factors), to ensure that the uncertainty in parameter estimates is fully represented in the outputs. In addition, the BSM is embedded in a decision analysis framework that permits scientists to include different hypotheses regarding the effectiveness of alternative management actions and the causes of extra mortality. Thus the modeling framework incorporates two kinds of uncertainty: uncertainty in model parameter estimates, and uncertainty in other key assumptions about life-cycle mortality and responses to management actions.

In all modeling efforts, it is the relative performance of alternative actions which matters more than the projected absolute levels of escapement or recruitment. Models of fish populations simply can't predict biological responses over decadal time scales with absolute accuracy. It is, however, justified to compare the relative performance of alternative actions under a range of hypotheses for key uncertainties. The inclusion of these uncertainties allowed us to assess how they affect the performance and ranking of alternative management actions.

The structure of the BSM and its basic assumptions and relationships were generally unchanged from the model used in previous PATH analyses, except for the Refinements discussed below.

Refinement #1: Spawner and recruit data

We updated the model to incorporate recruit data for lower Columbia and Snake River index stocks of spring and summer chinook through brood year 1994, spawner estimates through BY 1999, and updated conversion rates (up-river survival) rate[5] (Eric Tinus, ODFW, memos dated August 3, 2000 and September 26, 2000). Wild and hatchery spawners were accounted for separately, to allow for multiple hypotheses about the spawning effectiveness of hatchery adults that spawn in index streams (see below). The model used regulated water transit time data through water year 1998. With the addition of the updated data, the model estimated 96 parameters based on 464 data points. The simulation period in the model is now 2000 to 2099.

Refinement #2: Initiation of year effects

The BSM estimates "common-year effects", or "delta" values, which are survival factors experienced by both Snake River and lower Columbia chinook stocks. In the retrospective modeling analysis, these effects are estimated from the historical spawner-recruit data for brood years 1952 to 1993. The prospective modeling then draws from these historical values for use in future simulations. Previously in BSM, the initial delta value was selected from BY1952-1990 values, a period that included both bad and good climate conditions. In the updated version of BSM, the year-effect used for 1995 (the first year in which recruits are estimated) was assumed to equal the year-effect estimated for 1993. The intent was to seed the time series of year-effects with the value that reflected the most recent estimated climate conditions, although as is turned out the 1993 year-effect was positive (i.e., ocean conditions were better than the 1952-1993 average). Using the delta value from 1993 therefore had the unintended effect of seeding the simulations with favorable ocean conditions (see Appendix C for more details).

Refinement #3: D Values

In previous PATH analyses, model predictions of 1995-99 escapement under A1 using only S:R data up to 1994 were considerably higher than the observed escapements for 1995-99. This was a concern to PATH scientists and to the PATH Scientific Review Panel. This overestimate could have been due to several factors, including failure to fulfill all of the operating conditions in the 1995 BiOp, actual survival improvements resulting from 1995 BiOP measures were smaller than assumed in the passage models, worse than average year effects, and depensatory mortality. We explored some of these possible factors in Appendix C, and found that model results were most affected by the historical time period from which common year effects and total mortality factors were selected in the future simulations. By selecting climate and mortality effects from long time periods that included both good and bad survival conditions, the model assumed better future climate and mortality conditions than what would be expected if we had used only the most recent estimates.

Another possible cause was an overestimate of the improvement of system survival since historic conditions, and in particular an overestimate of the relative increase in D values (the ratio of the survival rate of transported fish to inriver fish <u>after</u> they have arrived

[5] Because of errors in 1999 spawner estimates for the John Day stocks, BSM estimates of mu and year-effects for BY1994 were ignored in the prospective simulations.

below Bonneville Dam) between the retrospective and prospective periods. The ratio of prospective:retrospective D exerts a very strong effect on results (Marmorek et al. 1998a). Recent analyses of D values that have been carried out since the original PATH analyses suggest that our original hypotheses about the magnitude of D and changes in D over time needed to be revised. First, PIT-tag data from 1994-1996 transport studies suggested that recent D values have averaged around 0.58 (Bouwes et al. 1999). This is somewhat higher than average D values estimated by FLUSH in previous PATH analyses (0.45), somewhat lower than values estimated by CRiSP (0.73), and similar to values used by CRI (0.68). Second, analyses of SARs of transported fish suggested that D values haven't changed substantially in recent years (Weber et al. in prep). D values used in this analysis were based on previous FLUSH estimates for water years 1977-1996, which were scaled so that they average 0.58. The scaled values were used both retrospectively and prospectively, because we presumed that more recent estimates of D are more accurate than historic estimates. These D values were used in conjunction with both CRiSP and FLUSH estimates of direct passage survival. We did not implement a similar scaling process with the previous CRiSP D estimates because we did not wish to do so without the participation of the CRiSP developers.

Refinement #4: Spawning effectiveness of hatchery spawners

Previous BSM analyses assumed that hatchery adults spawning in index streams were 100% effective – that is, the survival rate of the progeny of hatchery spawners was equal to that of wild spawners. The best case in the 2000 BiOp assumed 20% effectiveness, which produced the highest estimates of stock productivity (same number of recruits produced by fewer spawners). A review of studies by R. Waples (cited in NMFS 2000a, p. C-20) suggested that a reasonable range of spawning effectiveness for hatchery spawners is from 20 to 80%. To allow these alternative hypotheses, BSM was modified to allow the user to select a value for the "hatchery spawner effectiveness" (*E*) parameter. The *E* parameter was used to construct an effective spawner count (*S*) in a given year as a linear combination of the number of wild spawners plus *E* times the number of hatchery spawners. Better fits to the historical spawner-recruit data were obtained when one assumed a high value of *E*.

Refinement #6: Model outputs

As a product of the 1995 Biological Opinion, the PATH models have generally used the 1995 BiOp Jeopardy Standards developed by the Biological Requirements Working Group (BRWG 1995) as the primary form of output. We continued to focus on these standards in this report, because we believe that they are meaningful biological metrics for jeopardy determinations. The revised version of BSM also produced two other outputs, including one (#1 below) that approximated metrics used by CRI. We included this metric only to allow comparisons between actions using CRI results, not to make comparisons between the BSM and CRI models, because the "probability of extinction" metric is sensitive to differences in assumptions between the two modeling frameworks (Peters et al. 2000a). Differences between CRI and BSM metrics are much less important than the relative differences among alternative actions.

1) Probability of extinction measure. The probability of extinction measure produced by the revised PATH model was calculated as the fraction of the 4000 Monte Carlo simulations in which a stock falls to less than 2 spawners in any 5 consecutive years over a 100-year time period. This is a relatively stringent criterion for determining extinction (Oosterhout 2000).

2) Probability distributions (geometric means and standard deviation) of the projected number of spawners for each stock for each simulation year. The distributions are derived from the 4000 Monte Carlo simulations, and thus provide an indication of the uncertainty in projected spawners due to uncertainty in the estimated model parameters.

Summary of actions, uncertainties, and performance measures

Actions, uncertainties, and performance measures used in this analysis are summarized in Table 2-1. We evaluated four overall actions combining different actions in each of the four H's:

A1 Current operation of the hydro action with no additional actions in the other H's.

This assumed that operating improvements proposed in the 1995 BiOp were successfully and fully implemented in every year. Although these assumed survival improvements may not have been fully realized in recent years (see Appendix C), A1 was the closest of the scenarios that had already been defined and run by the passage models to the operating conditions prescribed in the 2000 BiOp.

A1+ Current operation of the hydro action, with additional mitigation in habitat, harvest, and hatchery. Because these mitigation actions have not yet been fully defined, we had to make some assumptions about what we think off-site mitigation might include and what the effects of those actions might be.

A3 Breaching of the four lower Snake River dams (assuming an 8-year delay in implementation), with no additional actions in the other H's.

A3+ Breaching with additional mitigation in habitat, harvest, and hatchery.

These actions and their components are described in the next section. We also looked at A1+Hatchery, A1+Habitat, A1+Harvest, and A1+Habitat + Harvest so that we could determine the relative effects of the non-Hydro actions individually.

Of the performance measures, we primarily used the 1995 BiOp Jeopardy Standards (particularly the 48-year recovery metric) for comparing the actions, because this metric provided a means for comparing the actions' outcomes to a fixed and independently-derived target number of spawners.

Table 2-1. Summary of actions, uncertainties, and performance measures.

Actions					Uncertainties		Performance Measures
	Hydro	**Habitat**	**Harvest**	**Hatchery**			
A1	1995 BiOp operations	None (no change in productivity)	FMP Tiered Schedule	No action	Passage Models	FLUSH CRiSP	1995 BiOp Jeopardy Standards
A1+	1995 BiOp operations	Action similar to ICBEMP option 2	Capped at current rates	Generic hatchery action	Extra Mortality	Hydro Hatchery Regime Shift Hybrid	Pr(<2 spawners,5 years) Distribution of projected spawners in each year
A3	Breach 4 Snake River dams	None (no change in productivity)	FMP Tiered Schedule	No action	Hatchery effectiveness	20% 80%	
A3+	Breach 4 Snake River dams	Action similar to ICBEMP option 2	Capped at current rates	Generic hatchery action			

Definition of Habitat, Harvest, Hatchery, and Hydro actions

We modeled four different overall actions, combining actions in each of the four H's (Hydro, Habitat, Harvest, Hatchery; Table 2-1). A1+ and A3+ actions included non-hydro mitigation efforts, while A1 and A3 did not. We made the following assumptions about each of the actions:

Habitat

The 2000 Draft BiOp calls for broad measures that improve freshwater habitat conditions. However, specific actions were not defined. Therefore, to reflect the possible effects of some unspecified habitat action, we implemented a scenario similar to the "Preferred" Option (#2) in the ICBEMP reports (Quigley et al. (eds.) 1996). This habitat action was implemented by specifying probabilities of no change, increase, or decrease in Ricker *a* values for each Snake River index stock according to present habitat condition, frequency of natural events, and potential for habitat protection/restoration (Marmorek et al. 1998b)[6]. These probabilities were estimated in previous PATH analyses by the multi-agency PATH habitat sub-group[7], which also estimated the likely improvement in Ricker *a* from a habitat action, and the probabilities of observing these improvements within a 12 and 24-year period. Of the seven index stocks, only Bear Valley had a significant probability of improvement in Ricker *a* resulting from habitat

[6] The habitat action corresponds to the "Hab C' habitat scenario described in Marmorek et al. (1998c).
[7] This sub-group included Ben Meyer, Bob Ries, Charlie Paulsen, Charlie Petrosky, Chris Pinney, Danny Lee, Ian Parnell, Olaf Langness, Ray Beamesderfer, and Mike Jones.

restoration actions. The other stocks had high probabilities of no improvement in Ricker a values because they either are already in relatively good habitat conditions, or are subject to periodic to declines in habitat quality because of natural conditions or past disturbances (Schaller et al. 1999; Beamesderfer et al. 1997).

The alternative habitat scenario was implemented with actions A1+ and A3+. In actions A1 and A3, Ricker *a* parameters were assumed to be unchanged throughout the simulation period.

Harvest

We simulated a harvest scenario where harvest rates were capped at current levels, which are around 5% (summer chinook) or 8% (spring chinook) in the mainstem, and 0% in the tributaries, based on the tiered Columbia River Fisheries Management Plan harvest schedule. The capped harvest rates were assumed to be in place for the full 100-year simulation period. Base case runs used the tiered harvest schedule developed under the Columbia River Fisheries Management Plan.

Hatchery

The BiOp calls for two general types of hatchery actions: supplementation (which we have not modeled explicitly), and unspecified improvements in hatchery operations. As an example of the possible effects of the latter action, we implemented a generic hatchery action that was assumed to reduce the portion of extra mortality attributed to hatcheries by 25%, where the reduction takes effect after 5 years to account for delays in implementation[8]. This value was consistent with our assumptions about the possible magnitude and effectiveness of a reduction in steelhead production from Snake River hatcheries (see section 4.3).

Note that under the hydro and regime shift hypotheses, implementing the generic hatchery action had no effect because with these hypotheses all of the extra mortality is attributed either to dam and reservoir passage or environmental conditions. With the "hybrid" extra mortality hypothesis, only the 0.3 portion of the extra mortality assigned to hatchery effects was reduced by 25% under the generic hatchery action (i.e., extra mortality was reduced by around 8% overall). The extra mortality hypotheses thus represented a range of possible reductions in extra mortality resulting from some hatchery action: the hydro and regime shift hypotheses represented no response, the hatchery hypothesis represented a 25% reduction in extra mortality, and the hybrid hypotheses represented an intermediate 8% reduction in extra mortality.

[8] Because this reduction in extra mortality applies to all of the Snake River stocks, we are assuming that the generic hatchery action reduces the degree of potentially harmful interactions between wild and hatchery smolts in the main migratory corridor and in barges. Other hatchery actions might have localized effects that benefit only those index stocks that have a significant hatchery influence.

Hydro

We analyzed two hydro scenarios alone, and in conjunction with the habitat, harvest, and hatchery actions described above. We used the FLUSH and CRiSP passage models to estimate the direct survival of juvenile fish under each of these actions (see next section). A3 was breaching of the four lower Snake River dams. A1 represented operation of the hydropower and smolt transportation system according to full implementation of the 1995 BiOp, although it is important to note that not all of the measures in the 1995 BiOp were actually implemented (CRITFC, 2000). The 2000 BiOp calls for some additional measures to supplement the measures prescribed by the 1995 BiOp. However, we thought the probable effects of these additional measures on total direct passage mortality rates of juvenile Snake R. spring/summer chinook to be relatively minor[9], and the A1 scenario to be a reasonable representation of actions described by the 2000 draft BiOp.

Model assumptions and uncertainties

We implemented three uncertainties:

- Uncertainty in estimates of direct survival rates of juveniles through the hydrosystem, as estimated by the two passage models (CRiSP and FLUSH).
- Uncertainty in the historical spawning effectiveness of hatchery fish (2 hypotheses: 20% and 80% effective).
- Uncertainty in the source of extra mortality of Snake River fish, relative to downstream stocks (Hydro, Hatchery, Regime Shift, and Hybrid hypotheses).

There were a total of 16 possible combinations of these assumptions (2 passage models X 2 hatchery effectiveness hypotheses X 4 extra mortality hypotheses). The range of outcomes over these 16 combinations provides a means for assessing the robustness of the outcomes of the actions. These combinations are numbered as in Table 2-2 for ease of reference throughout the remainder of the report.

Passage Models

The passage models provide estimates of M (total direct mortality of transported and non-transported fish), Vn (in-river survival rate of non-transported fish), and Pbt (the proportion of fish arriving below Bonneville that were transported). We used the versions of CRiSP and FLUSH developed for previous PATH analyses (October 1998) to estimate direct passage survival for the A1 and A3 hydro actions for brood years 1975 to 1990. We used intermediate assumptions about FGE (Fish Guidance Efficacy, the fraction of fish guided away from the turbines), turbine mortality, predator removal effectiveness,

[9] The primary change from the 1995 BiOp to the 2000 draft is in spill management. Instead of spill targets (e.g. percent of daily flow), the 2000 draft BiOp provides spill volumes up to state water quality standards for total dissolved gas levels. This, coupled with construction of improved deflectors at John Day and Ice Harbor, results in higher spill volumes than the 1995 BiOp spill program at most projects (the exception is The Dalles, where NMFS proposes lower spill levels). However, these improvements do not greatly affect the total direct survival rates of juvenile Snake River spring/summer chinook assumed in the model (M; see footnote 8) because, under the existing transportation program, the majority (70-80%) of these migrants are transported by truck and barge from projects upstream of Ice Harbor. Other proposed changes described in the 2000 draft BiOp are either minor or based on research and development of technologies that do not currently exist.

and survival of juveniles after breaching. A3 runs assumed an 8-year delay in implementing breaching.

With the updated spawner-recruit data, we required retrospective and prospective estimates up to brood year 1994. However, these estimates were generally available only up to brood year 1990, so we required some alternative approaches to fill in these missing years.

Retrospective: Passage estimates for lower Columbia stocks were only available for both models up to BY1990. Estimates for brood years 1991-1994 were based on a mapping of regulated flows in those years to regulated flows in earlier years for which passage model estimates were available. For the Snake River stocks, passage model estimates were available up to brood year 1994 for FLUSH but only to 1990 for CRiSP. Therefore, we approximated CRiSP estimates for brood years 1991-1994 using a regression between FLUSH and CRiSP estimates from BY1952-1990 (R^2 = 0.7 to 0.92).

Prospective: FLUSH and CRiSP passage model estimates were only available for brood years 1975-1990. We approximated passage model outputs for each brood year from 1991 to 1994 by using passage model estimates from an earlier year that had a similar regulated flow to the later year.

Hatchery Effectiveness

The revised BSM allowed user-defined inputs for spawning effectiveness of hatchery fish. Previous PATH analyses implicitly assumed 100% effectiveness, but for this analysis we used alternative hypotheses of 20 and 80% (the lower and upper bounds of the reasonable range identified by Waples in NMFS 2000a).

Extra mortality

Deriso et al. (1996) and Schaller et al. (1999) compared the survival to adulthood of seven Snake River wild spring chinook stocks (which migrate past 8 mainstem projects) with six conspecific downstream "control stocks" (which migrate through 1, 2, or 3 projects). Snake River stocks experienced higher total mortality (i.e., over the whole life-cycle) than the downstream stocks. The incremental mortality experienced by Snake River stocks was far in excess of the amount that could be explained by their estimated mortality at the 5 to 7 additional projects they migrate past, after accounting for differences in stock productivity and year to year variations in survival experienced by both Snake River and downstream stocks.

This incremental mortality is called "differential" or "extra" mortality. We implemented four alternative hypotheses about the cause of the "extra" mortality experienced by Snake River stocks relative to downriver stocks.

I. Hydro Hypothesis - extra mortality is hydro related. Without dam removal, extra mortality of non-transported smolts was assumed to continue as it has in the recent past (1975 – 1993). With dam removal, extra mortality was assumed to take on values estimated in the historical pre-dam data (prior to brood year 1970).

II. Hatchery Hypothesis - extra mortality is hatchery related. Without hatchery improvements, extra mortality of both non-transported smolts and transported smolts was assumed to continue as it has in the recent past. If generic hatchery actions are taken then we assumed that the extra mortality rate of both non-transported and transported smolts was reduced by 25% after a five year delay to allow for management changes to be implemented.

III. Regime Shift Hypothesis - extra mortality is due to a cyclical climate regime shift with alternating 30-year periods of good and bad ocean conditions. In our implementation of this hypothesis, the last shift from good to bad conditions occurred in brood year 1975; the next shift from bad to good conditions occurs in the model in BY2005.

IV. Hybrid Hypothesis - extra mortality is due to a mixture of the effects in hypotheses I, II, and III. Under this hypothesis the total passage + extra mortality term was the weighted average of these values across hypotheses I, II, and III, using weights of 0.5 (hydro), 0.3 (hatchery), and 0.2 (regime shift). The weights were similar to the average weights assigned by the SRP in the Weight of Evidence Process (PATH SRP 1998).

Table 2-2. Combinations of uncertainties.

Combination #	Passage Model	Extra Mortality	Hatchery Effectiveness
1	FLUSH	Hydro	20%
2	FLUSH	Hatchery	20%
3	FLUSH	Regime Shift	20%
4	FLUSH	Hybrid	20%
5	FLUSH	Hydro	80%
6	FLUSH	Hatchery	80%
7	FLUSH	Regime Shift	80%
8	FLUSH	Hybrid	80%
9	CRiSP	Hydro	20%
10	CRiSP	Hatchery	20%
11	CRiSP	Regime Shift	20%
12	CRiSP	Hybrid	20%
13	CRiSP	Hydro	80%
14	CRiSP	Hatchery	80%
15	CRiSP	Regime Shift	80%
16	CRiSP	Hybrid	80%

Base Periods for Selecting Model Parameters in Forward Simulations

Forward simulations with BSM used 4000 100-year prospective Monte Carlo simulations, each using a different set of parameters, to ensure that the uncertainty in parameter estimates was fully represented in the outputs. Ricker *a* and *b* parameters were drawn from their historical distributions and applied in every year of the simulation. Common year effect parameters were selected from the historical values estimated for brood years 1952 to 1993. The selection followed an autoregressive pattern, such that above-average delta years tended to be followed by above-average delta years, and below-average years tended to be followed by below-average years. Total mortality (*m*) factors were selected from historical values estimated for brood years 1975 to 1993. These factors were selected in proportion to the occurrence of each water year in the historical (1929 to 1996) flow record. Therefore, *m* values form years with very high or low flows, which historically occurred relatively infrequently, would be selected much less often than a *m* value from a year with an average flow which occurred more frequently in the historical record

We explored the effects of these base periods on model results (see Appendix C), and found that the outputs were very sensitive to our assumptions. This is due to the temporal trends in common year effects and total mortality factors within our base periods. For example, the base period for common year effects (1952-1995) included a period of above average ocean survival years (1952-1975) and a period of below average ocean conditions (1976-1995). Selecting future common year effects from both periods (as we have done) produced higher projections of spawners than if future climate conditions were drawn from strictly the 1975-1995 period of below average conditions. Compounding the effect of this assumption was that the first simulation year used the δ value from 1993, the last year for which an historical δ value was estimated. This essentially assumed that initial climate conditions in the simulation will be similar to recent conditions, but because the 1993 δ value was better than the historical average, this had the effect of seeding the simulation with better than average climate conditions. Similarly, total mortality factors in the early part of our base period (1975-1983) were quite low compared to the later part of the base period (1984-1995). Selecting from the entire period produced higher spawner projections than if we had only selected from the latter part of the base period. In general, then, the base periods we used represented more favorable future climate and mortality conditions, and produced higher projected numbers of spawners, than what would be expected if we had used only the most recent estimates of common year effects and total mortality factors.

Results

This section highlights some of the general results and conclusions from the analysis[10].

3.1 Summary of Main Conclusions

For all seven index stocks of Snake River spring/summer chinook, A3+ (breaching plus hatchery, habitat, and harvest actions) produced the largest projected increase in spawners, and A1 (1995 BiOp hydro operations alone) produced the smallest projected increase. For six out of seven stocks (Imnaha, Minam, Marsh, Sulphur, Poverty, and Johnson), A3 (breaching alone) provided a larger increase in spawners than A1+ (current hydro operations plus hatchery, habitat, and harvest actions). For these stocks, hatchery and harvest actions had a greater effect on spawner projections than habitat actions, because most of these stocks are already in generally good habitat conditions. For the exception, Bear Valley, A1+ and A3 provided similar increases in projected spawners because, unlike the other stocks, habitat conditions in large areas of Bear Valley are currently poor and therefore could potentially benefit more from habitat improvements. However, these benefits may be more pronounced at high population abundance because most spawning currently occurs in existing pockets of good habitat conditions. For all stocks, there was a smaller range of potential outcomes (resulting from uncertainty in estimated model parameters) for A3 than A1+ outcomes, and less uncertainty in A1 and A3 than in A1+ and A3+. A risk-averse approach would favor actions with smaller ranges of outcomes because this implies that actions have lower probabilities of producing extremely low projected escapements.

The model projected initial increases in spawners even in the absence of reductions in extra mortality or implementation of major hydro, habitat, harvest, or hatchery actions. Most of this projected increase in spawners was due to the historical period from which common year effects and total mortality factors were selected in the future simulations. Our model included assumed better future climate and mortality conditions than what would be expected if we had used only the most recent estimates of common year effects and total mortality factors. For example, the projected spawning escapement of six of the seven index stocks decreased to fewer than ten spawners when we selected common year effects and total mortality factors from only the brood year 1984-1993 period, instead of from 1952-1993 (common year effects) and 1975-1993 (total mortality factors).

The rank order of actions in terms of their projected probabilities of exceeding survival and recovery exceeding thresholds was generally the same as for the projected increase in spawners: A3+ with the highest probabilities, followed by A3, A1+ and lastly A1. An exception to this general result was when one assumed that all of the extra mortality was related to hatcheries: in this case, A1+ produced probabilities of exceeding survival and recovery thresholds that were slightly higher than A3, but still lower than the A3+ action.

[10] Additional results are provided in Appendix B.

Distributions of the probability of exceeding the recovery threshold after 48 years showed that the A3+ action was the most robust action in terms of meeting the recovery standard (i.e., this action met the standard under the largest number of combinations of assumptions). For example, for Sulphur stock (one of the weaker stocks):

- A3+ met this standard in 15 out of the 16 possible combinations of assumptions.
- Breaching alone (A3) met the standard in 8 out of 16 cases.
- A1+ met the standard in 4 out of 16 cases.
- A1 alone did not meet the standard with any of the combinations.

Section 4 of this assessment documents evidence for assumptions about the underlying hypotheses by which the actions lead to survival and recovery.

Sensitivity analysis of alternative harvest schedules for Snake River spring chinook stocks showed that the harvest rates developed by CRITFC staff were the lowest at low abundance of the three harvest schedules we assessed, and provided the best opportunity for improving escapements of these stocks. The CRITFC schedule provides for lower harvest rates at low spawner abundance than either the Fisheries Management Plan schedule (which was implemented in actions A1 and A3) or a capped harvest schedule (implemented in actions A1+ and A3+), and of the three harvest schedules assessed appears to offer the best opportunity for improving escapements of these stocks. Although harvest rate reductions on their own are insufficient for achieving recovery goals, reducing harvest rates when stocks are at critically low levels has a small but positive effect on stock abundance.

3.2 Projected Spawners

Projected Spawners Under Assumed 1995 BiOp conditions

We assessed the overall behavior of our model by examining the projected number of spawners under the assumption that the actions prescribed by the 1995 BiOp will continue indefinitely into the future. It is important to note that not all of the actions specified in the 1995 BiOp have been implemented. This scenario is most closely approximated with the A1action and the hydro extra mortality hypothesis. Under this scenario, the only major change from historical conditions is that the direct survival rates of smolts are assumed to increase because of 1995 BiOp operations.

Figure 3-1 shows the projected trend for Sulphur stock (other stocks show the same general behavior). With both passage models, the projected escapement for this stock showed an initial increase, particularly in the first 10 years, before leveling off by around simulation year 2030. The long-term geometric mean was higher than the most recent observed values, but was well within the range of observed spawners since around 1975. Although the long-term average was considerably less than the observed average over the entire historical time period, it was considerably higher than the most recent observed escapements for most stocks.

The A1 action assumed that the 1995 BiOp operation of the hydrosystem has been fully and successfully implemented since 1995 and will continue to implemented throughout the entire simulation period. However, improvements in mainstem passage and the transportation program have generally not resulted in improvements in overall smolt to adult survival rates. Thus it may be that in reality some improvements (such as extended length screens) may increase direct survival but also increase delayed mortality, with the result of no net gain in overall survival. The BSM and passage models, however, have assumed that such improvements will increase both direct and overall survival rates.

Given that this increase in direct component of passage survival was the only survival improvement in this scenario, we were surprised at the magnitude of the increase in projected spawners in Figure 3-1. Possible reasons for the initial increase (aside from the assumption that direct passage survival has improved as a result of implementing the 1995 BiOp operating conditions) included the use of the long-term average productivity estimates in the forward simulations, and the fact that the PATH models did not assume any depensatory mortality at low stock sizes[11]. We examined the effects of these factors on spawner projections in Appendix C. We found that the improvement in direct passage survival accounted for some of the increase in projected spawners under action A1. However, a larger proportion of the increase was accounted for by the historical period from which common year effects and total mortality factors were selected in the future simulations. In BSM, common year effects were selected from brood years 1952-1995, which included some above average ocean survival years, particularly in the 1952-197 period. Total mortality factors were selected from brood years 1975-1995, a period which included some years from 1975 – 1983 when total mortality was quite low. Our model results thus assume better future climate and mortality conditions than what would be expected if we had used only the most recent estimates. As an example of the importance of the base period assumption, the projected spawning escapement all of the index stocks except Minam decreased to fewer than ten spawners when we selected common year effects and total mortality factors from only the brood year 1984-1995 period. The Minam stock decreased to fewer than 20 spawners.

The 10^{th} and 90^{th} percentiles shown in Figure 3-1 provide an indication of the range in the projected number of spawners. That range is due to the range of uncertainty in estimates of the BSM parameters. With both passage models, in 10% of the 4000 simulations (the 10^{th} percentile) the projected long-term equilibrium was lower than around 30 fish. The upper end of the distribution was lower with FLUSH: the 90^{th} percentile with that passage model was around 600-800 fish (i.e., the projected equilibrium level was greater than this value in 10% of the simulations), while the 90^{th} percentile was around 800-1000 fish with CRiSP. Passage models affect the distributions of BSM parameter estimates

[11] Depensatory effects are demographic changes that could occur if escapement falls below critical thresholds. These effects reduce stock productivity below levels expected from historic population patterns. The survival spawning threshold developed for the 1995 Biological Opinion Jeopardy Standards by the Biological Requirements Working Group (BRWG 1994) was intended to represent this critical threshold. BSM did estimate a depensation parameter to account for depensatory mortality at low stock sizes. However, the estimated value of this parameter was very close to zero suggesting that there was little evidence in the spawner-recruit data for a depensatory effect.

because historical estimates of direct passage mortality (M) are input to BSM in the retrospective analyses.

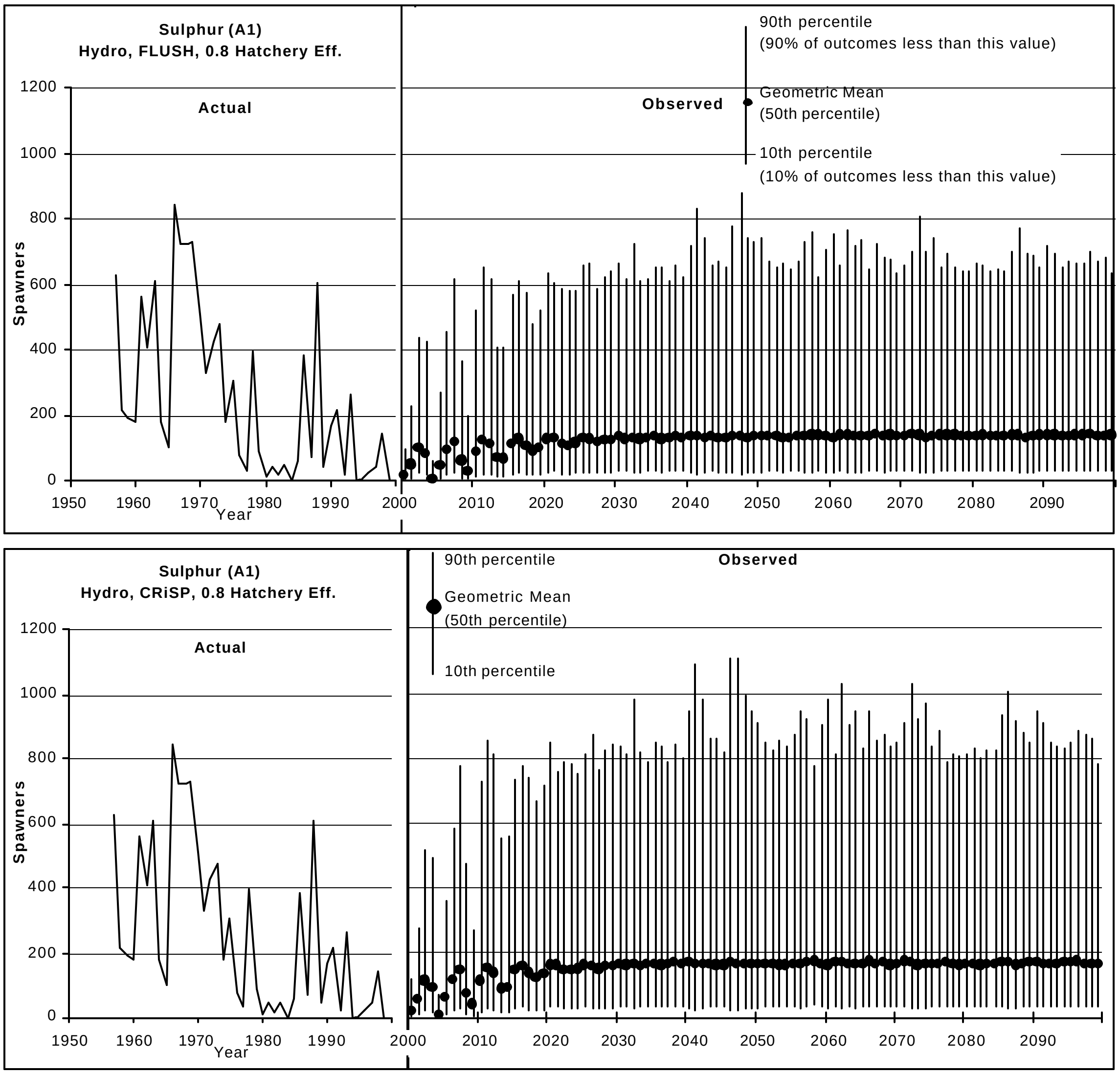
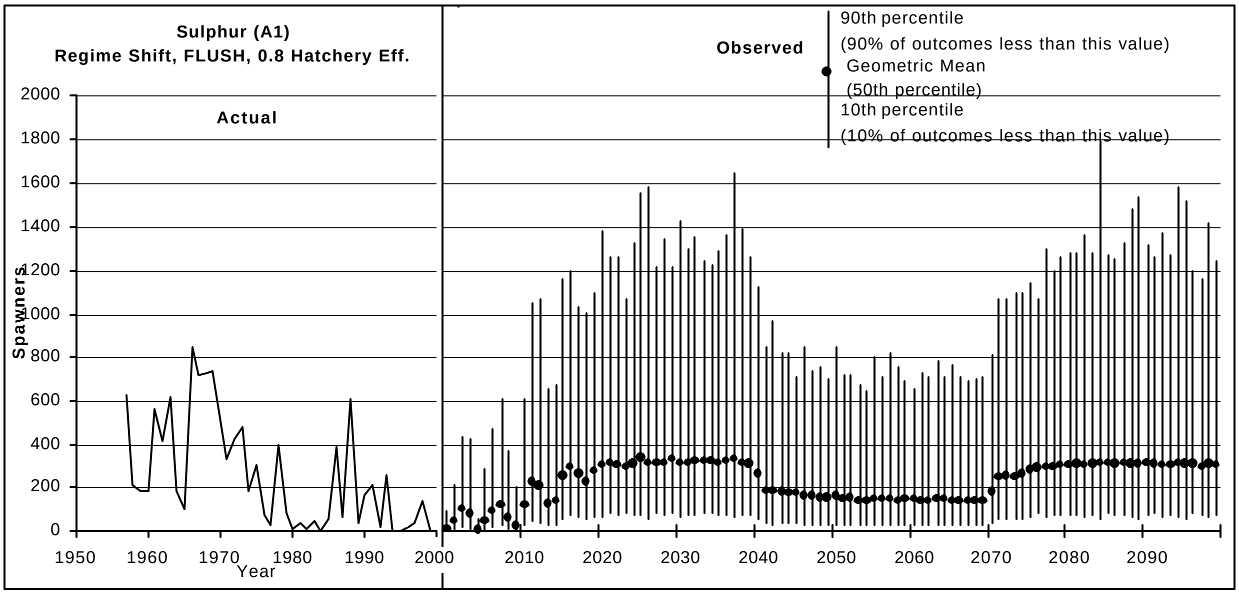


Figure 3-1. Geometric mean, 10th, and 90th percentiles of spawners in each simulated year for Sulphur stock, assuming the hydro extra mortality hypothesis, the FLUSH (top) and CRiSP (bottom) passage models, and 80% hatchery spawning effectiveness (combinations 5 and 13 from Table 2-2). Results were similar when hatchery spawning effectiveness was assumed to be 20%. Actual spawner data goes to 1999. The initial increase in spawners is due to assumed improvements in passage survival associated with 1995 BiOp operating conditions, and to selecting common year effects and total mortality factors from the entire historical period.

Spawner projections were much higher if one assumed that a climatic regime shift is imminent and that this shift would reduce extra mortality of Snake River chinook (Figure 3-2). With this extra mortality hypothesis, extra mortality returned to zero from 2005 to 2034; equilibrium spawners during this period of good climatic conditions was more than double that expected if a regime shift did not occur or was not assumed to be the major source of extra mortality (Figure 3-1). Under the regime shift hypothesis, the extra mortality experienced by Snake River stocks in the late 1970's through the early 1980's was due to poor environmental conditions affecting both transported and non-transported Snake fish, but not lower Columbia River stocks. This extra mortality is assumed to disappear with the hypothesized regime shift in 2005.



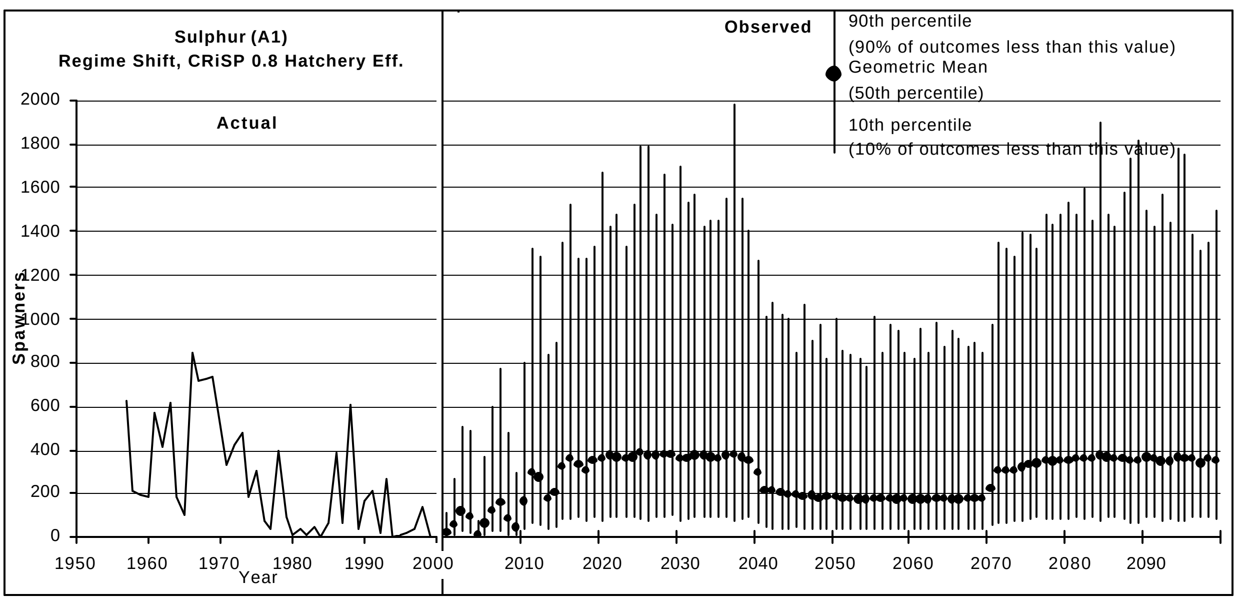


Figure 3-2. Geometric mean, 10th, and 90th percentiles of spawners in each simulated year for Sulphur stock, assuming the regime shift extra mortality hypothesis, the FLUSH (top) and CRiSP (bottom) passage models, and 80% hatchery spawning effectiveness (combinations 5 and 13 from Table 2-2). Results were similar when hatchery spawning effectiveness was assumed to be 20%. Actual spawner data goes to 1999.

Comparison of Actions

Explicitly acknowledging and incorporating uncertainty in model parameters through Monte Carlo simulations allows us to examine the full range of outcomes that actions could potentially produce, and the relative probabilities of these outcomes. Distributions of spawners over the 4000 simulations were approximately log-normal, with geometric means closer to the lower end (10^{th} percentile) of the distribution than the upper end (90^{th} percentile). Figure 3-3 shows probability distributions of projected spawners for the Sulphur stock at three simulation years: 2010 (10 years in to the simulation), 2020, and 2050 (by which time projected escapement has reached a steady-state level – see Figure 3-1). Results for the Sulphur stock are representative of six of the seven index stocks (the exception is discussed below; results for all stocks are shown in Appendix B). These results used the hybrid extra mortality hypothesis, the FLUSH passage model, and hatchery spawning effectiveness of 80% (i.e., combination #8 in Table 2-2). We focussed on this particular set of hypotheses because: a) the hybrid extra mortality hypothesis most closely represented a weighted average using the weights applied by the SRP, and b) the FLUSH passage model produced the narrowest distribution of outcomes (Figure 3-1) and was the only passage model for which we had actual survival rate estimates for 1991-1994 (CRiSP estimates for those years were based on a regression between FLUSH and CRISP estimates for brood years 1952-1990). The hatchery spawning effectiveness assumption had virtually no effect on the results.

A risk-averse approach would favor actions that produced smaller probabilities of producing extremely low outcomes (i.e., had higher 10^{th} percentiles). In this context, breaching actions were more risk-averse than non-breaching actions. The 10th percentile for A3 and A3+ was around 100 spawners (indicating that 10% of the simulations produced spawners below this value), whereas the 10^{th} percentile for the A1 and A1+ actions was around 30 spawners. Note that the distributions for the A1+ and A3+ actions are wider (i.e. there is more uncertainty in the projected outcomes) than for A1 and A3. A possible explanation for this is that the survival improvements resulting from the hatchery component of these actions result from reductions in extra mortality, and are therefore more sensitive to uncertainty in the BSM's estimates of extra mortality. In addition, there is greater uncertainty associated with the habitat actions because the assumed productivity increases are based on estimated Ricker *a* values (and are thus more sensitive to uncertainty in this model parameter), and because the realization of potential productivity improvements is uncertain (as represented by the probabilities of achieving increases in Ricker *a* values).

In the short-term (simulation year 2010) all actions produced similar numbers of spawners because of assumed delays in realizing the effects of breaching (10-year delay), hatchery (5-year delay) and habitat (12-24 year delay) actions. After 20 and 50 years, however, the breaching actions (A3 and A3+) produced larger numbers of spawners than the non-breaching actions. A3+ produced the largest increase in escapement, followed by A3 (breaching alone). This result was consistent with NMFS' conclusion that breaching provides the largest improvement in survival rates of listed Snake River salmon stocks (NMFS 2000a p. 9-216). A1+ produced some improvement in projected spawners over A1 alone, but this increase was not as large as could be obtained by implementing breaching alone.

Although we have concentrated here on projected <u>spawners</u>, we note that the effects of the A3 vs. A1 action would be much greater if one were to look at the projected number of <u>recruits to the river mouth</u>. This was because with the tiered harvest schedule, A3 provides higher in-river harvest rates (and thus supports higher catches in important mainstem and tributary fisheries) than the A1 action. For example, mainstem harvest rates for Sulphur stock with the hybrid hypothesis were around 0.4 at equilibrium for the A3 action, but were around 0.14 at equilibrium for A1. The higher in-river harvest rates with A3 tends to dampen the relative effects of A3 and A1 on recruitment.

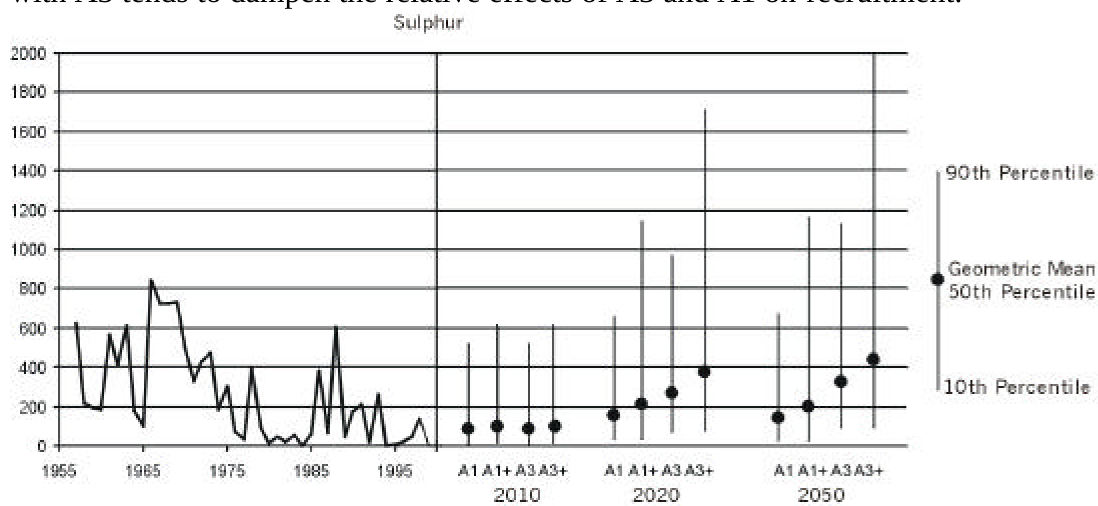


Figure 3-3. Geometric mean, 10th, and 90th percentile of spawners in simulation years 2010, 2020, and 2050 for Sulphur stock, assuming the hybrid extra mortality hypothesis, the FLUSH passage model, and 80% hatchery spawning effectiveness (combination 8 from Table 2-2). Actual spawner data goes to 1999. The "+" actions include habitat, hatchery, and harvest improvements.

The general pattern shown in Figure 3-3 was typical of six out of the seven index stocks. For the exception, Bear Valley, A3+ again provided the largest survival improvement and A1 the smallest. Unlike Sulphur and the other stocks, however, the Bear Valley stock showed a pattern where projected spawners with the A1+ action were about equivalent to results for A3 alone (Figure 3-4). This pattern was the result of the relatively high probability of an improvement in productivity associated with habitat protection and restoration (Figure 3-5 top panel; this figure again assumes the hybrid extra mortality hypothesis, the FLUSH passage model, and 80% hatchery effectiveness). Because this stock currently has large areas of poor habitat, it has the most to gain from actions to improve habitat conditions. However, the positive effects of habitat improvements on Bear Valley at low spawner abundance, and therefore on the ability of habitat actions to recover this stock, may be overstated because there are pockets of good habitat conditions where fish currently spawn. Therefore, assumed productivity increases associated with habitat restoration may not be realized until escapements are large and actively spawning in areas where habitat is currently poor and has most to gain from restoration activity. Because our implementation of the habitat action assumes that all Bear Valley fish (even those that spawn in the good habitat that currently exists) realize productivity increases from habitat restoration, we may be overestimating the efficacy of habitat restoration for increasing abundance of the Bear Valley stock from its currently low levels to levels approaching its recovery threshold.

Although the geometric mean of spawners for A1+ and A3 were similar, their distributions were not. A1+ had a wider distribution of outcomes, with higher probabilities of both very large and very small projected escapements than A3. A3 is therefore a more risk-averse strategy because it produces a lower probability of very small projected escapements. Overall, distributions for Bear Valley were considerably wider than Sulphur, primarily because the estimated carrying capacity for Bear was larger than most of the other stocks and because the spawner-recruit data for Bear Valley produced less precise estimates of Ricker *a* and *b* parameters (the same was true for Marsh Creek – see Appendix B).

For stocks other than Bear Valley, improvements in freshwater spawning and rearing habitat alone provided only a small improvement or even a reduction in spawners if harvest rates were not simultaneously capped (bottom of Figure 3-5). Most of the difference between A1 and A1+ in these stocks was a result of capping harvest rates and assuming a reduction in extra mortality from some generic hatchery action. The hatchery action provided a bigger boost if the hatchery extra mortality hypothesis was given higher weight than that assigned by the PATH SRP (recall that the reduction in extra mortality due to the generic hatchery action was 25% when full weight placed was on the hatchery extra mortality hypothesis, compared to only a 8% reduction with the hybrid extra mortality hypothesis).

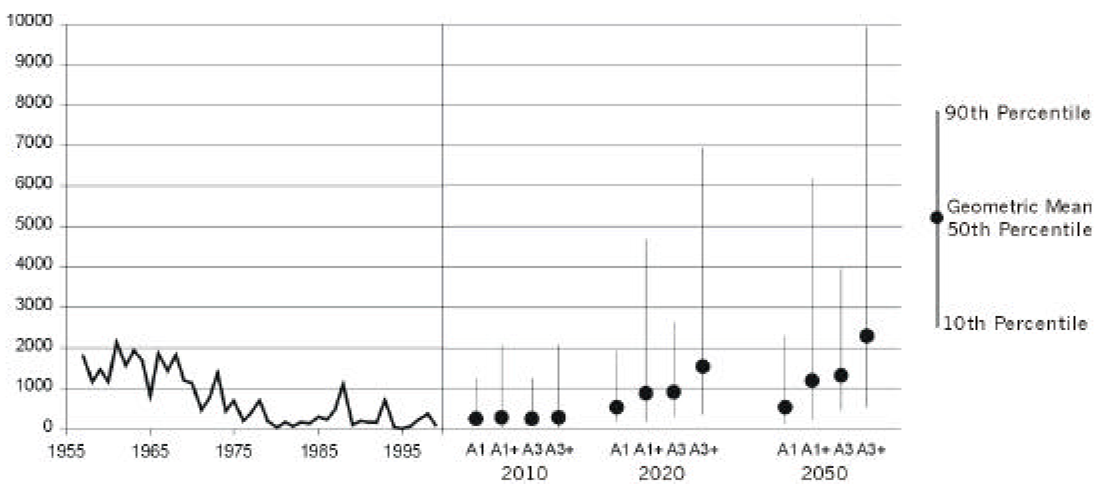


Figure 3-4. Geometric mean, 10th, and 90th percentile of spawners in simulation years 2010, 2020, and 2050 for Bear Valley stock, assuming the hybrid extra mortality hypothesis, the FLUSH passage model, and 80% hatchery spawning effectiveness (combination 8 from Table 2-2). Actual spawner data goes to 1999. The "+" actions include habitat, hatchery, and harvest improvements.

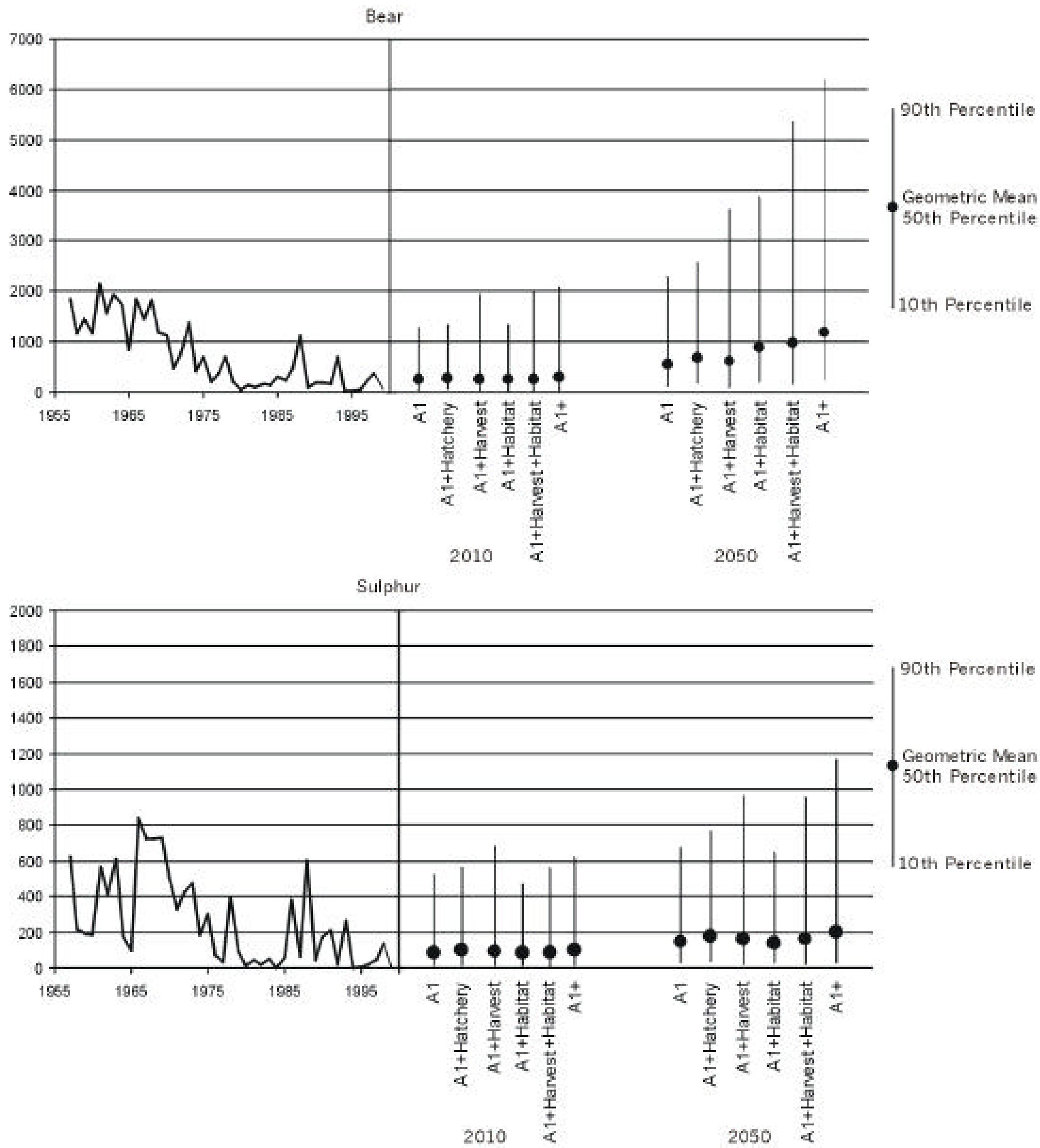


Figure 3-5. Effect of non-hydro actions on geometric mean, 10th, and 90th percentile of spawners in simulation years 2010 and 2050 for Bear Valley (top) and Sulphur (bottom) stocks, using the hybrid extra mortality hypothesis the FLUSH passage model, and 80% hatchery spawning effectiveness (combination 8 from Table 2-2).

3.3 1995 BiOp Jeopardy Standards

In this section, we focus on the relative performance of the actions in achieving the 1995 BiOp jeopardy standards. We were particularly interested in how the relative performance of actions is affected by our uncertainties in passage survivals (represented by FLUSH and CRiSP passage models), hatchery spawning effectiveness (20% or 80%), and hypothesized causes of extra mortality (hydro, hatchery, regime shift, or hybrid).

Comparing the projected number of spawners across actions provides an intuitive measure of the relative performance of actions, but it is important to emphasize that these projections do not provide an absolute criterion for determining whether the stocks will have increased sufficiently to achieve recovery. The 1995 BiOp jeopardy standards provide absolute criteria by comparing projected spawner numbers to absolute survival and recovery escapement thresholds. The jeopardy standards integrate uncertainties in estimated model parameters by calculating the probability of exceeding these thresholds over the 4000 simulations. Higher probabilities indicate that an action produces an increase in spawners that is sufficient to exceed the thresholds under a wide range of estimates of model parameters and is thus less sensitive (more "robust") to uncertainty in those parameters. In the 1995 BiOp, NMFS provided yardsticks for measuring the success of actions by specifying minimum levels for these probabilities: 0.7 for the survival probabilities and 0.5 for the recovery standards (i.e., for an action to meet the survival standard 0.7 of the 4000 simulations must produce an increase in spawners that exceeds the survival threshold). NMFS also specified that six out of the seven stocks must achieve these minimum levels, so we present results for the 6th best stock[12].

Sensitivity of Ranking and Performance of Actions to Uncertainties

In general, model results were most sensitive to extra mortality hypotheses. Table B-1 shows the outcomes of the actions for each of the 16 combinations of passage models, hatchery spawner effectiveness, and extra mortality hypotheses. Here, we concentrate on the effects of the extra mortality hypotheses (Table 3-1), and calculate an average over the 4 combinations of passage models and hatchery spawner effectiveness hypotheses for each extra mortality hypothesis (i.e., we calculate the average of combinations 1, 5, 9, and 13 from Table 2-2 for the Hydro hypothesis, 2, 6, 10, 14 for the Hatchery hypothesis, etc.). There were a few cases where the passage models produced notably different outcomes; these are noted in Table 3-1 with footnotes. Assumptions about hatchery spawning effectiveness had very little effect.

A3+ produced the highest probabilities of achieving the survival and recovery thresholds with all extra mortality hypotheses. In most cases, A3 produced the next highest probability (in some cases outcomes for A3 were very close or equal to the results for A3+)., followed by A1+ and A1. One exception to this general pattern was with the hatchery hypothesis, where all probabilities for A1+ were higher than A3 (but still lower

[12] The sixth best stock can vary between performance measures and combinations of assumptions, because different stocks respond differently to uncertainties, effects of the actions, and other factors that influence the results. In general, Sulphur is the 6th best stock most often for the 24-year survival standard, Marsh Creek is 6th best most often for the 100-year survival standard, and Imnaha is 6th best most often for the 48-year recovery standard.

than A3+) because of the 25% reduction in extra mortality that is assumed to result from improvements in hatchery operations under this hypothesis. Another exception was with the regime shift hypothesis, where the 24-year survival probability for all actions were relatively similar.

A3+ met the 100-year survival and the 48-year recovery standard regardless of the extra mortality assumption. The ability of the other actions to meet these standards depended on the extra mortality hypothesis:

- A3 met both standards with all extra mortality hypotheses except the hatchery hypothesis.
- A1+ met the 100-year survival standard with all extra mortality hypotheses except the hydro hypothesis, but only meets the 48-year recovery standard with the hatchery hypothesis.
- A1 only meets the 100-year survival standard with the regime shift hypothesis, but doesn't meet the recovery standard with any of the hypotheses.

None of the actions under any circumstances achieved the 24-year survival standard. That is, although all of the actions produced an increase in the projected number of spawners (e.g. Figure 3-3 and 3-4), these increases were apparently not large enough to exceed the survival escapement thresholds in the first 24 years 70% of the time, as required to achieve the survival standard. These thresholds are quite high (150 or spawners), compared to the low spawning abundance of most stocks in recent years. Therefore, it is not surprising that most of the stocks have a low probability of exceeding this threshold in the first 24 years of the simulation.

Table 3-1. Average probabilities of exceeding survival and recovery thresholds for the 6th best stock. Results shown are for each of the extra mortality hypotheses, and are averaged over the passage models and hatchery effectiveness hypotheses (i.e., combinations 1, 5, 9, and 13 for the Hydro hypothesis; 2, 6, 10, and 14 for the Hatchery; 3, 7, 11, and 15 for Regime Shift, and 4, 8, 12, and 16 for Hybrid). Values that exceed the NMFS standards of 0.7 for survival measures and 0.5 for recovery measures are in **bold**. Cases where passage models affected the ability of action to achieve the standards are noted with footnotes.

Performance Measure	Extra Mortality Hypothesis	A1	A1+	A3	A3+
24-year Survival	Hybrid	0.42	0.47	0.48	0.52
	Hatchery	0.40	0.51	0.42	0.51
	Hydro	0.39	0.40	0.49	0.51
	Regime Shift	0.54	0.56	0.55	0.56
100-year Survival	Hybrid	0.59	**0.73**	**0.82**	**0.85**
	Hatchery	0.54	**0.81**	0.69[a]	**0.83**
	Hydro	0.52	0.58	**0.83**	**0.85**
	Regime Shift	**0.77**	**0.79**	**0.84**	**0.84**
48-year Recovery	Hybrid	0.24	0.43[b]	**0.79**	**0.87**
	Hatchery	0.20	**0.66**	0.49[c]	**0.80**
	Hydro	0.19	0.27	**0.89**	**0.90**
	Regime Shift	0.32	0.41	**0.53**	**0.58**

[a] CRiSP results (0.75) met the 0.7 standard, but FLUSH results (0.64) did not.
[b] CRiSP results (0.50) met the 0.5 standard, but FLUSH results (0.37) did not.
[c] CRiSP results (0.59) met the 0.5 standard, but FLUSH results (0.39) did not.

Robustness of Results

The results in Table 3-1 raise the issue of robustness – that is, how does an action perform across a broad range of different uncertainties. Because the exact biological response to a recovery action can never be known in advance, taking any action involves the risk that the selected action will not have its intended effect. Minimizing such a risk, which is an important component of a precautionary approach to decision-making (FAO 1996), can be achieved by identifying robust actions that perform well across a broad range of these uncertainties. Such actions have a much higher chance of producing a favorable outcome (i.e. recovery of stocks) even if our hypotheses about the source of extra mortality, for example, turns out to be wrong.

Embedding the BSM in a decision analysis framework allowed us to examine the robustness of the four actions with respect to uncertainty about extra mortality, passage models, and hatchery spawning effectiveness. We did this by examining the frequency distributions of the outcomes across all possible combinations of these hypotheses (i.e., all 16 combinations of assumptions in Table 2-2) (Figure 3-6). We focus here on the 48-year recovery standard, using Sulphur as an example because the results for this stock are typical of all other stocks except Bear Valley (see Figure B-2). In Figure 3-6, the horizontal length of each bar shows the proportion of the 16 combinations that produced a particular likelihood. For example, 0.25 of the 16 combinations (i.e., 4 out of 16) for Action A1 resulted in a likelihood of exceeding the recovery threshold of 0.1 to 0.15. A robust action is one where there is a high proportion of the 16 combinations resulting in a high likelihood of exceeding the threshold. The figure also shows the overall mean and median likelihoods over all 16 combinations, and the proportion of the 16 combinations that resulted in a likelihood that equaled or exceeded NMFS standard of 0.5. For example, none of the combinations for A1 resulted in a likelihood that met the 0.5 standard, whereas results of 0.94 of the 16 (15 out of 16) combinations for A3+ met the standard.

These distributions show that the A3+ action was the most robust action because the standard was met in 0.94 of the 16 possible combinations of assumptions. Breaching alone (A3) met the standard in 0.5 of 16 cases, while A1+ met the standard in 0.25 out of 16 cases. A1 alone did not meet the standard with any of the combinations.

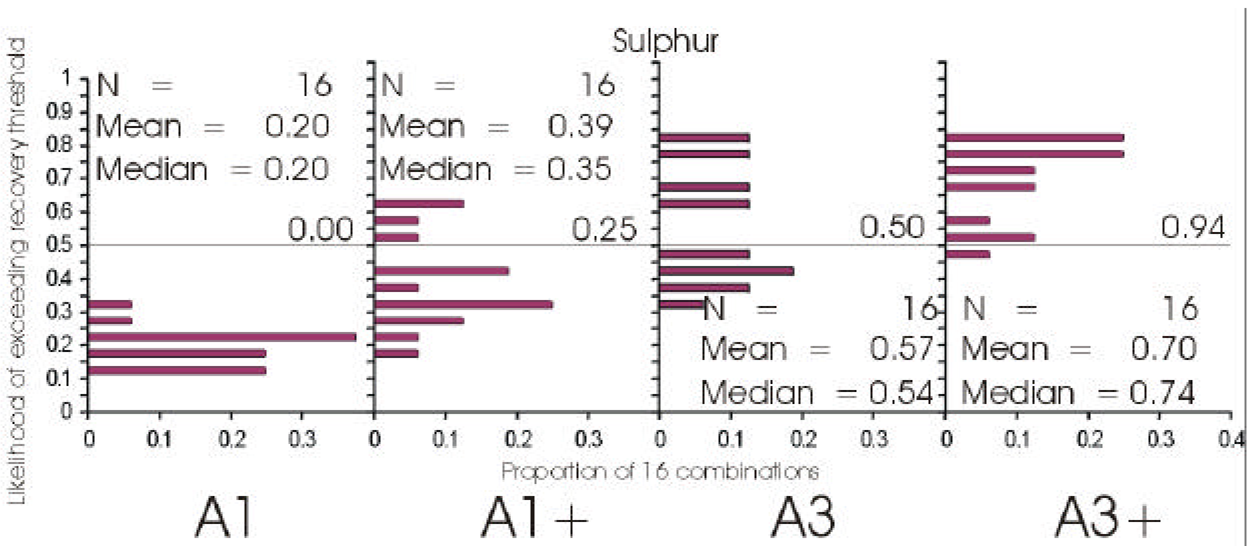


Figure 3-6. Distributions of 48-year recovery probabilities over all combinations of passage models, extra mortality, and hatchery effectiveness hypotheses (all 16 combinations in Table 2-2) for Sulphur stock. The "+" actions include habitat, hatchery, and harvest improvements. Overall mean and median probabilities (calculated over the 16 combinations of passage model, hatchery spawner effectiveness, and extra mortality hypotheses) are also shown, along with the proportion of the 16 combinations of passage model, hatchery spawner effectiveness, and extra mortality hypotheses that exceed the 0.5 recovery standard. For example, for action A1+ the mean and median probability of exceeding the recovery threshold over 48 years were 0.39 and 0.35 respectively, and 0.25 of the 16 combinations produced a probability of exceeding the recovery threshold of 0.5 or greater.

We conducted a similar analysis of the non-hydro actions (Figure 3-7). The figure shows distributions of 48-year recovery probabilities for Sulphur and Bear stocks, for various combinations of A1 and non-hydro actions. As was demonstrated in Figure 3-5, the non-hydro actions (particularly the combination of habitat and harvest) provided a greater benefit for the Bear stock than for Sulphur and the other stocks. However, as we noted earlier the efficacy of habitat restoration for increasing abundance of the Bear Valley stock at current stock sizes may be overestimated because our implementation of the habitat action assumes that all Bear Valley fish (even those that spawn in existing pockets of good habitat) realize productivity increases from habitat restoration.

For both stocks, the effects of the hatchery action were most strongly influenced by the uncertainties (i.e. the distribution was broadest). Table B-1 suggests that of the three uncertainties, extra mortality had the greatest influence on the performance of the hatchery action.

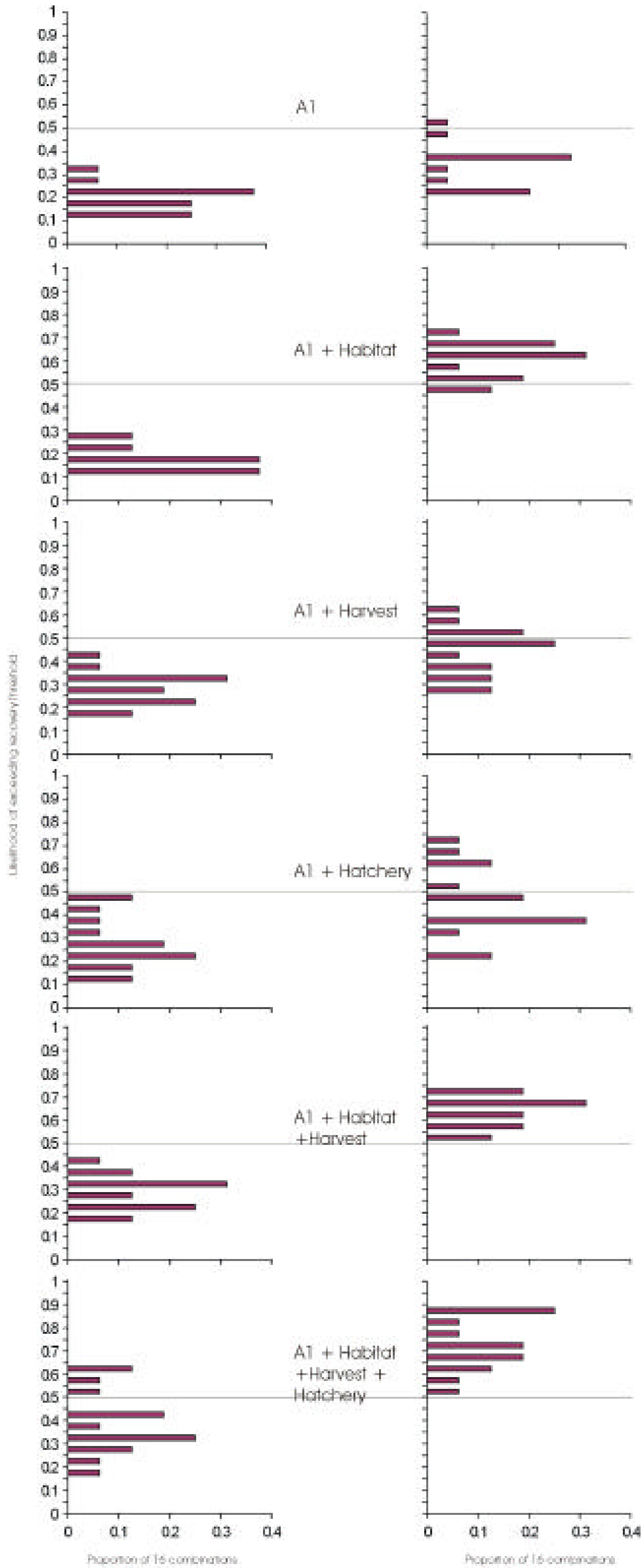


Figure 3-7. Effects of non-hydro actions on distributions of 48-year recovery probabilities for Sulphur (left) and Bear (right) stocks over all combinations of passage models, extra mortality, and hatchery effectiveness hypotheses (i.e., all combinations listed in Table 2-2) The 1995 BiOp standard is 0.5.

Evaluation of Feasibility and Assumptions

NMFS has recommended a strategy that seeks to recover stocks through a combination of non-breach hydro actions and actions in the "other H's" (habitat, harvest & hatcheries). Although most offsite mitigation efforts have not yet been defined, in general, it seems likely that many of the strategies NMFS has proposed may benefit listed Snake River stocks. However, using any model to project what those benefits might be requires assumptions about:

a) whether and to what extent the action can be feasibly implemented from a practical (i.e. institutional, legal, economic, etc.) point of view, and
b) the magnitude and timing of effects of the action on the survival rate of Snake River spring/summer chinook index stocks (including direct survival and extra mortality)

This section discusses these issues from both the biological and institutional perspectives. We examine both the assumptions that implicitly underlie NMFS' recommended action, and the assumptions that we made in our assessments described in this report. Assumptions are particularly tenuous for the non-hydro mitigation efforts prescribed in the Draft Biological Opinion because NMFS and the action agencies have yet to work out the details about exactly what the management actions would be, where and how they would be implemented, and the evidence for expected survival improvements. Without this detailed information, it is difficult to make a thorough assessment of the practical limitations of implementing these actions and their likely effects on survival of salmon. In the absence of detailed descriptions of the actions, the best we can do is to evaluate these assumptions in general terms, and provide some information that suggests that certain assumptions are or are not tenable.

Evaluation of feasibility and assumptions related to Habitat actions

NMFS concludes that the freshwater and estuary life stages offer the greatest potential for improvement (CRI 2000). This conclusion assumes first of all that implementing actions to achieve this improvement is possible. In reality, efforts to improve habitat in these life stages face a number of practical hurdles, particularly on private lands (see CRITFC's comments on the 2000 Biological Opinion and All-H Papers (CRITFC 2000) for a summary of these obstacles). One particular concern is that despite many plans and processes, meaningful large scale habitat measures are rarely implemented. In addition, improvements on federal land have been taken off the table (Federal Caucus 2000). If one makes the assumption that these obstacles can be overcome, the reliance on habitat improvements next assumes that such actions will have immediate and significant detectable effects on survival rates. This assumption illustrates the need for improved understanding about the relationship between habitat quality and survival.

CRI is unquestionably correct in its assertion that there are high levels of mortality in both the freshwater and estuarine life stages for Snake River spring/summer chinook. These are stages when comparatively small fish are required to find food sources for their first time while simultaneously avoiding previously unencountered predators. Habitat conditions and natural disturbances or management actions which affect habitat have been widely observed to affect salmonid survival during freshwater rearing (PATH Habitat Subgroup 1997). In addition, egg-to-smolt mortality rates (which typically exceed 90%) suggest that scope exists for habitat-related changes in freshwater rearing survival, although in watersheds with good habitat conditions most of this mortality is natural mortality about which little can be done. Properly done, a feasibility analysis focuses on human induced mortality or, in other words, that portion of the mortality in different life stages where management actions can reasonably be assumed to increase survival.

However, it is often difficult to quantify relationships between population productivity and habitat condition or changes in those conditions resulting from some action. Comparisons of stock-recruitment data for spring chinook salmon generally failed to show significant correlations between landscape or land use variables and index stock productivity (Paulsen et al. 1997). Confounding problems included a lack of adequate measures of habitat quality, incomplete datasets on land use, difficulties in defining appropriate spatial scales, and uncertainties in defining lag times for effects. Thus, while few would disagree that habitat can be a critical limiting factor in freshwater rearing or that changes in land use can affect habitat quality and survival, the effects of any given set of habitat improvement activities on stock productivity is extremely difficult to predict (PATH Habitat Subgroup 1997).

One can make qualitative observations about the effectiveness of freshwater habitat actions by examining the status of stocks in both damaged and healthy habitat. The fact that there are stocks in pristine areas (Marsh Creek) and designated wilderness areas (Sulphur Creek) that are in immediate risk of extirpation strongly indicates that improving habitat quality and quantity, though desirable, is insufficient to recover spring/summer chinook.

NMFS has used the Feist et al. (in prep.) analysis as the basis for its quantitative assessments of the benefits of habitat improvements . This analysis is reviewed in CRITFC's comments on the Draft BiOp (CRITFC 2000). CRITFC found that the results of Fiest et al., cannot be used to estimate future change in spawner abundance/redd density due to change in just a few of the land use factors that were found to correlate with redd density. Almost all of the predictor variables analyzed exhibited significant cross-correlation, making it impossible to credibly estimate any improvement in salmon abundance or redd density resulting from the change in a single land use variable.

We have based our quantitative assessment on a set of assumptions developed by the PATH Habitat sub-group, which is similar to ICBEMP's preferred alternative. These assumptions were based on the probability of changes in stock productivity, where the range of plausible changes was described by the observed range of variability in stock-recruitment parameters among index populations from habitats of varying condition. The sub-group focused their attention on the Ricker *a* parameter because the stocks of interest were generally accepted to be at levels far below their carrying capacities, based on historical estimates of abundance. This implied that habitat changes, while they may in fact affect both *a* and *b* values, were far more likely to affect the probability of stock survival or recovery through their influence on *a*, which directly affects productivity at low stock sizes. The *a* parameter can be thought of as reflecting the quality of the habitat in the area utilized by the stock for spawning and pre-smolt juvenile rearing. The challenge was thus to judge how changes to habitat might affect average egg-to-smolt survival for the stock, translated into a change in the Ricker *a* parameter.

For each stock, the PATH habitat sub-group judged the probability that the Ricker *a* value would either (1) increase by up to one unit, but to a value no higher than the observed maximum; (2) remain the same; or (3) decrease by one unit, over the next 48 years (the proposed NMFS recovery standard time frame). The habitat sub-group chose to define a range of no greater than a unit increase or decrease in the *a* value based on the fact that: a) for the Snake River basin stocks, the range in current estimated Ricker *a* values is approximately one; b) a preliminary analysis of PIT tag recoveries showed an approximately three-fold variation in average recovery rates between releases in wilderness areas and releases in managed areas; c) smolt production models developed during the sub-basin planning exercise assumed a three-fold range of smolt density capacities between sites classified as having "fair" habitat, and those having "excellent" habitat. The sub-group constrained the plausible increases in the Ricker *a* value to not exceed the maximum *a* value observed for the up-river stocks, to reflect limits on intrinsic productivity for that area determined by physiography and climate. In contrast, they did not believe there is a similar constraint on the down-side; stock productivity can reasonably decline by a factor of three, even if it is relatively low to begin with, provided habitat conditions worsen considerably.

The probabilities assigned by the Habitat subgroup reflected current habitat conditions as well as possible effects of future habitat scenarios. This is an important point, because it means that habitat actions for stocks that either currently experience declines in habitat quality because of natural events or past management (such as Poverty and Johnson), or are already in pristine habitat conditions (such as Minam, Imnaha, Sulphur, and to a lesser extent Marsh), have a significant probability of having no effect on Ricker *a* values. An assessment of current habitat trends in the Snake Basin appears in Espinosa (2000). For the Salmon River tributaries, Huntington (1998) reported that data on weighted embeddedness at four monitoring stations suggest a general pattern of <u>poorer streambed conditions</u> (higher embeddedness) in the more recent years of sampling. Huntington (*op. cit*.) also reported that there was a general increasing trend in percent surface fines at each station, with <2mm fines significantly higher in 1995 than in 1990 at all stations, and <6mm fines significantly higher in 1995 than in 1990 in all but one monitoring station (Little Slate).

The habitat sub-group also judged how rapidly the changes would occur, should a change occur at all. This is summarized by specifying the probability that *a* will have changed to a new value by year 12 (or 24), **given** that it is expected to change by year 48. If the change is likely to occur very slowly (i.e., a gradual reduction of fines in stream substrates following sediment control, or a slow phase-in of a riparian management option) then the probability of the change occurring in twelve years, even if it does occur after 48 years, is very low. On the other hand, if the change is likely to result from a sudden event (more likely for a negative change due to a catastrophic event) the probability of the effect occurring in the first 12 years would be higher. These assumptions recognize that improvements in habitat conditions tend to happen gradually, and appear to be more plausible than the assumption in the BiOp that habitat actions will have immediate effects on survival rates.

The habitat sub-group's judgments of each of the probabilities for each of the index stocks included in the prospective modeling are summarized in Table 4.1-1. The conclusion supported by this analysis was that all but one stock (Bear Valley) are unlikely to benefit to any great extent through habitat improvement. Considering that the current state of habitat for these stocks is either already good or greatly affected by natural or past disturbances, this conclusion appears to be well-warranted.

Table 4.1-1: Probabilities of future Ricker *a* values for seven Snake River spring/summer chinook stocks given three alternative scenarios of future habitat management. Prob(no change) means the probability that the *a* value does not change from its current (prospective simulation year 1) state by year 48 of the simulation. Prob(increase) and Prob(decrease) are interpreted similarly. The "increase" and "decrease" columns list the percent change in *a* value in the specified direction, relative to maximum likelihood estimates of the Ricker *a* values. Prob(12|increase) is the conditional probability that an increase occurs by simulation year 12, given that it occurs by year 48. The other conditional probabilities – Prob(*year|direction*) - have similar interpretations.

Stock	Prob (no change)	Relative Increase in a	Prob (increase)	Prob (12|increase)	Prob (24|increase)	Relative Decrease in a	Prob (decrease)	Prob (12|decrease)	Prob (24|decrease)
Status Quo									
Imnaha	1.0	12%	0	0	0	29%	0	0	0
Minam	1.0	0%	0	0	0	0%	0	0	0
Bear Valley	1.0	9%	0	0	0	28%	0	0	0
Marsh	1.0	11%	0	0	0	28%	0	0	0
Sulphur	1.0	0%	0	0	0	0%	0	0	0
Poverty Flats	1.0	14%	00	0	0	29%	0	0	0
Johnson	1.0	10%	0	0	0	28%	0	0	0
Action similar to ICBEMP #2									
Imnaha	0.88	12%	0.1	0.1	0.5	29%	0.02	0.25	0.5
Minam	1	0%	0	0	0	0%	0	0	0
Bear Valley	0.08	9%	0.92	0.2	0.8	0%	0	0	0
Marsh	1	11%	0	0	0	0%	0	0	0
Sulphur	1	0%	0	0	0	0%	0	0	0
Pov erty Flats	0.79	14%	0.21	0	0.3	0%	0	0	0
Johnson	0.73	10%	0.27	0.4	0.8	0%	0	0	0

The assumption of the Habitat Group that productivity improvements will result in Bear Valley from implementation of ICBEMP may be optimistic. The positive effects of habitat improvements on Bear Valley at low spawner abundance, and therefore on the ability of habitat actions to recover this stock, may be overstated because there are pockets of good habitat conditions where fish currently spawn. Therefore, assumed productivity increases associated with habitat restoration may not be realized until escapements are large and actively spawning in areas where habitat is currently poor and has most to gain from restoration activity. Because our analysis of the habitat action assumes that all Bear Valley fish (even those that spawn in the good habitat that currently exists) realize productivity increases from habitat restoration, we may be overestimating the efficacy of habitat restoration for increasing abundance of the Bear Valley stock from its currently low levels to levels approaching its recovery threshold.

Espinosa (2000) reviewed the aquatic conservation strategy of ICBEMP and noted deficiencies including the absence of watershed condition indicators, implementation and budget commitments, and monitoring and evaluation. He also notes heavy reliance on planning and little emphasis on enforcement or other accountability measures. While improvements in Bear Valley habitat conditions may result from recent commitments to the cessation of grazing in portions of this drainage, these commitments flow from direct payments to ranching interests by BPA and not as a result of ICBEMP implementation. ICBEMP anticipates little or no reduction in grazing AUMs.

This analysis has focussed on freshwater spawning and rearing habitat. NMFS also calls for improvements in the estuary (NMFS 2000a p. 9-112). While there may be some benefit to improving the habitat in the estuary, it is unlikely to accrue to Snake River spring chinook, a stock that has undergone smoltification and rides out to sea in a turbid mass of water. It is also unlikely that Snake River spring/summer chinook would be experiencing some form of mortality in the estuary that the downriver control stocks wouldn't. Finally, it would seem that some important components of estuary habitat such as salinity, turbidity, etc. strongly depend on the timing, amount, and quality of water entering the estuary from the Columbia River. Because of this and other factors, NMFS scientists have argued elsewhere that a primary means for improving estuary survival would be via breaching the Snake River dams (Kareiva et al. 2000). It thus seems clear that making meaningful changes in these aspects of estuary survival would require significant modification to operation of the hydropower system.

Evaluation of feasibility and assumptions related to Harvest actions

Because harvest rates are already low, further reductions in harvest on spring/summer chinook and sockeye will have little effect on their likelihood of recovery (Marmorek et al. 1998b; NMFS 2000a). The alternative considered in this analysis is similar to the harvest rates that NMFS has recently approved in biological opinions on Columbia River mainstem fisheries (NMFS 2000b). According to NMFS' 2000 Harvest BiOp,

> Even with zero harvest the analysis indicates that all of the index populations will continue to decline unless conditions affecting survival in other sectors are improved…. Elimination of harvest cannot change that result. Growth rates decline with increasing harvest, but the effect on the growth rate is relatively small – on the order of one or two percentage points. p.57

Harvest rates on Snake River spring/summer chinook have dropped significantly since the 1960s in response to declining adult returns. Appendix G compares alternative harvest schedules from the now expired Columbia River Fish Management Plan, the NMFS Harvest BiOp, and an alternative prepared by CRITFC.

Evaluation of feasibility and assumptions related to Hatchery actions

The All-H Paper calls for changes in hatchery operations that reduce the threats hatchery fish are assumed to pose to wild fish. These effects could be due to behavioral, predation, competitive, pathogenic, or other within- and between-stock interactions between hatchery and wild fish (Wilson 1996). Concerns that hatchery fish may be having a negative impact on wild stocks in the Columbia basin have focussed on two types of interactions.

The first concern is that hatchery fish compete with wild fish for resources in natal streams. Wilson's (1996) literature review of within-stock hatchery-wild interactions suggests that there is more evidence for negative effects on survival rates of wild fish than for positive effects. It is true that there has been an increase in the numbers of hatchery fish released in the Snake Basin since the late 1970's because hatchery fish were intended to mitigate for hydro losses. However, substantially higher densities of hatchery fish were released lower in the system and they were released decades earlier as a part of the Mitchell Act. Such fish were subjected to unenlightened hatchery practices that the Snake River hatcheries have attempted to remedy. It would seem that if hatchery fish could result in severe declines, it would have been evident among lower river stocks decades before the Snake River hatcheries were built. It is also important to note that the Middle Fork Salmon River stocks such as Marsh and Sulphur Creek stocks, have had no history of hatchery plantings but have still experienced declines. This suggests that hatchery interactions in natal streams are not the cause of these declines.

Second, NMFS and others have hypothesized that spring/summer chinook are negatively impacted by their interaction with larger steelhead in bypass and holding systems and in barges used for transportation (e.g. Williams et al. 1998; Paulsen and Hinrichsen 1998). The resulting stress could be a factor in delayed mortality, although we note that the current operation of the hydropower and transportation system increase these interactions by concentrating hatchery and wild fish into confined times and spaces. These effects were assumed to apply to all Snake River index stocks regardless of the hatchery influence in their natal streams. Previous PATH analyses have used three sources of information to explore the relationship between hatchery effects and survival. These analyses are summarized below. We note that they are based on some tenuous assumptions, and that their quantitative results do not form a strong basis for predicting the effects of hatchery actions. However, at the very least these analyses demonstrate that there are potential approaches one could use to quantify hatchery effects, and provide a starting point for regional discussion of the assumptions implicit in recommending hatchery actions. Well-designed management experiments that intentionally vary hatchery releases are likely the only way to obtain quantitative estimates of hatchery effects; implementation of such experiments may be difficult.

1. Relationships between ln(R/S) for wild fish and hatchery-related variables

Wilson (1996) conducted a pilot analysis using linear regressions to explore the relationship between ln(R/S) of wild Imnaha and Warm Springs fish and various variables including number of wild spawners, number of hatchery releases, release methods, and other variables related to hatchery operations in those sub-basins. He found a significant effect of number of wild spawners and hatchery releases on wild ln(R/S) for the Warm Springs stock, but not for the Imnaha stock. A major limitation of the analysis was that the dependent variables (number of wild spawners and hatchery releases) were related because hatchery releases have increased over time as mitigation for declining escapements.

2. Relationships between hatchery steelhead releases and total mortality of Snake River spring/summer chinook

Peters et al. (2000) conducted a regression analysis between historical estimates of m (total passage + extra mortality; see Appendix A) from spawner-recruit data and historical numbers of steelhead hatchery releases (Figure 4.3-1). Assuming that reducing production of hatchery steelhead is a feasible approach, we can use the regression to infer the magnitude of reductions in hatchery steelhead releases needed to achieve the hypothesized reductions in extra mortality. The regression analysis builds on observed similarities in the historical trend in total mortality and number of hatchery steelhead released (Williams et al. 1998; Paulsen and Hinrichsen 1998). The regression analysis was based on data 1957 to 1990, the last year for which both hatchery releases and spawner-recruit data were available. The regression was negative (lower survival at higher numbers of releases) and significant, explaining about 50% of the variability in the data. It is important to note that the fact that this regression exists does not constitute evidence that hatchery releases are the cause of reduced survival (i.e., correlation does not equal causation). In fact, as Wilson noted in his regression analysis, such a correlation might be expected because hatchery releases were a mitigative measure implemented in response to declining fish populations. Therefore, the coincidence of increased hatchery production with declining survival rates does not necessarily mean that the one is the cause of the other. Because of this, the regression relationship, while informative, provides only weak evidence for negative hatchery effects.

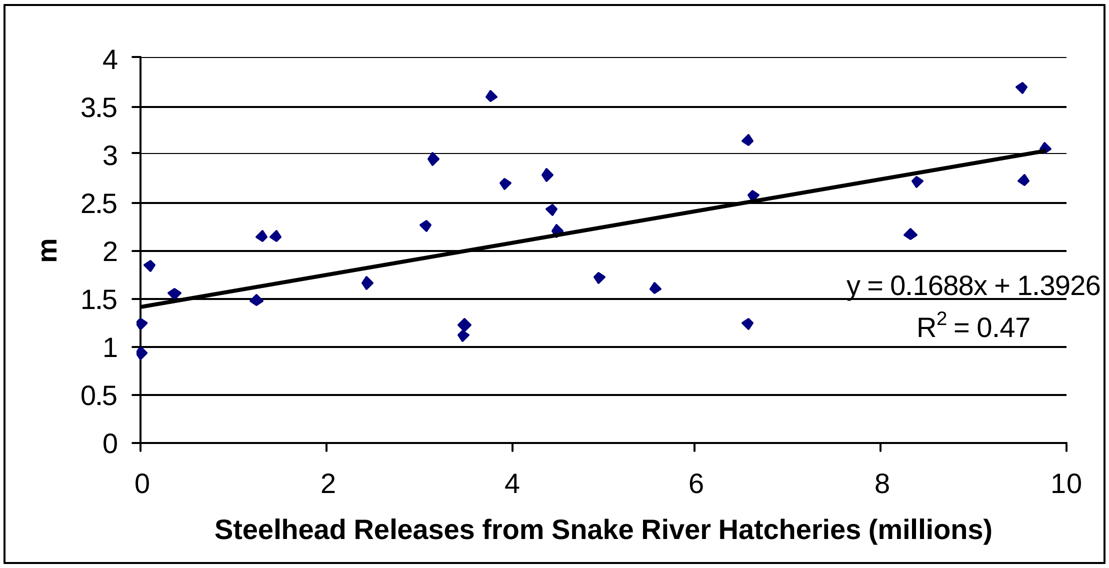


Figure 4.3-1. Regression of m vs. number of steelhead hatchery releases from Snake River hatcheries, 1957-1990.

3. Relationship between hatchery steelhead abundance and wild SARs

A separate analysis suggested no clear relationship between relative abundance of hatchery steelhead and spring/summer chinook (measured as passage indices) and SARs for spring/summer chinook from 1990 to 1995 (example for 1995 shown in Figure 4.3-2; full analysis in Appendix D of Peters et al. 2000b). These data suggest that hatchery actions would have no effect on survival, and that other factors besides the presence of hatchery steelhead are at work.

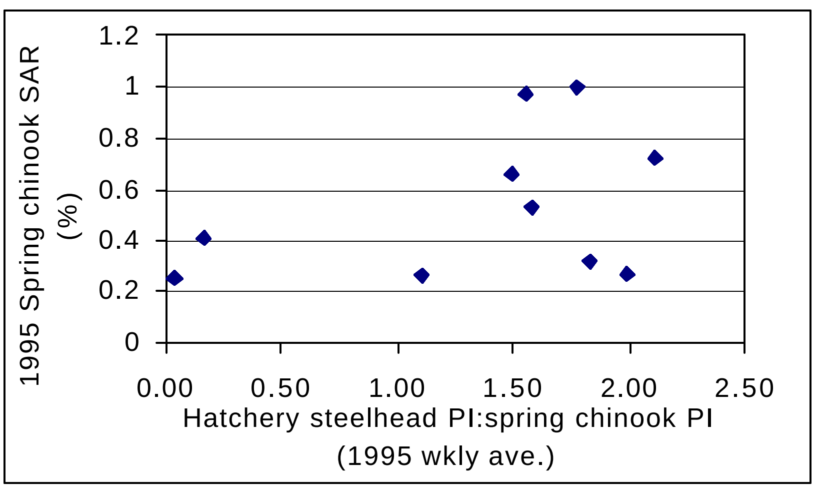


Figure 4.3-2. 1995 Spring/summer chinook SAR vs. hatchery steelhead passage index: spring chinook PI.

The generic hatchery action implemented in the All-H analysis was intended to account for potential interaction between hatchery and wild fish in barges and bypass systems by reducing extra mortality that by 0, 8 or 25%, depending on how much of the extra mortality was assumed to be due to hatchery effects. The lower bound is based on analyses 1 and 3, which suggest no relationship between steelhead hatchery releases and survival rates. This scenario is represented in the All-H analysis by results for A1+Habitat+Harvest action (Figure 5). The upper bound of 25% (which was the implied benefit of implementing the generic hatchery action if all extra mortality was assumed to be due to hatcheries) is consistent with a 50% reduction in hatchery steelhead production, assuming that the regression relationship in Figure 4.3-1 represents a causal effect. A 50% reduction in hatchery production was the largest we thought to be likely. An 8% reduction in extra mortality (the benefit of implementing the generic hatchery action if 30% of extra mortality was assumed to be due to hatcheries) would imply a 15% reduction in hatchery steelhead production.

Some of the issues related to the feasibility of achieving recovery through changes in hatchery production are addressed in CRITFC 2000. From the institutional perspective, Snake River hatcheries are federally mandated as mitigation for hydropower losses. Without significant scientific and public support, large reductions in hatchery programs may not be acceptable, and considerable delays in implementing hatchery reforms (i.e., delays longer than the 5 years assumed in these simulations) might be anticipated. A scientifically credible analysis analyzing the components of interaction (namely geographic and temporal overlap) would be required before a decision to limit hatchery production could be credibly proposed. For example, if the temporal and geographic overlap of naturally spawned steelhead and chinook salmon is similar to that of hatchery-reared groups, then negative interactions will likely be present regardless of the origin (hatchery or natural) of the groups. Such a result might suggest that operation of the FCRPS is sabotaging the historical mechanisms that allowed co-existence of the two species. Alternatively, if such an analysis suggests that hatchery-reared and naturally spawned groups have different geographic and temporal distributions, hatchery management could likely be altered to more appropriately match the timing and distribution that historically allowed the sympatry.

Evaluation of feasibility and assumptions related to Hydro actions

Our analysis incorporated three major assumptions about the response of chinook populations to operation of the hydropower and transportation system.

1. Hydrosystem Effects on Direct Survival Rate of In-river Migrants

We used CRiSP and FLUSH passage models to estimate hydrosystem effects on direct survival rates of juvenile migrants. In the 2000 draft BiOp NMFS did not use FLUSH or CRiSP to evaluate hydrosystem mortality, but relied instead upon the modified spreadsheet model SIMPASS to generate both the assumed current (which the BiOp called the “Base case”) and future (which the BiOp called the “Aggressive case”) estimates for hydrosystem mortality. CRITFC (2000) noted several concerns with NMFS SIMPASS analysis, particularly NMFS’ assumptions related to flow and temperature.

When CRITFC staff reran the SIMPASS model with what they thought to be more reasonable model parameters, they found that NMFS' assumptions produced higher survival estimates at each project and through the migration corridor than those produced by CRITFC's alternative assumptions. CRITFC did not have time to run CRiSP or FLUSH for a comparison, but this would be a useful endeavor.

The A3 actions assume that breaching will lead to increases in direct survival of in-river fish (Vn, see section 2.3) over what they currently experience, from an average of 0.26 (with FLUSH; 0.44 with CRiSP) to around 0.59 (with FLUSH; 0.61 with CRiSP). The hypothesized increase was based on 1993-1996 estimates of survival rates for wild juveniles in free-flowing reaches of the Snake River above Lower Granite Dam, expanded to correspond to the 210-km reach encompassed by the four Snake River dams. By basing the estimates of survival on current free-flow survival rates, we are implicitly assuming that survival rates will not return to the same level as they were prior to the dams because of changes since the historical period, including increased shoreline development, the effects of introduced species, changes in upstream water regulation, and permanent changes in predator communities that have resulted from impoundment of the river. This survival estimate is the lowest of the two originally developed by PATH; the other assumed that survival rates would increase back to pre-dam levels, which were about 0.11 higher than the estimates we used. Using this other hypothesis would have had small but positive effects on projected escapements and probabilities of exceeding survival and recovery thresholds for the A3 and A3+ actions.

Concerns have been raised that breaching would have adverse short-term impacts on survival rates because of release of sediments from reservoirs. We explored the potential effects of such impacts through sensitivity analysis in the PATH Weight of Evidence exercise (Marmorek et al. 1998b), but found that even a 50% reduction in juvenile survival rates in the first 5 years after breaching had almost no effect on probabilities of exceeding the survival and recovery standards. Some have also predicted adverse effects of breaching on the regional power supply, and hence on the aluminum and other industries, and agriculture. Others argue that there is significant potential for new forms of business and offsets to potential losses due to the increased allure of the Pacific Northwest. Several economic studies detail such arguments (e.g. US Army Corps of Engineers 1999, Whitelaw 2000).

2. Extra Mortality

We explored four alternative explanations for the extra mortality estimated by Deriso et al. (1996) and Schaller et al. (1999): Hydro, Hatchery, Regime Shift, and Hybrid (see section 2.1).

As in previous PATH analyses, the projected performance of All-H actions were critically dependent on these assumptions.

Evidence for and against each of these hypotheses appears in PATH's Weight of Evidence Report (Marmorek et al. 1998a). There is a large body of science documenting stress and injury of fish while they migrate through the hydrosystem, and all four PATH Scientific Review Panel members gave the Hydro hypothesis either the highest or tied for highest weighting of the three hypotheses (weights ranged from 0.4 to 0.6) (PATH SRP 1998). NMFS, in a series of white papers, has described a number of hydrosystem-related factors affecting spring/summer chinook ranging from stress, delay and injury, to mortality. Their comments are summarized in Appendix D. It is noteworthy that the white papers provide no alternative biological mechanism whereby the Snake River stocks would collapse while downriver spring chinook stocks would not.

The second extra mortality hypothesis (Hatchery) has generally been interpreted to mean any combination of factors that could cause mortality that would not go away with dam breaching. PATH's Scientific Review Panel (SRP) gave moderate support (weights ranged from 0.25 to 0.4) to this hypothesis.

The SRP gave little support for the third hypothesis, which holds that ocean cycles (regime shifts) are the source of extra mortality (weights ranged from 0.01 to 0.2). They justified the low weights because of two problems with this hypothesis. First, while oceanic cycles certainly exist, there is no evidence of periodic near extirpations of stocks in the historic data as would be suggested by the term "cycle". Second, as noted previously, no one has been able to describe a biological mechanism whereby, after existing for millions of years in the North Pacific Ocean, Snake River salmon would suddenly become unable to survive while the downstream stocks would not experience this problem. For this to occur for all Snake River stocks (but not their downstream counterparts) just as dam construction was taking place, and yet have nothing to do with it, is unlikely (Schaller et al. 1999).

In light of the available evidence, the weights assumed for the "Hybrid" hypothesis (0.5, 0.3, and 0.2 for hydro, hatchery and regime shift, respectively) appear to be a reasonable reflection of the likely sources of extra mortality, and approximates the average weights applied by the SRP. We felt that it was better not to place too much weight on any one hypothesis to avoid the risks associated with relying too much on any one set of circumstances in an evaluation of recovery actions. The main conclusions that we have drawn from the modeling analysis (section 3.1) thus do not depend on having complete certainty about any single hypothesis.

Given the importance of extra mortality in the PATH and CRI models, any evaluation of alternative actions to recover Snake River chinook stocks either explicitly or implicitly makes assumptions about extra mortality and its causes. The preceding discussion has attempted to document and justify the assumptions we made in the analysis of the All-H actions. A discussion and critique of the assumptions about extra mortality used in the BiOp and All-H Paper can be found in CRITFC (2000).

3. The Effectiveness of Transportation

Transported Snake River wild spring/summer chinook survive to adulthood at very low rates (Weber et al. in prep.; Mundy et al., 1994). However, by continuing to rely on transportation as the main source of mitigation for the hydro system, NMFS is tacitly asserting that their poor survival may be attributable to something other than the stress and injury discussed earlier, and that some other factor may be masking what otherwise would be a successful transportation program. As noted earlier, to date no one has been able to describe just what this factor is or how it results in mortality.

There are other concerns with NMFS' treatment of transportation. Since the late 1960's NMFS has been conducting transportation studies that consist of marking juvenile fish, assigning them to transport and control (inriver) groups, and counting the adult returns for each group. Traditionally NMFS has simply compared the smolt-to-adult-returns (SARs) of the transport group to those of the controls. This created a transport-to-control ratio or TCR. Mundy et al. (1994), however, concluded that the TCR was "moot" if the fish were not surviving at rates high enough for their populations to persist. Thus Toole et al. (1996) established a minimum goal of two to six percent as an absolute goal for Snake River spring/summer chinook. This goal was based on Snake River SARs from the mid 1960s and recent SARs from the Warm Springs River, a downstream control stock.

The shift in focus to delayed mortality led to "D" values, a third method of measuring transportation. D is the ratio of the survival rate of transported fish to inriver fish <u>after</u> they have arrived below Bonneville Dam. A D of 0.5, for example, would mean that transported fish survive at half the rate of inriver fish after both groups had arrived below Bonneville Dam. We have used a D value of 0.58 for this analysis, based on analyses of the 1994-1996 transportation studies. While D's close to one are better than D's close to zero, high values of D are not indicative of a successful transportation program for two reasons. First, the conclusion of Mundy et al (1994) applies to D's as much as it does to TCRs: the survival of transported fish <u>relative</u> to that of inriver migrants is not as important as the <u>absolute</u> survival. Second, if D values are assumed to be high (transported fish have high survival relative to non-transported), then more of the empirical total life-cycle mortality has to be attributed to the extra mortality, and the hypotheses about extra mortality become more important. SARs don't increase with increased D; the allocation of mortality is simply rearranged. Therefore, even if one assumes that D's are reasonably high, populations do not reach survival or recovery levels unless one also assumes that extra mortality is not related to the hydro system (Table 3-1).

This underscores the importance of a weight of evidence process as part of the decision making process. The evidence discussed earlier in this report, in Appendix D, and in the PATH Weight of Evidence Report (Marmorek et al. 1998a) suggests that the most plausible hypothesis is that extra mortality is linked directly to the hydrosystem. If plausible alternative hypotheses for extra mortality are to achieve broad support, they need to be accompanied by biological mechanisms whereby, 12 to 13 million years after speciation, and concurrent with the development of the hydrosystem, the Snake River spring chinook stocks underwent severe declines that the downriver stocks did not experience.

Additional research will provide a few more years of data which could help produce more accurate and/or precise estimates of D (see Appendix F in Peters et al. 2000b). However, these tag and release studies would do little to shed light on the magnitude and source of extra mortality of non-transported fish. And given the fact that SARs of wild transported Snake River spring/summer chinook are currently averaging approximately 0.5%, well below even the minimum goal of 2% established by PATH (Toole et al. 1996), it is unlikely that minor refinements to the transportation system are apt to result in required increases in overall survival necessary for survival and recovery.

Feasibility of Recovering Other Listed Stocks

The discussion above focussed primarily on Snake River spring/summer chinook. The opportunities for recovering some other listed stocks in the Snake Basin through an All-H approach are more limited. Spawning habitat for mainstem-spawning Snake River fall chinook has been reduced by construction of the Lower Snake and Hells Canyon dams to about 20% of the historical amount (Battelle and USGS 2000, p. 1.30). Currently, spawning of Snake River fall chinook is mostly limited to the Hell's Canyon reach of the Snake R, which has poor quality spawning habitat relative to historically accessible reaches upstream of Hells Canyon Dam (Battelle and USGS 2000, p. 1.30, 1.33), and was historically an insignificant spawning area (Battelle and USGS 2000, p. 1.19, 1.22). Geomorphic modelling suggests that more than half of the 238 km stretch of the Lower Snake now inundated by dams would be suitable fall Chinook spawning habitat if the dams were breached (Battelle and USGS 2000, p. 3.46). Most of this habitat would be in the vicinity of Little Goose and Lower Granite dams, where 87% of the area would be conducive to spawning (Battelle and USGS 2000, p. 3.46). As noted by an expert panel convened to assess the potential for fall chinook recovery in the mainstem Columbia and Snake Rivers[13]:

> "it is not possible to increase natural production of fall chinook salmon in the Columbia River Basin without restoring those controlling factors and processes

[13] The panel was convened in August 1999 to discuss restoration of mainstem habitat. Individuals were invited to participate based on their involvement with regional assessments of hydrosystem operations and knowledge of mainstem habitats. Panel members were Chris Frissell (U. of Montana), John Pizzimenti (Harza), Jim Ruff (NW Power Planning Council), Dave Bennet (U. of Idaho), Jim Anderson (U. of WA), Phil Groves (Idaho Power), Steve Reidel (Battelle), Dennis Dauble (Battelle), David Geist (Battelle), Tim Hanrahan (Battelle), Mindi Sheer (USGS), Dennis Rondorf (USGS), Jim Petersen (USGS), and Mike Parsley (USGS).

> that supported their life history requirements. In this context, selective reservoir drawdown and/or dam breaching, in combination with establishment of more normative flow regimes, is the only viable strategy for restoring mainstem habitats (Battelle and USGS 2000 Epilogue, p. viii)."

Fall chinook were not the targets of hatchery programs during the years of declines. Ocean harvest rates for fall chinook are higher than those for spring/summer chinook. Achieving recovery through harvest reductions, though, would require severe reductions among both U.S. and foreign nationals in excess of recently negotiated treaties (Peters et al. 1999). Conversely, the hydropower system accounts for high direct mortality on fall chinook during the mid and late summer because of high mainstem temperatures, combined with prolonged migration times (Williams et al. 1996). Fall chinook also appear to suffer higher rates of mortality associated with bypass systems than spring/summer chinook (Peters et al. 1999).

With respect to Snake River sockeye, good habitat is abundant in Redfish Lake, but there are very few sockeye present. Their near absence is more than likely due to unusually high descaling rates for sockeye that encounter bypass screens (Marmorek et al. 1998c). This descaling led PATH to conclude that their recovery was unlikely under the current hydro configuration (Marmorek et al. 1998c). In addition, transportation studies conducted in the Mid-Columbia indicated transported sockeye survived at a lower rate than their inriver controls (Carlson et al. 1988;1991). Sockeye harvest rates are lower than those for spring/summer chinook, and until their recent interment through a captive broodstock program sockeye had no history of hatchery programs in the Snake Basin.

References Cited

Battelle (Pacific Northwest Division) and U.S. Geologic Survey, Biological Resources Division. 2000.
Assessment of the Impacts of Development and Operation of the Columbia River Hydroelectric System on Mainstem Riverine Processes and Salmon Habitats. Report for Bonneville Power Administration, June 2000.

Beamesderfer, R.C.P., and 5 coauthors. 1997. Spawner-recruit data for spring and summer chinook salmon populations in Idaho, Oregon, and Washington. *In* Plan for Analyzing and Testing Hypotheses (PATH): Retrospective and Prospective Analyses of Spring/Summer Chinook Reviewed in FY1997. *Edited by* D.M. Marmorek and C.N. Peters. Vancouver, BC. 693 pp. Available from http://www.efw.bpa.gov/Environment/PATH/reports/1997retro/toc.htm

Bouwes, N., and 9 coauthors. 1999. An analysis of differential delayed mortality experienced by stream-type chinook salmon of the Snake River. ODFW Technical report, October 4, 1999.

Carlson, C.D., S. Achord, G. Matthews, D.E. Weitkamp, R.p. Whitman, R. Raleigh and D. Chapman.
1988. Fish transportation studies Priest Rapids Dam 1987. Grant County PUD.

Carlson, C.D. and G. Matthews, 1991. Fish transportation studies Priest Rapids Dam 1989. Grant County PUD.

CRITFC (Columbia River Inter-Tribal Fisheries Commission). 2000. Comments on the BiOp and All H Paper. October 19,2000. Portland, Oregon.

Deriso, R.B, D.R. Marmorek, and I.J. Parnell. 1996. Retrospective Analysis of Passage Mortality of Spring Chinook of the Columbia River. *Chapter 5 in* Marmorek et al. 1996. Plan for Analyzing and Testing Hypotheses (PATH): Final report on retrospective analyses for fiscal year 1996. Compiled and edited by ESSA Technologies Ltd., Vancouver, B.C. 620 pp. Available from
http://www.efw.bpa.gov/Environment/PATH/reports/ISRP1999CD/PATH%20Reports/FY96_Retro_Report/

Espinosa, F.A. 2000. "Feasibility Analysis (Critique) of Basin-Wide Salmon Recovery Strategy (Draft)
Volume Two: The Habitat Element. Report included in CRITFC's comments on the 2000 Biological Opinion and All-H Paper.

FAO (Food and Agriculture Organization of the United Nations). 1996. Precautionary Approach to Capture Fisheries and Species Introductions. Food and Agriculture Organization of the United Nations, Lysekil, Sweden

Federal Caucus. 2000. Conservation of Columbia Basin Fish, Draft Basin-Wide Salmon Recovery Strategy. Draft dated July 27, 2000. Available from www.bpa.gov/federalcaucus

Huntington, C. W. 1998. Stream Conditions and Salmonid Abundance at Four Monitoring Stations on the Salmon River Ranger District, Nez Perce National Forest. 1988-1995. Special Report to Nez Perce National Forest. Clearwater BioStudies, Canby, Oregon.

Kareiva, P., M. Marvier, and M. McClure. 2000. Recovery and Management Options for Spring/Summer Chinook Salmon in the Columbia River Basin. *Science* 290: 977-979.

Marmorek, D.R., and 28 coauthors. 1998a. Plan for Analyzing and Testing Hypotheses (PATH): Weight of Evidence Report. Compiled and edited by ESSA Technologies Ltd., Vancouver, BC. 116 pp. plus appendices and 25 submissions. August 21, 1998. Available from http://www.efw.bpa.gov/Environment/PATH/reports/ISRP1999CD/PATH%20Reports/WOE_Report/

Marmorek, D.R., and 27 coauthors. 1998b. Plan for Analyzing and Testing Hypotheses (PATH): Preliminary decision analysis report on Snake River spring/summer chinook. Draft Report, March 1998, Vancouver, BC., Canada. 92 pp. + appendices. Available from http://www.efw.bpa.gov/Environment/PATH/reports/pdar/index.html

Marmorek, D.R., and 34 coauthors. 1998c. PATH final report for fiscal year 1998. Prepared by ESSA Technologies Ltd., Vancouver, BC, 263 pp. December 16, 1998. Available from http://www.efw.bpa.gov/Environment/PATH/reports/1998Final/1998Final.pdf

Mundy, P.R. and 9 co-authors. 1994. Transportation of juvenile salmonids from hydroelectric projects in the Columbia River Basin; an independent peer review. Final Report, US Fish and Wildlife Service, 911 N.E. 11th Avenue, Portland, OR 97232-4181.

NMFS (National Marine Fisheries Service). 2000a. DRAFT Biological Opinion. Operation of the Federal Columbia River Power System, including the juvenile transportation system and the Bureau of Reclamation's 31 projects, including the Entire Columbia Basin Project. Draft dated July 27, 2000.

NMFS (National Marine Fisheries Service). 2000b. Biological Opinion on Impacts of Treaty Indian and non-Indian Year 2000 Winter, Spring, and Summer Season Fisheries in the Columbia Basin. February 29, 2000.

Oosterhout, G. 2000. Analysis of a decision: A critique of the National Marine Fisheries Service's draft Biological Opinion on the Operation of the Federal Columbia River Hydropower System, from the perspective of the sciences of decision analysis and risk assessment. Decision Matrix, Inc. for Columbia River Inter-Tribal Fish Commission, Trout Unlimited, Save Our Wild Salmon, Earthjustice Legal Defense Fund, and American Rivers, Eagle Point, OR.

PATH Habitat Subgroup. 1997. Freshwater Spawning and Rearing Habitat. *In* Plan for Analyzing and Testing Hypotheses (PATH): Retrospective and Prospective Analyses of

Spring/Summer Chinook Reviewed in FY1997. *Edited by* D.M. Marmorek and C.N. Peters. Vancouver, BC. 693 pp. Available from http://www.efw.bpa.gov/Environment/PATH/reports/1997retro/toc.htm

PATH SRP (Scientific Review Panel, consisting of Steve Carpenter, Jeremy Collie, Saul Saila, and Carl Walters). 1998. Conclusions and Recommendations from the PATH Weight of Evidence Workshop. Edited by C. Peters, I. Parnell, D. Marmorek, R. Gregory, and T. Eppel. October 21, 1998.

Paulsen, C. and R. Hinrichsen. 1998. Testing the hypothesis that extra mortality of wild Snake River spring/summer chinook varies with releases of Snake River hatchery fish. *Submission 2 to* Marmorek et al. 1998. PATH Weight of Evidence Report. Compiled and edited by ESSA Technologies Ltd., Vancouver, BC. 116 pp. plus appendices and 25 submissions. August 21, 1998. Available from http://www.efw.bpa.gov/Environment/PATH/reports/ISRP1999CD/PATH%20Reports/WOE_Report/

Paulsen, C.M., R. Hinrichsen and T. Fisher. 1997. Chapter 4 Update: Effects of Climate and Land Use on Index Stock Recruitment. *In* Plan for Analyzing and Testing Hypotheses (PATH): Retrospective and Prospective Analyses of Spring/Summer Chinook Reviewed in FY1997. *Edited by* D.M. Marmorek and C.N. Peters. Vancouver, BC. 693 pp. Available from http://www.efw.bpa.gov/Environment/PATH/reports/1997retro/toc.htm

Peters, C.N. and 26 coauthors. 1999. PATH Decision Analysis Report for Snake River Fall Chinook. Prepared by ESSA Technologies Ltd., Vancouver, BC, 332 pp.

Peters, C., D. Marmorek and R. Deriso. 2000a. PATH-CRI Model Comparison. Memo dated May 25, 2000.

Peters, C.N., and 14 coauthors. 2000b. PATH Preliminary Evaluation of the Learning Opportunities and Biological Consequences of Monitoring and Experimental Management Actions. April 11, 2000. Prepared by ESSA Technologies Ltd., Vancouver, BC, 154 pp.

Quigley, Thomas M.; Haynes, Richard W.; Graham, Russell T.; technical editors. 1996. Integrated Scientific Assessment for Ecosystem Management in the Interior Columbia Basin and Portions of the Klamath and Great Basins. 303 p.

Schaller, H.E., C.E. Petrosky, and O.P. Langness. 1999. Contrasting patterns of productivity and survival rates for stream-type chinook salmon (*Oncorhynchus tshawytscha*) populations of the Snake and Columbia Rivers. Can. J. Fish. Aquat. Sci. 56:1031-1045.

Toole, C., A. Giorgi, E. Weber, and C. McConnaha. 1996. Hydro decision pathway and review of existing information. *Chapter 6 in* Marmorek et al. 1996. Plan for Analyzing and Testing Hypotheses (PATH): Final report on retrospective analyses for fiscal year 1996. Compiled and edited by ESSA Technologies Ltd., Vancouver, B.C. 620 pp. Available from http://www.efw.bpa.gov/Environment/PATH/reports/ISRP1999CD/PATH%20Reports/

FY96_Retro_Report/

US Army Corps of Engineers. 1999. Improving Salmon Passage: DRAFT Lower Snake River Juvenile Salmon Migration Feasibility Report / Environmental Impact Statement. U.S. Army Corps of Engineers, Walla Walla District. December 1999.

Whitelaw, E. 2000. Dam breaching myths. Pages 16-20. *Oregon quarterly.*

Williams, J., G. Matthews, J. Myers, S.G.Smith, T. Cooney, and C. Toole. Hatchery Extra Mortality Hypothesis. *Submission 1 to* Marmorek et al. 1998. PATH Weight of Evidence Report. Compiled and edited by ESSA Technologies Ltd., Vancouver, BC. 116 pp. plus appendices and 25 submissions. August 21, 1998. Available from http://www.efw.bpa.gov/Environment/PATH/reports/ISRP1999CD/PATH%20Reports/WOE_Report/

Wilson, P. 1996. Hatchery Impacts. *Chapter 11 in* Marmorek et al. 1996. Plan for Analyzing and Testing Hypotheses (PATH): Final report on retrospective analyses for fiscal year 1996. Compiled and edited by ESSA Technologies Ltd., Vancouver, B.C. 620 pp. Available from http://www.efw.bpa.gov/Environment/PATH/reports/ISRP1999CD/PATH%20Reports/FY96_Retro_Report/

Appendix A. Technical description of the Bayesian Simulation Model (BSM) and implementation of the extra mortality hypotheses

The generalized Ricker model employed in this study is the "delta" version used in previous PATH analyses:

$$\ln(R_{t,i}) = (1+p)\ln(S_{t,i}) + a_i - b_i S_{t,i} - M_{t,i} - \Delta m_{t,i} + d_t + e_{t,i} \qquad \text{(a1)}$$

in which we can write total passage + extra mortality rate *m* as

$$m = M + \Delta m \qquad \text{(a2)}$$

A number of relationships can be written between parameters of the model in (a) and the version used for prospective simulations. From previous PATH documents (Marmorek et al. 1998) we know that

$$\exp[-\Delta m] = \lambda_n [DP + 1 - P] \qquad \text{(a3)}$$

$$\omega = \exp[-M][DP + 1 - P] \qquad \text{(a4)}$$

$$\exp[-m] = \omega \lambda_n \qquad \text{(a5)}$$

in which, ω is system survival and λ_n is post-Bonneville survival factor for non-transported smolts and in which *D* is the ratio of post-Bonneville survival factors of transported to non-transported smolts and *P* is the fraction of smolts at Bonneville which were transported.

The last equation given above can be used to write an equation for total passage + extra mortality during any prospective year *y* in terms which involve it's coupled retrospective water year *r*:

$$m_y = m_r - \ln\left[\frac{\omega_y \lambda_{n,y}}{\omega_r \lambda_{n,r}}\right] \qquad \text{(a6)}$$

The delta model in prospective mode can be written :

$$\ln(R_y) = (1+p)\ln(S_y) + a - bS_y - m_r + \ln(\omega_y / \omega_r) + \ln(\lambda_{n,p} / \lambda_{n,r}) + d_y + e_y \qquad \text{(a7)}$$

The retrospective water year coupled to each prospective year is chosen from brood years 1975-1994. The prospective system survival term ω_y is calculated from the M and Pbt values provided by the passage models and the D values (FLUSH D values scaled to average 0.58).

Modeling alternative hypotheses and management actions:

I. Hypothesis that extra mortality is hydro related: Without dam removal, extra mortality of non-transported smolts is assumed to continue as it has in the recent past (hence the ratio of lambda terms in equation a7 is set to one), but transported smolts benefit from improvements that have caused *D* to improve as specified in the prospective passage model input file. In other words, system survival in prospective years, ω_y , will be calculated based on input *M*, *P*, and *D* prospective values.

With dam removal, extra mortality is assumed to take on values estimated in the historical data prior to brood year 1970.

II. Hypothesis that extra mortality is hatchery related: Without hatchery improvements , extra mortality of both non-transported smolts and transported smolts is assumed to continue as it has in the recent past. In other words, the ratio of lambda terms in equation a7 is set to one and system survival in prospective years, ω_y , will be calculated based on input *M* and *P* prospective values, but the *D* values in the prospective years will be chosen randomly from the retrospective 1980 to 1996 water year estimates, which are thought to be representative of *D* conditions in the recent past.

If generic hatchery actions are taken then we assume that the extra mortality rate of both non-transported and transported smolts is reduced by 25% after a five year delay to allow for management changes to be implemented. The extra mortality rate for non-transported smolts in a retrospective year equals [$-ln(l_{n,r})$] and a reduction of 25% implies the prospective rate is [$-ln(l_{n,p}) = -(0.75)*ln(l_n)$]; a similar reduction applies to extra mortality rate [$-ln(l_T)$] of transported smolts. Reductions of 25% in those extra mortality rates implies that the D_p , prospective *D* value, is related to the retrospective D_r value by the relationship $D_p = (D_r)^{(0.75)}$.

III. Hypothesis that extra mortality is due to a cyclical climate regime shift with a period of 60 years, crossing 0 in brood year 1975: The delta model is written exactly as in (a7), except that the retrospective water year chosen for a given prospective year is one which occurred during the same phase of the cycle. For example, until brood year 2005 the coupled retrospective years are chosen from brood years 1975-1990, then from brood year 2006 for the next 30 years the coupled retrospective years are those chosen from brood years 1952-1974 (1952 is first year of S/R data). The system survival in prospective years, ω_y , will be calculated based on input *M* and *P* prospective values, but the *D* values in the prospective years will be chosen randomly from the 1980 to present water year estimates, which are thought to be representative of *D* conditions in the recent past. The ratio of lambda terms in equation a7 is set to one.

IV. Hypothesis that extra mortality is due to all of the effects in I, II, and III. Under this hypothesis the total passage + extra mortality term in (a2) is the weighted average of the *m*'s across hypotheses I, II, and III, where the weights are 0.5 (hydro), 0.3 (hatchery), and 0.2 (regime shift).

Appendix B. Additional Results

B.1 Overall Summary – All Performance Measures

Table B-1. Summary of performance measures for all four actions and 16 combinations of passage model, hatchery spawner effectiveness, and extra mortality hypotheses. Results are for the sixth best stock, which varies between actions, performance measures, and combinations of assumptions. The "+" actions include habitat, hatchery, and harvest improvements.

Combination # (from Table 2-2)	Passage Model	Hatchery Spawning Effectivenes s	Extra Mortality	Action			
				A1	A1+	A3	A3+
24-Year Survival							
1	FLUSH	20%	Hydro	0.36	0.37	0.45	0.46
2	FLUSH	20%	Hatchery	0.36	0.48	0.37	0.47
3	FLUSH	20%	Regime	0.50	0.52	0.50	0.52
4	FLUSH	20%	Hybrid	0.38	0.43	0.43	0.47
5	FLUSH	80%	Hydro	0.36	0.37	0.46	0.47
6	FLUSH	80%	Hatchery	0.37	0.48	0.37	0.47
7	FLUSH	80%	Regime	0.51	0.52	0.52	0.53
8	FLUSH	80%	Hybrid	0.39	0.44	0.45	0.48
9	CRiSP	20%	Hydro	0.43	0.44	0.53	0.55
10	CRiSP	20%	Hatchery	0.44	0.54	0.47	0.55
11	CRiSP	20%	Regime	0.56	0.59	0.58	0.60
12	CRiSP	20%	Hybrid	0.46	0.50	0.52	0.56
13	CRiSP	80%	Hydro	0.43	0.44	0.54	0.55
14	CRiSP	80%	Hatchery	0.44	0.54	0.47	0.55
15	CRiSP	80%	Regime	0.57	0.59	0.59	0.60
16	CRiSP	80%	Hybrid	0.46	0.51	0.53	0.57
100-Year Survival							
1	FLUSH	20%	Hydro	0.48	0.52	0.81	0.83
2	FLUSH	20%	Hatchery	0.49	0.79	0.64	0.81
3	FLUSH	20%	Regime	0.72	0.77	0.81	0.82
4	FLUSH	20%	Hybrid	0.53	0.69	0.79	0.83
5	FLUSH	80%	Hydro	0.48	0.50	0.82	0.83
6	FLUSH	80%	Hatchery	0.49	0.78	0.63	0.81
7	FLUSH	80%	Regime	0.73	0.77	0.82	0.82
8	FLUSH	80%	Hybrid	0.53	0.68	0.80	0.83
9	CRiSP	20%	Hydro	0.57	0.66	0.85	0.87
10	CRiSP	20%	Hatchery	0.58	0.83	0.75	0.85
11	CRiSP	20%	Regime	0.80	0.82	0.86	0.85
12	CRiSP	20%	Hybrid	0.64	0.78	0.85	0.87
13	CRiSP	80%	Hydro	0.56	0.64	0.86	0.87
14	CRiSP	80%	Hatchery	0.58	0.83	0.74	0.85
15	CRiSP	80%	Regime	0.81	0.82	0.86	0.85

16	CRiSP	80%	Hybrid	0.64	0.78	0.85	0.87

48-Year Recovery							
1	FLUSH	20%	Hydro	0.14	0.22	0.87	0.88
2	FLUSH	20%	Hatchery	0.15	0.62	0.40	0.78
3	FLUSH	20%	Regime	0.30	0.37	0.52	0.56
4	FLUSH	20%	Hybrid	0.17	0.37	0.76	0.85
5	FLUSH	80%	Hydro	0.13	0.21	0.88	0.90
6	FLUSH	80%	Hatchery	0.13	0.61	0.38	0.77
7	FLUSH	80%	Regime	0.25	0.35	0.47	0.55
8	FLUSH	80%	Hybrid	0.16	0.36	0.77	0.86
9	CRiSP	20%	Hydro	0.26	0.35	0.91	0.90
10	CRiSP	20%	Hatchery	0.27	0.71	0.60	0.83
11	CRiSP	20%	Regime	0.38	0.48	0.57	0.61
12	CRiSP	20%	Hybrid	0.33	0.51	0.82	0.87
13	CRiSP	80%	Hydro	0.24	0.32	0.92	0.92
14	CRiSP	80%	Hatchery	0.26	0.70	0.58	0.82
15	CRiSP	80%	Regime	0.33	0.44	0.54	0.61
16	CRiSP	80%	Hybrid	0.32	0.49	0.82	0.89

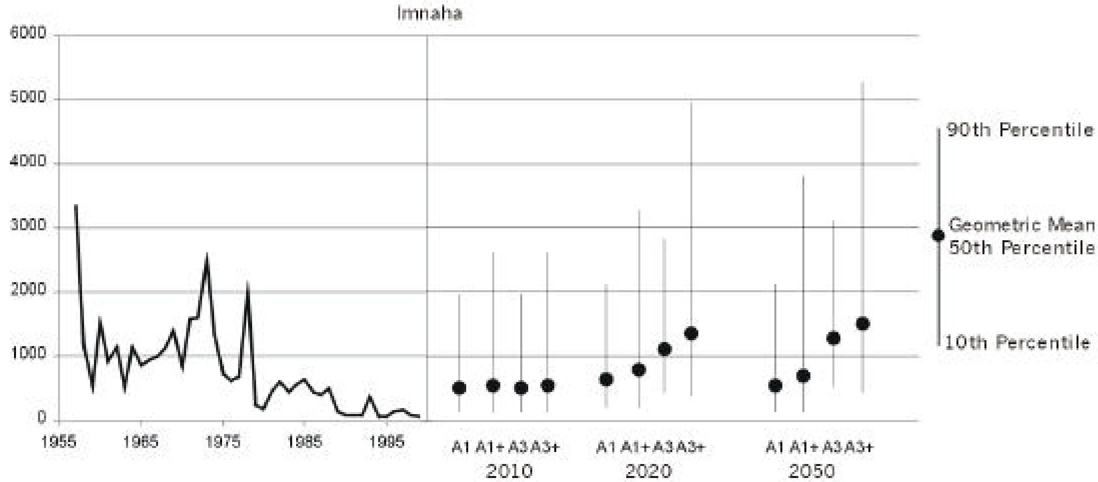
Our analysis has focussed primarily on the 1995 BiOp Jeopardy Standards developed by the Biological Requirements Working Group. However, we recognize that other analyses have used different metrics to evaluate recovery actions, such as probability of extinction metrics. We modified BSM to produce similar metrics, and show probability of extinction results in Table B-2 below. We caution that the probability of extinction shown in Table B-2 cannot be directly compared to the analogous metric produced by CRI because of the differences in structure and assumptions between BSM and other analytical frameworks. For example, we have assumed that direct passage survival rates of smolts will improve as a result of 1995 BiOp hydrosystem operations, and selected parameters from the entire historical period (brood years 1952 to 1993) in forward simulations. Both of these assumptions contribute to the lower probabilities of extinction produced by BSM in comparison to those produced by CRI. In a sensitivity analysis, we found that BSM projected much lower spawner abundance (and consequently higher probabilities of extinction, although we did not calculate that metric in the sensitivity analysis) if we selected parameters only from brood years 1984-1993. A previous PATH-CRI comparison also showed that the probability of extinction metric is sensitive to model assumptions (Peters et al. 2000a).

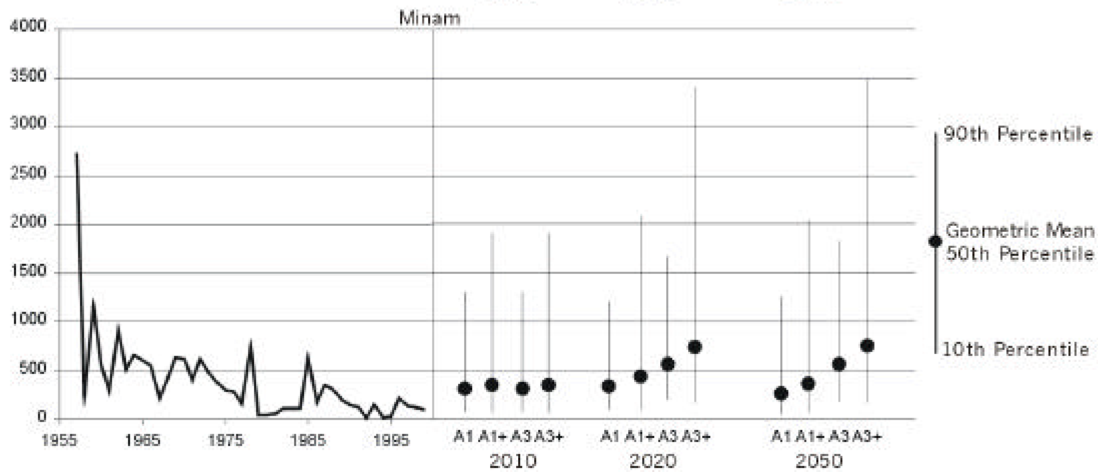
In all modeling efforts, it is the relative performance of alternative actions which matters more than the projected absolute levels of escapement or recruitment. Models of fish populations simply can't predict biological responses over decadal time scales with absolute accuracy. It is, however, justified to compare the relative performance of alternative actions under a range of hypotheses for key uncertainties. Therefore, the differences between the CRI and BSM metrics are much less important than the relative differences among alternative actions over a wide range of uncertainties, as examined in this paper.

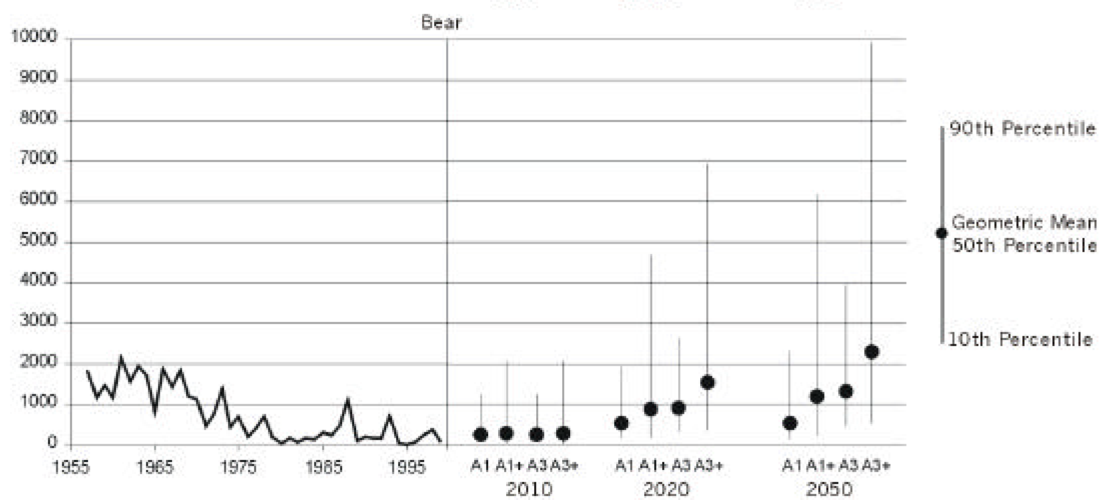
Table B-2. Summary of performance measures for all stocks and actions. Results assume the hybrid extra mortality hypothesis, and are averaged over passage models and hatchery effectiveness hypotheses (combinations 4, 8, 12, and 16 from Table 2-2). The "+" actions include habitat, hatchery, and harvest improvements.

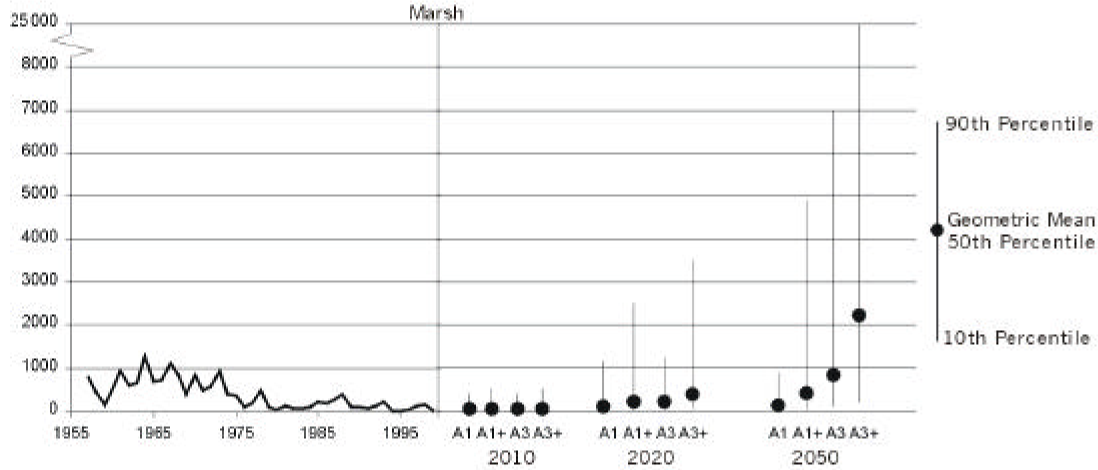
Stock	Performance Measure	A1	A1+	A3	A3+
Imnaha	24 Year Survival	0.722	0.730	0.761	0.759
	48 Year Recovery	0.384	0.538	0.900	0.891
	Pr(<2 Spawners, 5 years)	0.000075	0.002825	0	0
Minam	24 Year Survival	0.779	0.786	0.817	0.814
	48 Year Recovery	0.308	0.501	0.795	0.869
	Pr(<2 Spawners, 5 years)	0	0	0	0.000125
Bear	24 Year Survival	0.588	0.634	0.637	0.664
	48 Year Recovery	0.323	0.757	0.880	0.946
	Pr(<2 Spawners, 5 years)	0.000075	0	0	0.000075
Marsh	24 Year Survival	0.361	0.430	0.418	0.478
	48 Year Recovery	0.243	0.567	0.838	0.941
	Pr(<2 Spawners, 5 years)	0.017225	0.002275	0.00045	0.0002
Sulphur	24 Year Survival	0.423	0.470	0.484	0.521
	48 Year Recovery	0.196	0.378	0.649	0.775
	Pr(<2 Spawners, 5 years)	0.000075	0.000075	0	0.00035
Poverty	24 Year Survival	0.624	0.639	0.680	0.683
	48 Year Recovery	0.287	0.432	0.889	0.883
	Pr(<2 Spawners, 5 years)	0.000725	0.000075	0	0
Johnson	24 Year Survival	0.598	0.624	0.658	0.669
	48 Year Recovery	0.407	0.570	0.912	0.914
	Pr(<2 Spawners, 5 years)	0.0004	0.000075	0	0

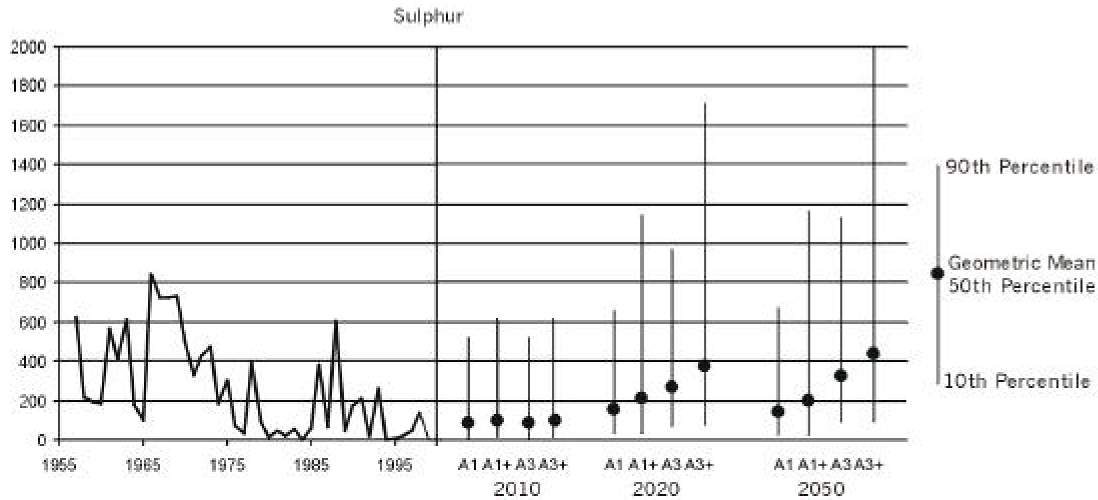
B.2 Projected Distributions of Spawners

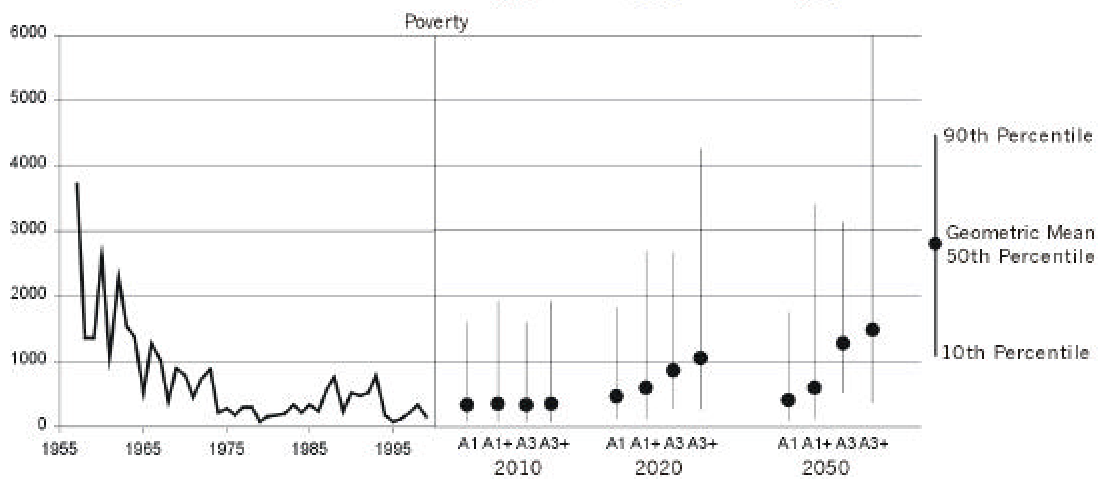

Imnaha
6000
5000
4000
3000
2000
1000
0
1955
1965
1975
1985
1995
A1 A1+ A3 A3+
2010
A1 A1+ A3 A3+
2020
A1 A1+ A3 A3+
2050
90th Percentile
Geometric Mean
50th Percentile
10th Percentile


Minam
4000
3500
3000
2500
2000
1500
1000
500
0
1955
1965
1975
1985
1995
A1 A1+ A3 A3+
2010
A1 A1+ A3 A3+
2020
A1 A1+ A3 A3+
2050
90th Percentile
Geometric Mean
50th Percentile
10th Percentile


Bear
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
1955
1965
1975
1985
1995
A1 A1+ A3 A3+
2010
A1 A1+ A3 A3+
2020
A1 A1+ A3 A3+
2050
90th Percentile
Geometric Mean
50th Percentile
10th Percentile


Marsh
25000
8000
7000
6000
5000
4000
3000
2000
1000
0
1955
1965
1975
1985
1995
A1 A1+ A3 A3+
2010
A1 A1+ A3 A3+
2020
A1 A1+ A3 A3+
2050
90th Percentile
Geometric Mean
50th Percentile
10th Percentile


Sulphur
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1955
1965
1975
1985
1995
A1 A1+ A3 A3+
2010
A1 A1+ A3 A3+
2020
A1 A1+ A3 A3+
2050
90th Percentile
Geometric Mean
50th Percentile
10th Percentile


Poverty
6000
5000
4000
3000
2000
1000
0
1955
1965
1975
1985
1995
A1 A1+ A3 A3+
2010
A1 A1+ A3 A3+
2020
A1 A1+ A3 A3+
2050
90th Percentile
Geometric Mean
50th Percentile
10th Percentile

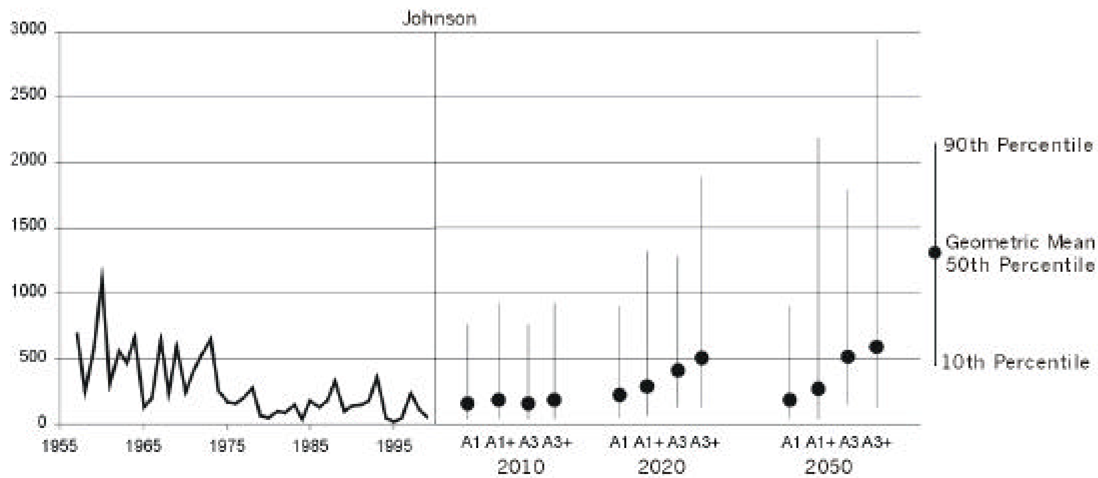
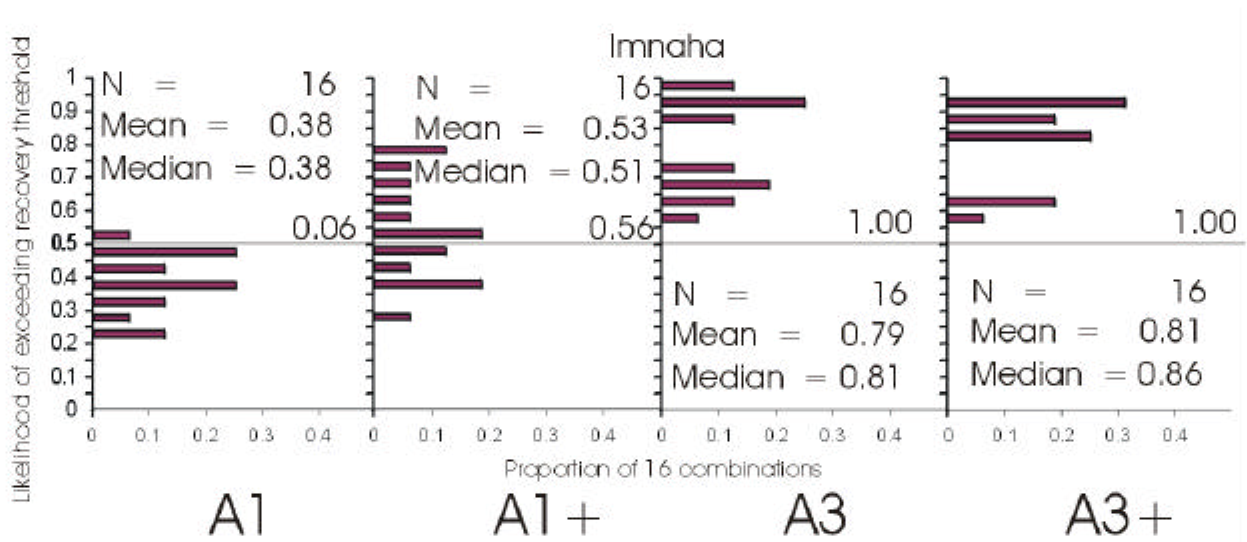
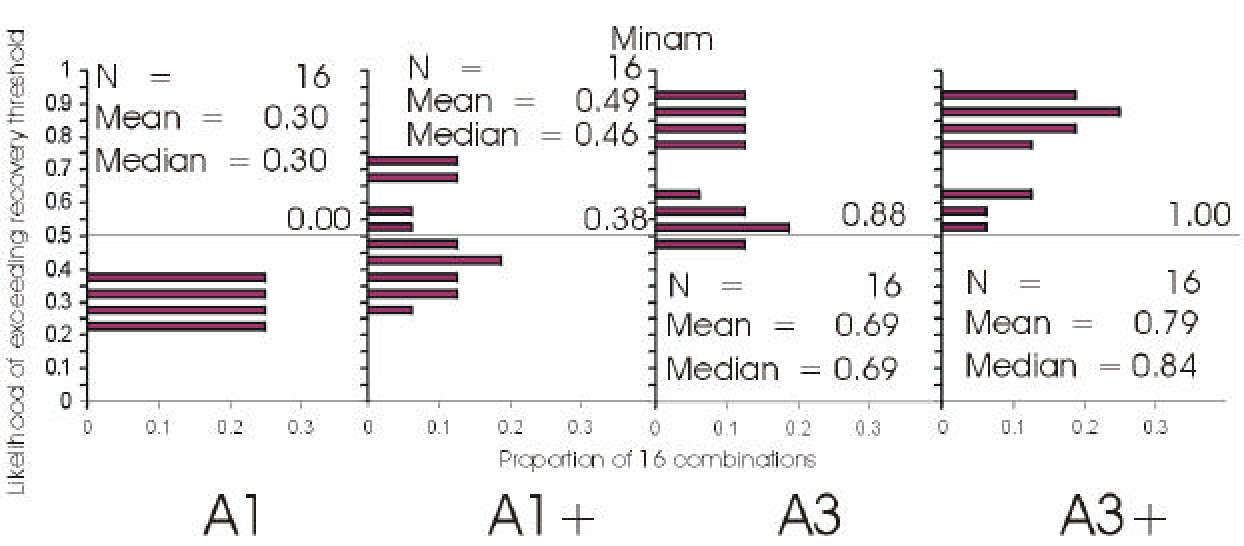
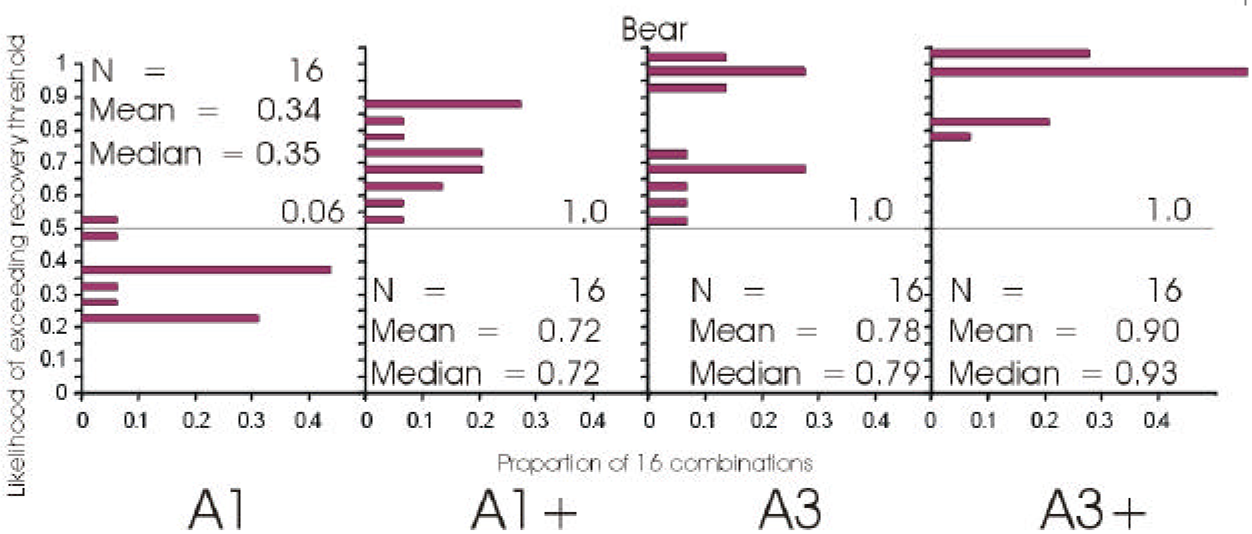
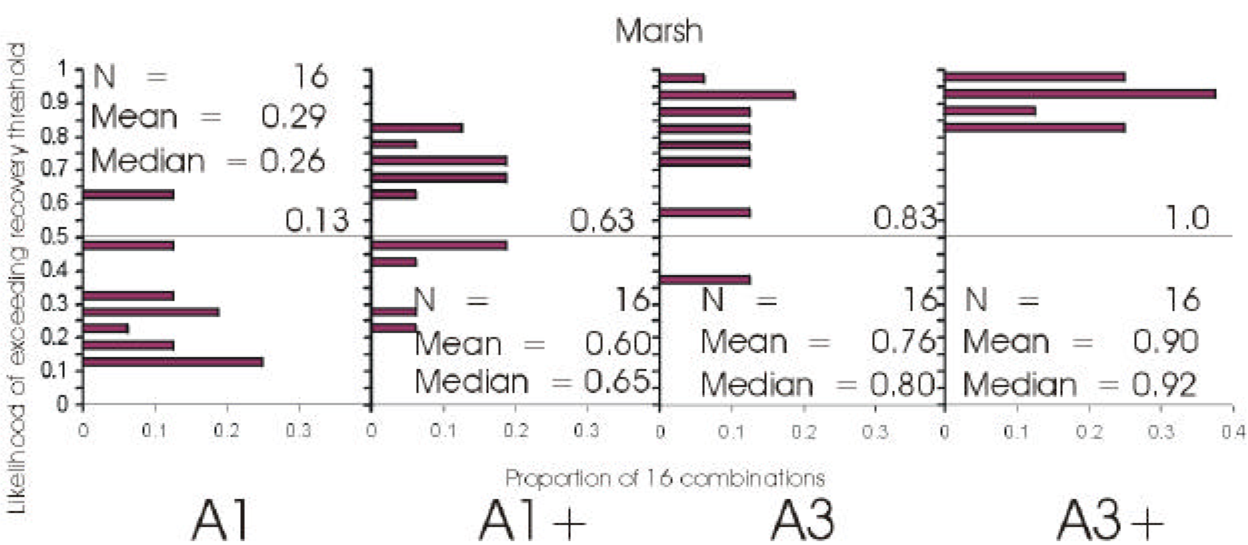


Figure B-1. Geometric mean, 10th, and 90th percentile of spawners in simulation years 2010, 2020, and 2050 for Snake River spring/summer chinook stocks, assuming the hybrid extra mortality hypothesis, the FLUSH passage model, and 80% hatchery spawning effectiveness (combinations 8 and 16 from Table 2-2). Actual spawner data goes to 1999. The "+" actions include habitat, hatchery, and harvest improvements.




Minam
Likelihood of exceeding recovery threshold
N = 16
Mean = 0.30
Median = 0.30
0.00
N = 16
Mean = 0.49
Median = 0.46
0.38
0.88
N = 16
Mean = 0.69
Median = 0.69
1.00
N = 16
Mean = 0.79
Median = 0.84
Proportion of 16 combinations
A1
A1+
A3
A3+


Bear
Likelihood of exceeding recovery threshold
N = 16
Mean = 0.34
Median = 0.35
0.06
1.0
N = 16
Mean = 0.72
Median = 0.72
1.0
N = 16
Mean = 0.78
Median = 0.79
1.0
N = 16
Mean = 0.90
Median = 0.93
Proportion of 16 combinations
A1
A1+
A3
A3+


Marsh
Likelihood of exceeding recovery threshold
N = 16
Mean = 0.29
Median = 0.26
0.13
0.63
N = 16
Mean = 0.60
Median = 0.65
0.83
N = 16
Mean = 0.76
Median = 0.80
1.0
N = 16
Mean = 0.90
Median = 0.92
Proportion of 16 combinations
A1
A1+
A3
A3+

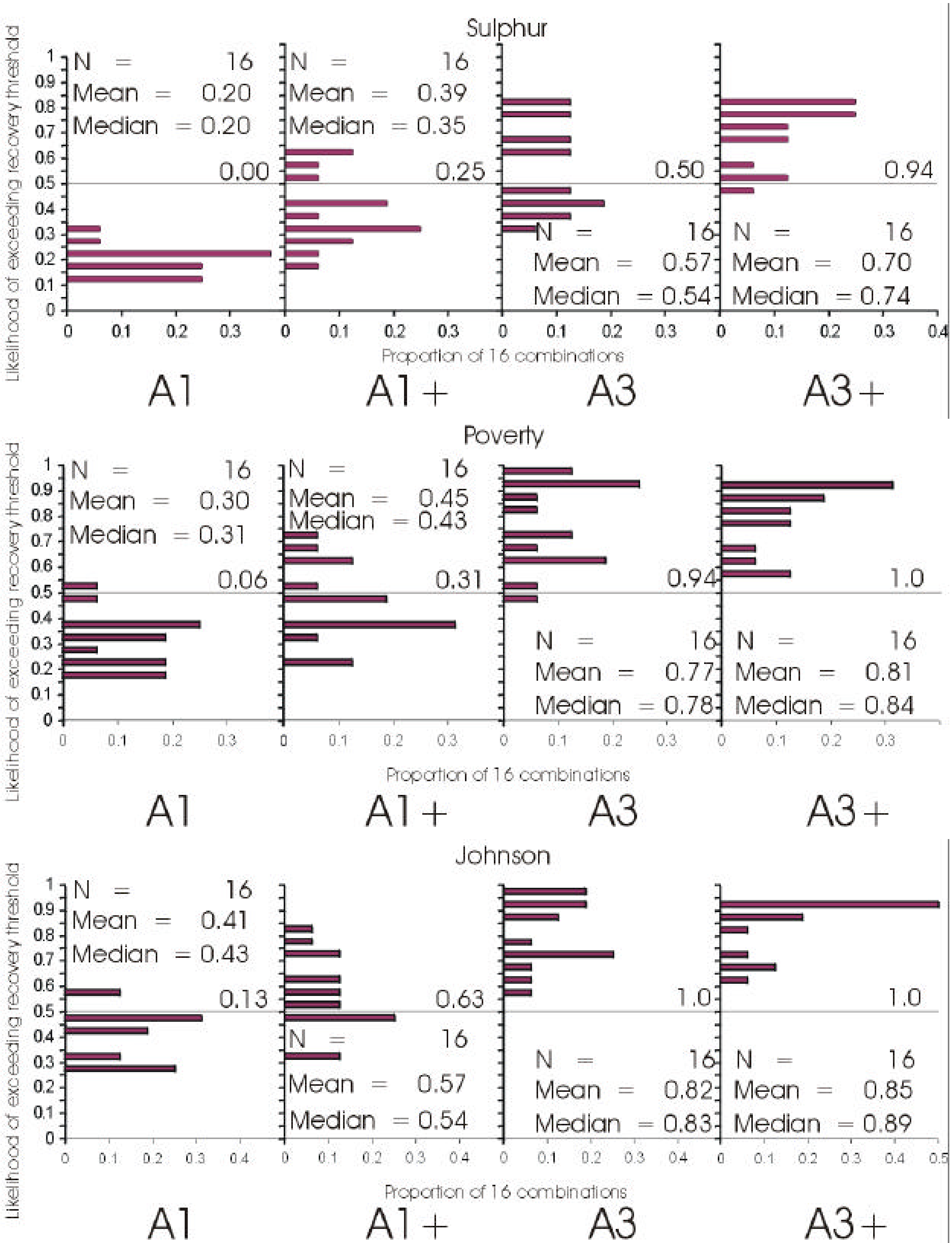
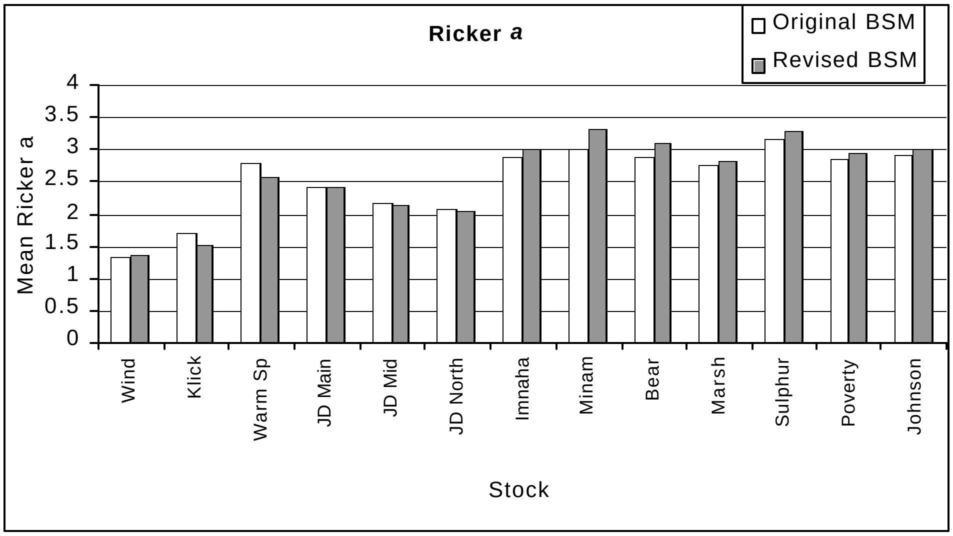
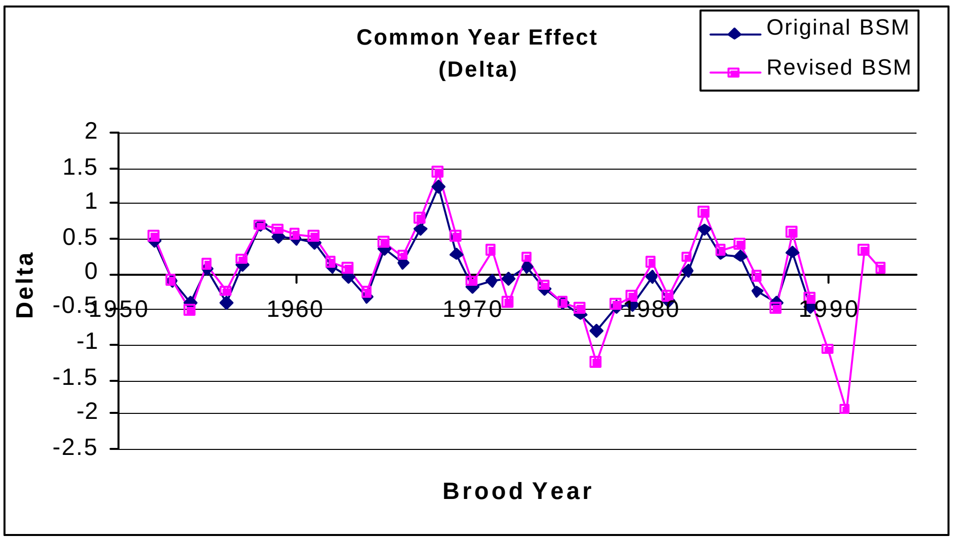


Figure B-2. Distributions of 48-year recovery probabilities over all combinations of passage models, extra mortality, and hatchery effectiveness hypotheses (all 16 combinations in Table 22) for Snake River spring/summer chinook index stocks. The "+" actions include habitat, hatchery, and harvest improvements. Overall mean and median probabilities are also shown (calculated over the 16 combinations of passage model, hatchery spawner effectiveness, and extra mortality hypotheses), along with the proportion of the 16 combinations of passage model, hatchery spawner effectiveness, and extra mortality hypotheses that exceed the 0.5 recovery standard.

B.3 Effects of Refinements of Models and Data on Model Parameters





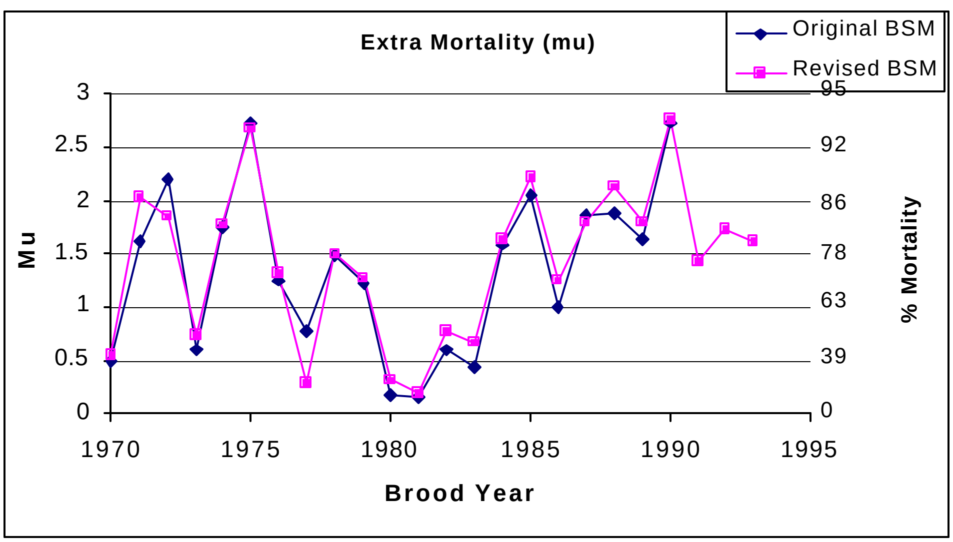


Figure B-3. Comparison of Ricker a, delta, and mu estimates from the original BSM and the revised BSM. BSM was revised to include spawner estimates through BY1999, recruit data through BY1994, regulated WTT data through water year 1998, and updated conversion rates. The year-effect used for 1995 is assumed to equal the year-effect estimated for 1993. The revised BSM results in this figure assumed 100% hatchery effectiveness, to be consistent with assumptions in the original BSM.

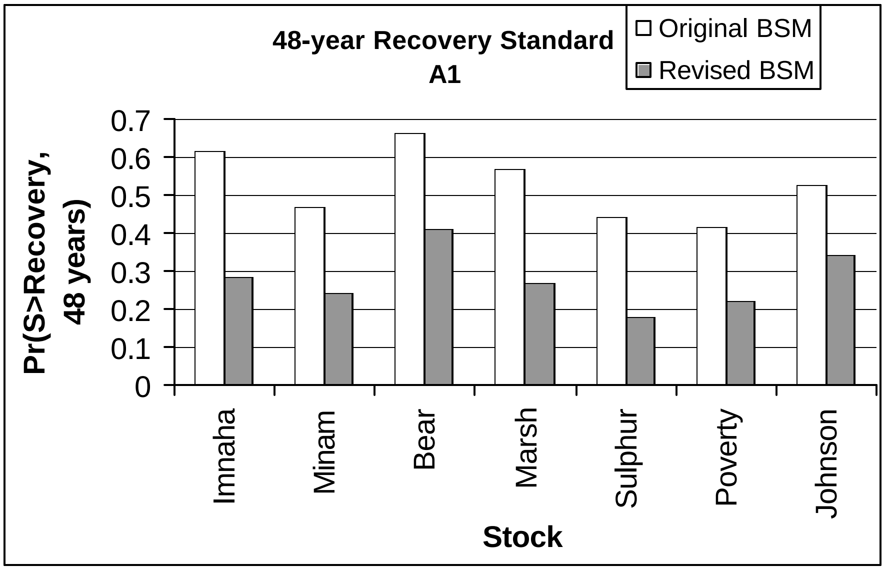


Figure B-4. Comparison of 48-year recovery probabilities for A1 produced by the original and revised BSM. The revised BSM results in this figure assumed 100% hatchery effectiveness, to be consistent with assumptions in the original BSM. The revised model produces results that are lower than the original version.

Appendix C. Effects of passage survival and base period assumptions on model results

C.1 Introduction

Figure 3-1 showed that under current hydrosystem operations with no non-hydro mitigation (i.e. hydro action A1), all stocks experienced an initial increase in projected spawners before reaching some steady-state level. This was true even though:

- extra mortality was assumed to persist at current levels indefinitely (i.e. the Hydro extra mortality hypothesis was assumed)
- the average relative post-Bonneville survival of transported fish (i.e. the "D" value) remained constant at a value of 0.58 from the retrospective to the prospective period, and
- there were no improvements in productivity due to habitat or harvest actions.

Given that this scenario therefore assumed only an improvement in the direct component of passage survival, we were interested in the cause of the initial increase in projected spawners. There were at least five possible explanations:

1. Hydro action A1 represents hydrosystem operations prescribed by the 1995 Biological Opinion. As in past PATH analyses, we assumed that direct survival rates of Snake River chinook smolts through the hydrosystem would increase in response to these operations. This assumption was implemented through the passage models inputs to BSM. For example, Figure C-1 shows the passage models' estimates of Total Direct Survival Rate, which is the overall survival rate of all smolts (transported and non-transported) from the head of Lower Granite reservoir to below Bonneville Dam. Estimates for A1 are considerably higher than the historical estimates under similar flow conditions. This improvement is a result of assumed increases in the survival rate of non-transported fish through the hydrosystem (Vn; Figure C-2) resulting from implementation of the 1995 Biological Opinion starting in 1996).

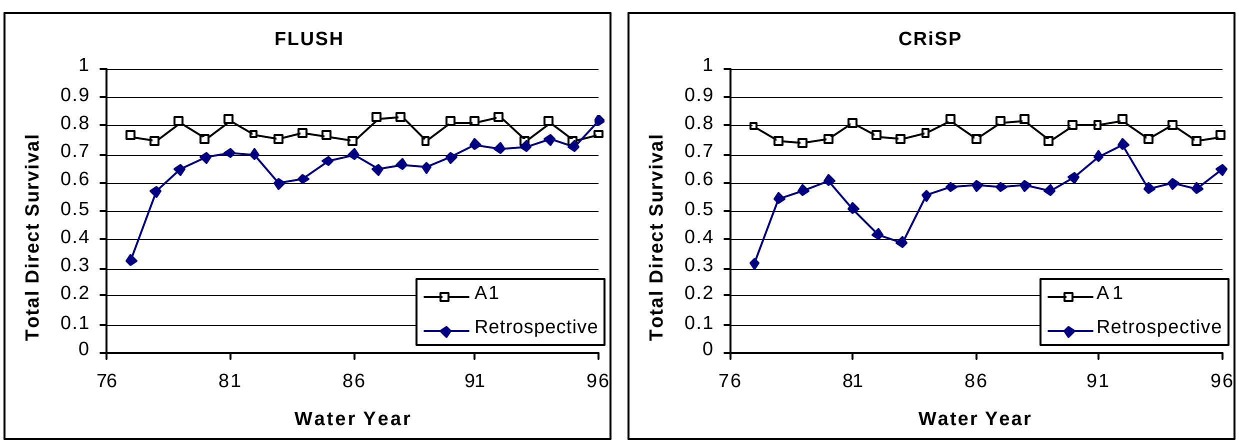


Figure C-1. Retrospective and A1 values of Total Direct Survival (e^{-M}) estimated by FLUSH (left) and CRiSP (right).

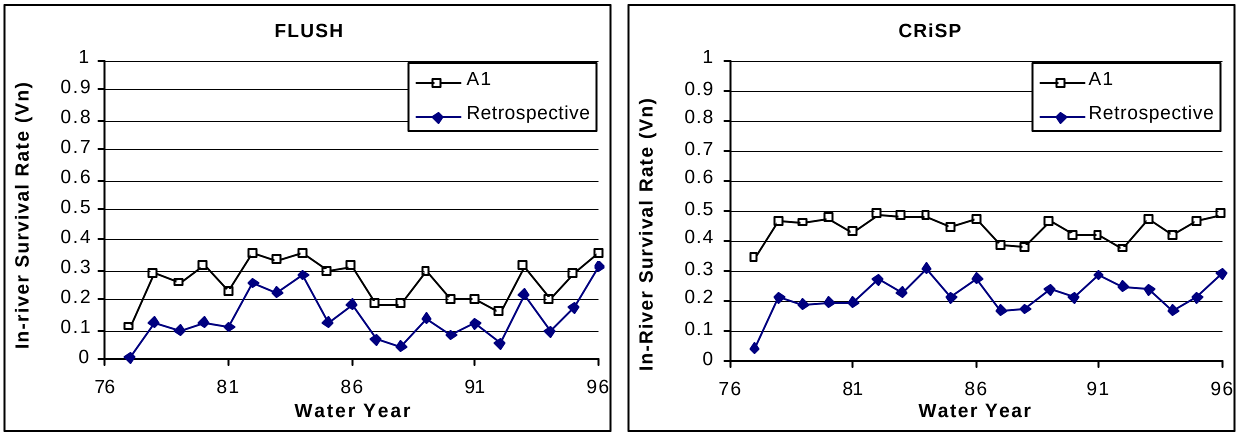


Figure C-2. Retrospective and A1 values of In-River Survival of Non-Transported Fish (Vn) estimated by FLUSH (left) and CRiSP (right).

2. The increase was due to the fact that the simulations assumed that future climate conditions, which are represented by the δ ("delta", or "common year effect") parameter in BSM, will be similar to what was experienced between 1952 to 1993. That is, in future simulations the δ parameter was selected[14] from the historical δ values estimated for brood years 1952 to 1993 (the historical time series of δ is shown in Figure C-3). Because this time period included both good and bad ocean conditions, this could lead to higher projections of spawners if future climate conditions were more similar to an historical period in which climate conditions were predominantly worse than average. Compounding the effect of this assumption was that the first simulation year used the δ value from 1993, the last year for which an historical δ value was estimated. This essentially assumed that initial climate conditions in the simulation will be similar to recent conditions, but because the 1993 δ value was positive (i.e., better than the historical average; see Figure C-3), this had the effect of seeding the simulation with better than average climate conditions.

[14] The selection followed an autoregressive pattern, such that above-average delta years tended to be followed by above-average delta years, and below-average years tended to be followed by below-average years.

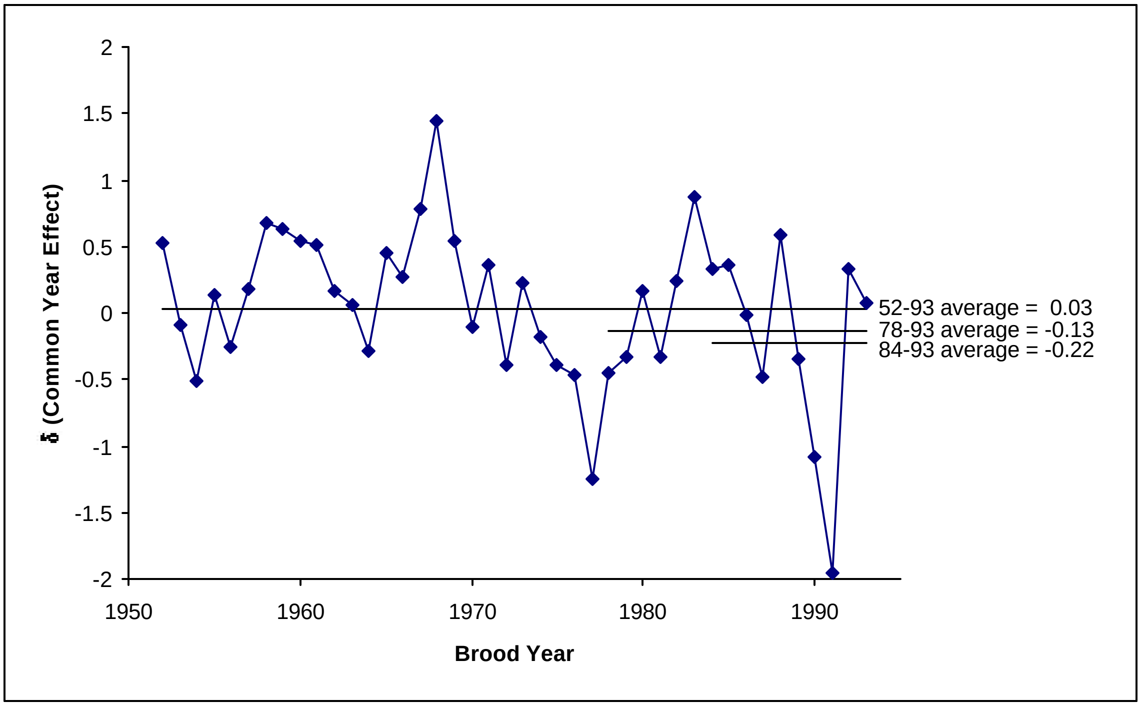


Figure C-3. Time series of estimated δ values.

3. Values of total mortality (passage + extra mortality, "*m*" in Appendix A) in the prospective simulations were selected[15] from values estimated for brood years 1975 to 1993 (Figure C-4). One could argue that these *m* values should be selected from a more recent period (such as 1978-1995, or 1986-1995) that more closely resembles the operations and flow conditions that would be expected in the future.

4. The increase was due to the lack of depensatory effects in the prospective simulations that would cause productivity to decrease at very low spawner numbers. BSM estimated a depensation parameter *p*, but the estimated value of this parameter was very close to zero, indicating that no depensatory signal was evident within the range of observed spawner-recruit data. Depensation may occur at lower spawner values than have been observed, but implementing these effects in the model would require some ad hoc approach. In the absence of a regional scientific discussion, we declined to implement an arbitrary depensation mechanism.

[15] *m* values from this time period were selected in proportion to the occurrence of each water year in the historical (1929 to 1996) flow record. Therefore, *m* values form years with very high or low flows, which historically occurred relatively infrequently, would be selected much less often than a *m* value from a year with an average flow which occurred more frequently in the historical record.

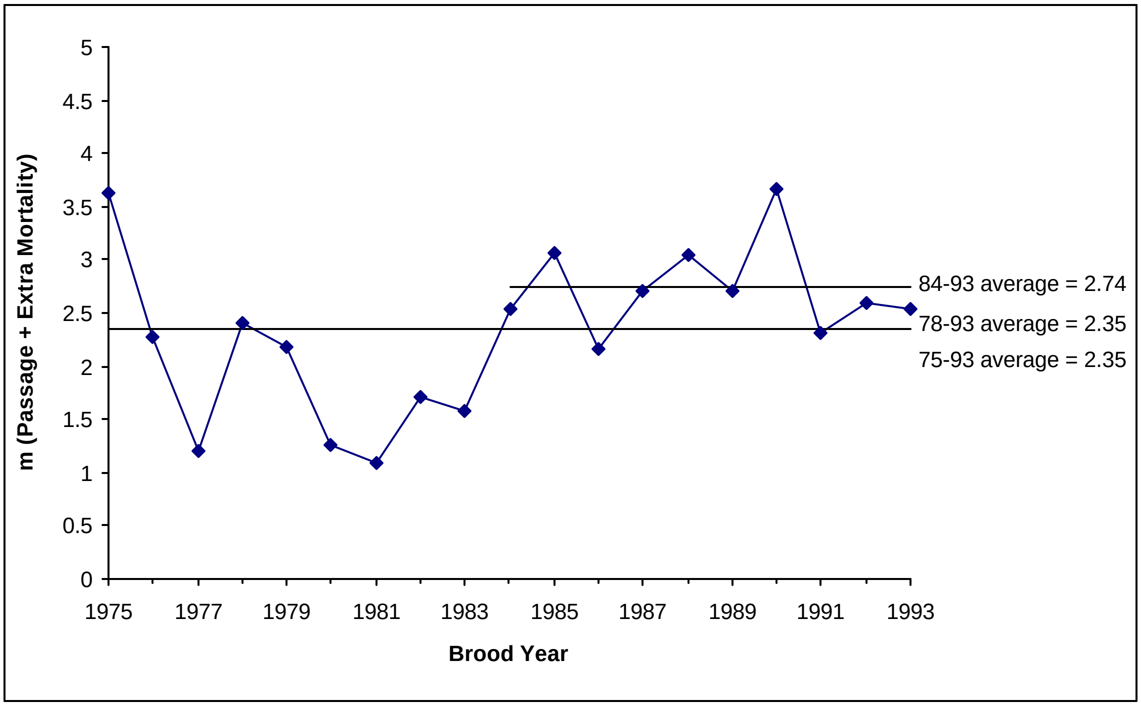


Figure C-4. Time series of estimated total mortality (*m*).

5. The Ricker *a* (productivity) parameter was estimated from the entire set of spawner-recruit data (1957 to 1994). This time span included a period before the mid-1970's when all of the stocks were relatively productive compared to recent returns. Because the forward projections draw Ricker *a* values from the distribution of estimated values, the model essentially assumed that the stocks will sustain their average historical level of productivity into the future.

All five of these factors are potential contributors to the observed jump in projected spawner abundance under current operating conditions. This Appendix describes a sensitivity analysis of the first, second, and third factor. Because these factors together account for most of the initial increase in spawners (see Results section), we did not explore the effects of the other two factors.

C.2 Methods

To determine the effects of assumptions about direct passage survival (factor #1) and selection periods for δ and *m* parameters (factors 2 and 3) on projected spawner abundance, we compared outputs from the base model and four alternative models that make different assumptions about these factors. The main assumptions in these models are described below and summarized in Table C-1.

<u>Base model.</u> The base model was the one used to generate all of the results in the main report and Appendix B. Selection periods for the δ and *m* parameters were brood years

1952 to 1993 and brood years 1975 to 1993, respectively. δ parameters were selected with autoregressive properties, and the *m* values were selected in proportion to their frequency in the historical water record. The δ value in the first simulation year was set to the BY1993 value. For this comparison, we used the "A1" passage model estimates of M (total direct mortality), Vn (in-river survival rate of non-transported fish), and Pbt (proportion of smolts arriving below Bonneville that were transported) with the base model to conduct the simulations. These estimates assume that current (1995 BiOp) hydro operations produce higher passage survivals than historical (pre-BiOp) estimates (Figures C-1 and C-2).

Alternative #1 (A0BY52-93). In this model, we applied the retrospective passage model estimates of M, Vn, and Pbt in the prospective projections. That is, we assumed that passage survival rates in the future would be the same as those observed from brood years 1975 to 1994, before the 1995 Biological Opinion was implemented. We call this passage scenario "A0". Base selection periods and selection methods for δ and *m* parameters were the same as in the base model. The δ value in the first simulation year was set to the BY1993 value.

Alternative #2 (A0BY78-93). This model also used "A0" passage assumptions, but δ and *m* parameters were selected from brood years 1978 to 1993. These parameters were selected randomly from this time period, as opposed to the autoregressive selection method of δ and the historical water year selection of *m*. The δ value in the fist simulation year was selected randomly from BY1978-1993 values.

Alternative #3 (A0BY84-93). This alternative model used A0 passage assumptions, but selected δ and *m* parameters from brood years 1984 to 1993 (the last ten years in which these parameters were estimated). The δ value in the fist simulation year was selected randomly from BY1984-1993 values.

Alternative #4 (A1BY84-93). This alternative model used A1 passage assumptions, but selected δ and *m* parameters from brood years 1984 to 1993 (the last ten years in which these parameters were estimated). The δ value in the fist simulation year was selected randomly from BY1984-1993 values.

Table C-1. Assumptions used in base and alternative models.

Model	Passage Survival	Total mortality (*m*)		Climate conditions (d)		
		Selection Period	**Selection Method**	**Selection Period**	**Selection Method**	**Simulation year 1**
Base	A1	BY1975-93	Historical water year	BY1952-93	Autoregressive	Set to 1993 value
Alt. #1	A0	BY1975-93	Historical water year	BY1952-93	Autoregressive	Set to 1993 value

Alt. #2	A0	BY1978-93	Random	BY1978-93	Random	Selected from BY1978-93
Alt. #3	A0	BY1984-93	Random	BY1984-93	Random	Selected from BY1984-93
Alt. #4	A1	BY1984-93	Random	BY1984-93	Random	Selected from BY1984-93

These five sets of models were used to generate projections of spawner abundance over a 100-year simulation period. For all model runs, we used FLUSH passage model estimates, 0.8 hatchery spawner effectiveness, and the Hydro extra mortality hypothesis (which implies that future extra mortality remains at historical levels). That is, we used combination #5 from Table 2-2.

C.3 Results

Assuming no improvement in direct passage survival (the A0 scenario) reduces geometric mean projected spawner abundance at steady-state levels by about one half for most stocks compared to the A1 scenario where an improvement was assumed (Figure C-3). However, the largest effects were seen when we used different assumptions about the appropriate base period from which to select future year effects and total mortality factors. Using a BY1984-1993 base period is sufficient to cause all of the index stocks except Minam to go below 10 spawners by the end of the 100-year simulation period, even with A1 passage assumptions (Minam declined to fewer than 20 spawners). Spawner abundances were slightly lower when a 1984-1993 base period was coupled with A0 passage assumptions - Bear, Marsh, Poverty, and Johnson stocks are reduced to < 2 spawners at equilibrium; Imnaha, Minam and Sulphur are reduced to <6 spawners. Results with a base period of 1978-1993 are intermediate to results with base periods of 1952-1993 and 1984-1993.Most stocks show fairly high escapements in the early part of the simulation (around simulation years 2001-2003) relative to the rest of the simulation period. These large early escapements represent returns of age 3+ adult fish from strong observed spawning escapement in 1997 and 1998.

The effects of these base period assumptions are consistent with the patterns in estimated values of the δ and m parameters shown in Figure C-3 and C-4. Truncating the base periods for selecting δ and m values in future simulations to include only recent years leads to lower average δ values and higher average m values; both of these lead to poorer overall survival rates than when the longer base periods are applied. Put another way, selecting δ values from the entire time period includes the generally positive delta values (indicative of better than average climate conditions) estimated in the earliest part of the time series. Similarly, selecting m values from the entire time period includes the relatively low values in the earliest part of the time series. Our base model, which selects from the entire time periods for both of these factors, thus assumes better future climate and mortality conditions than what would be expected if only the most recent estimates were used. This in turn leads to increasing upward trends in projected spawner abundance, even in the absence of major management efforts in hydro and the other H's.

These effects of changing the base period on spawner projections are somewhat confounded by the simultaneous changing of the selection method for δ and *m* in our alternative models. However, we note that in similar sensitivity analyses conducted for our earlier PATH-CRI comparison, the selection method had a much smaller effect on model results than the base period from which these parameters were selected (Peters et al. 2000a, compare Models 1 and 2 in Table A-1).

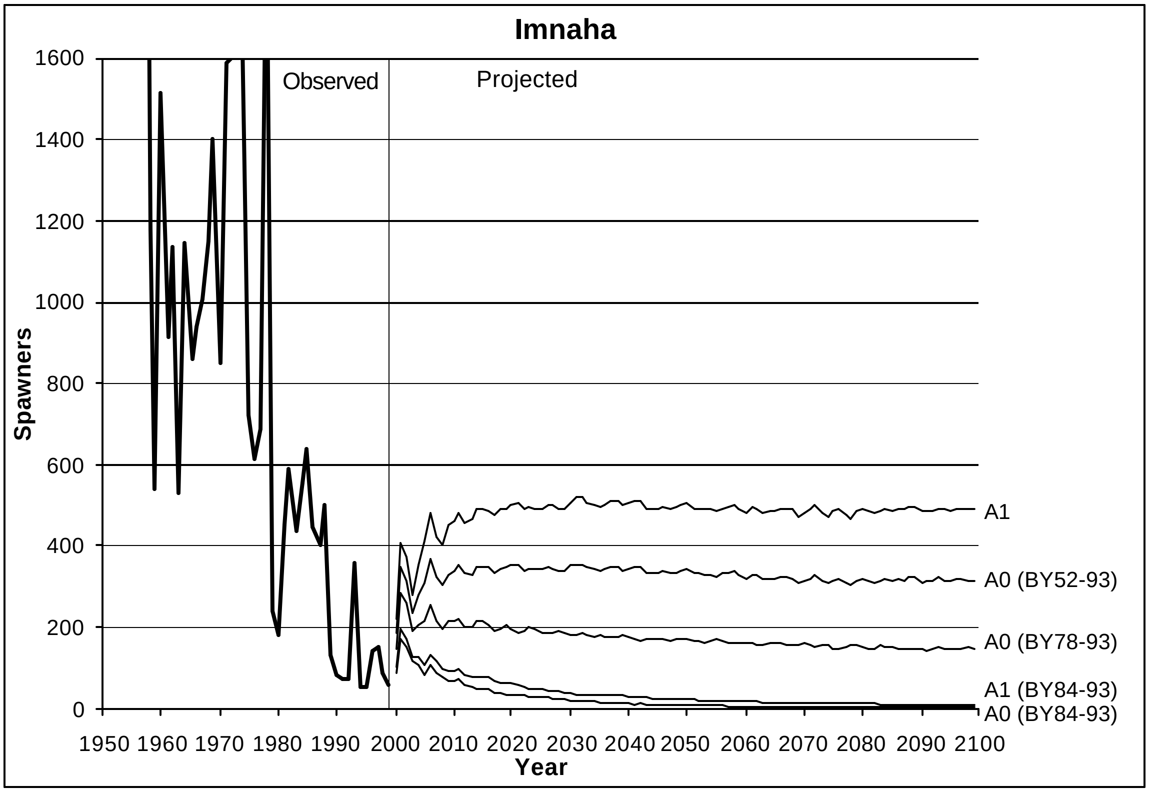
C.4 Discussion

The base period appears to have a larger effect on model outputs than assumptions about survival improvements resulting from the 1995 BiOp. With the entire base period (1952-1993 for common year effects, 1975-1993 for total mortality factors) the direct passage survival improvements assumed under A1 are sufficient to reverse the declining trend in spawner abundance observed over the last 20 years. However, when only the latter portion of this period (1984-1993) is used as the base period, the survival improvements assumed under A1 are unable to halt the declining trend and the stocks approach extinction.

These results highlight the significant influence that base periods can have on the results of models that are based on historical data (similar effects of different base periods on estimates of intrinsic population growth rates (lambda) are described in Appendix E). Because we can never know for sure what future conditions will be like, we must rely on past experience to make some reasonable assumptions. Of course, assumptions about future conditions can never be tested ahead of time, but can and should be explored through sensitivity analysis to determine their effects.

The A0 scenario, while intended only as a sensitivity analysis, could be interpreted as a scenario in which either a) not all aspects of hydrosystem operations prescribed by the 1995 Biological Opinion were successfully implemented (CRITFC 2000) or b) operations have changed but have had no effect on direct passage survival. In either case, attempts to compare reach survival data from before 1995 to data collected after 1995 to see if such survival improvements have occurred are confounded by having only a few years of data since 1995 and by between-year variability in flow and other environmental conditions. Scenario A0 provides a worst case scenario of no improvement in passage survival and therefore bounds the effects.

Even if such improvements in direct passage survival have occurred, these improvements have generally not resulted in improvements in overall smolt to adult survival rates in recent years. This suggests that in reality some improvements (such as extended length screens) may increase direct survival but may increase delayed mortality, and thus produce no gain in overall survival. The results of this sensitivity analysis suggest that below average climate and total mortality conditions can mask the improvements in direct passage survival assumed to result from the 1995 BiOp, leading to poor returns.


Imnaha
Spawners
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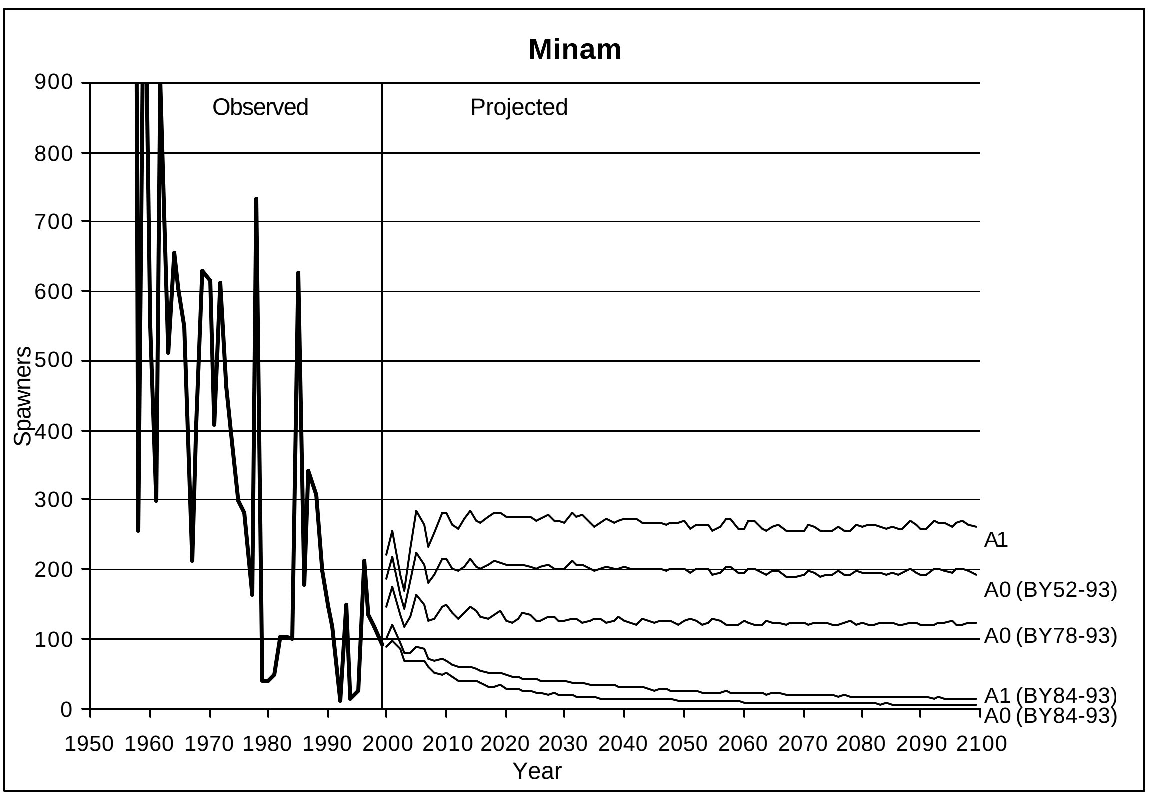
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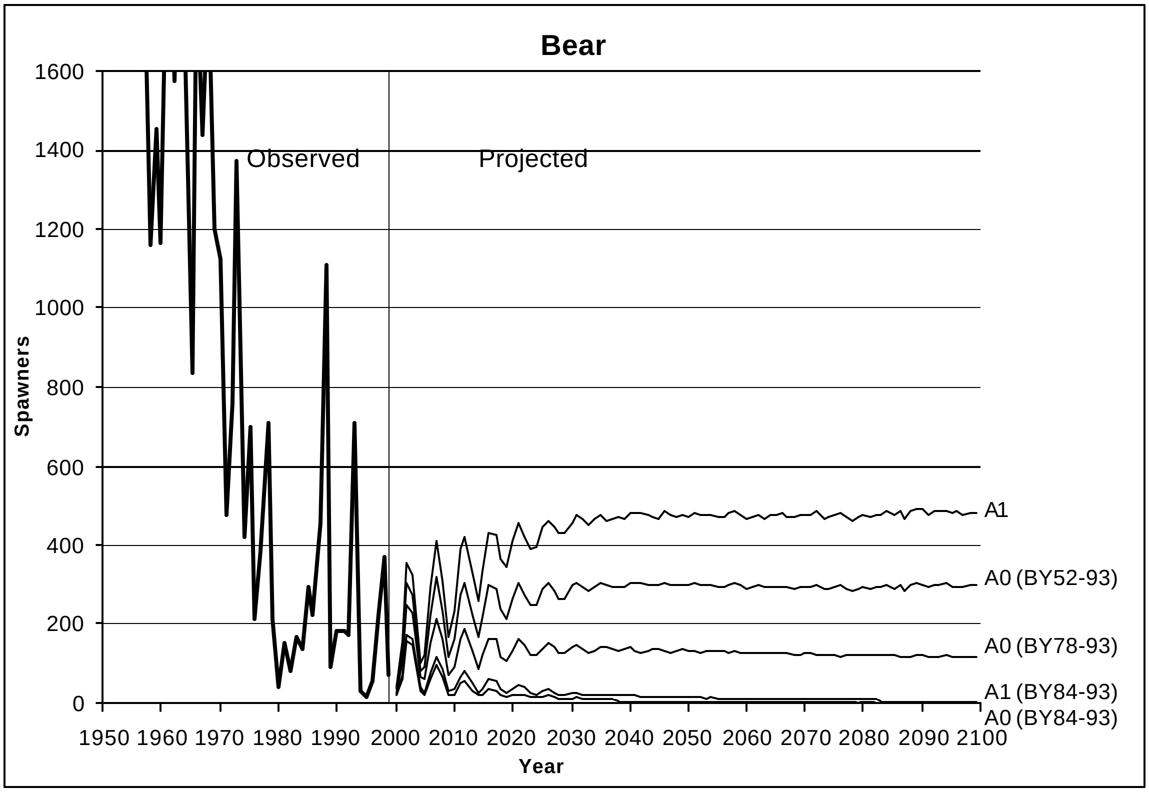
Bear
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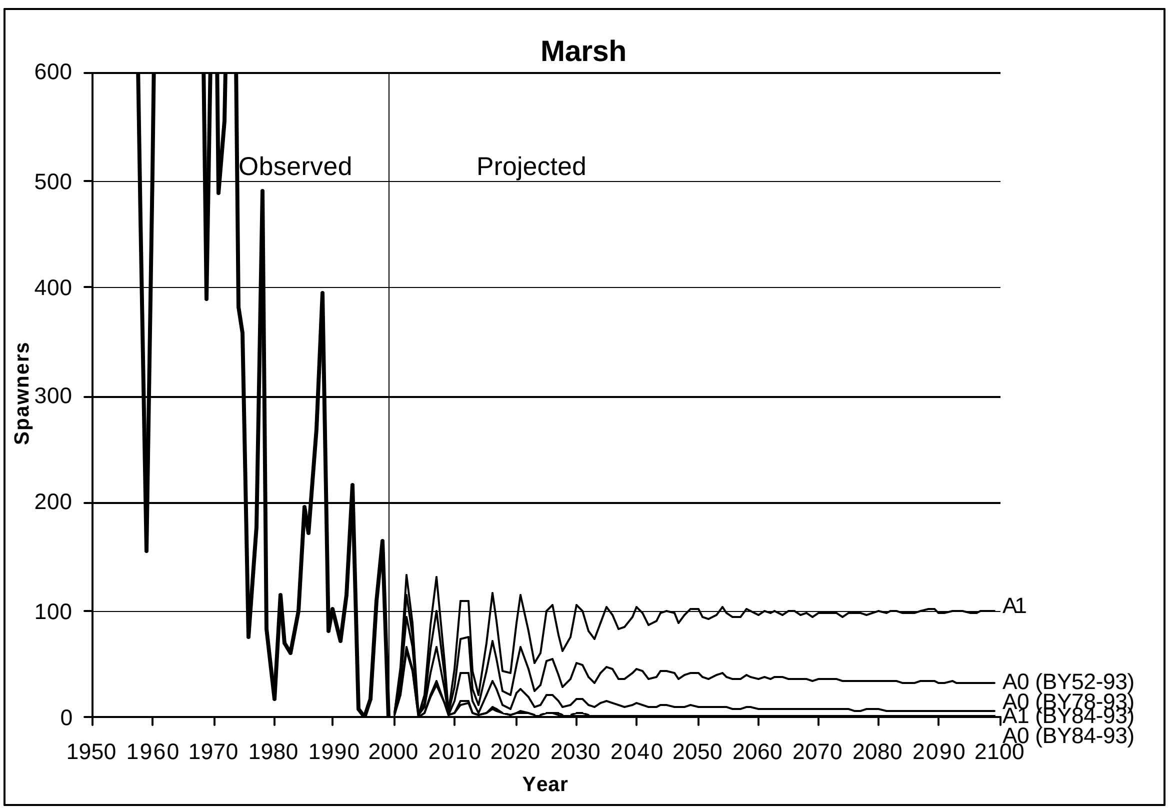
Marsh
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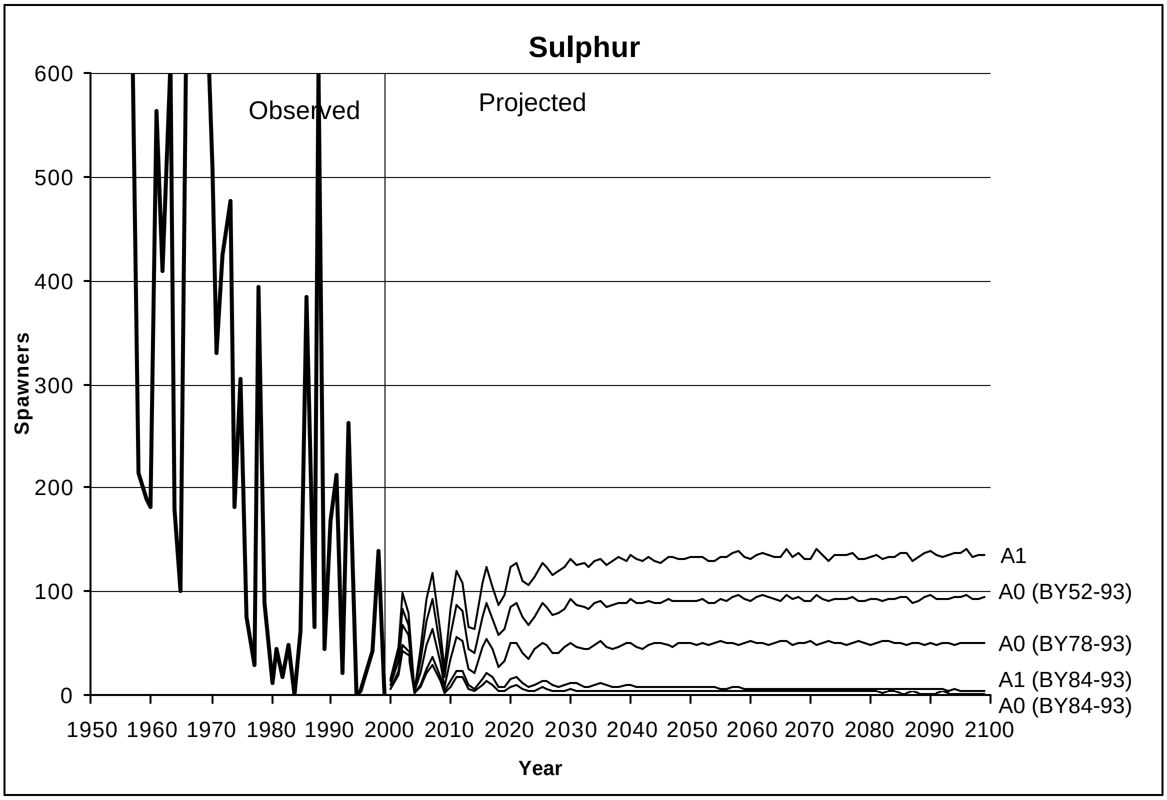
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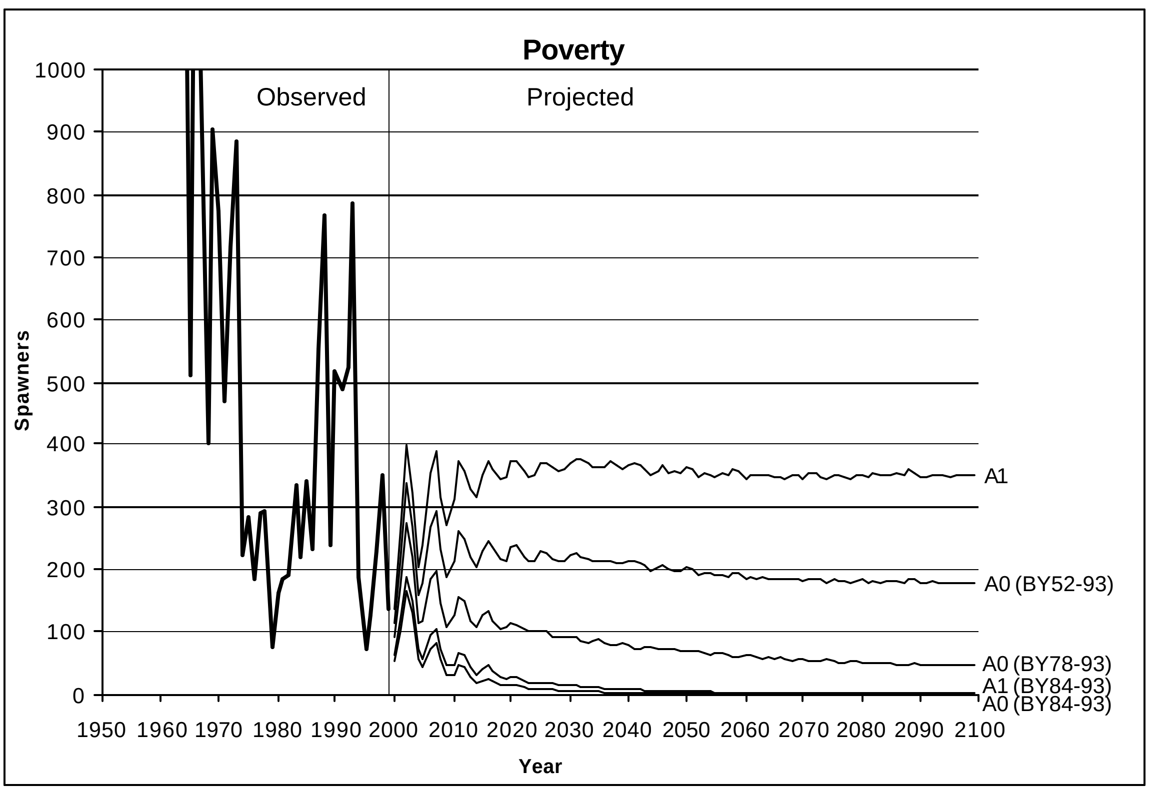
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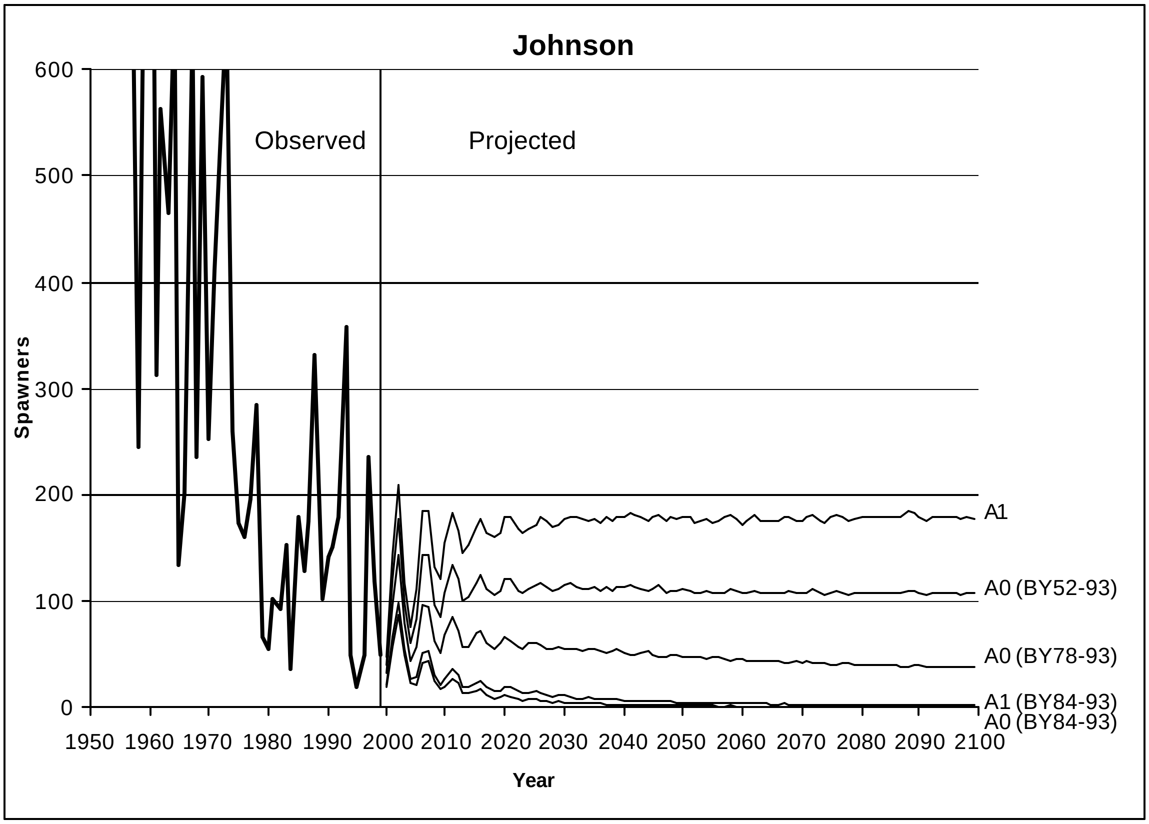

Figure C-5. Geometric mean of spawners in each simulated year for Snake River spring/summer chinook stocks, using different assumptions about passage survival improvements and base periods for selecting delta and *m* values in forward projections. A0 assumes that passage survival rates do not increase as a result of the 1995 BiOp; A1 assumes that passage survival rates do increase. Results assume the FLUSH passage model, 80% hatchery spawning effectiveness, and the Hydro extra mortality hypothesis (combination 5 from Table 2-2).

Appendix D. Delayed Hydrosystem Mortality: Evidence from NMFS' White Papers

The NMFS' March 2000 White Papers generally avoided the pivotal issue of delayed hydrosystem mortality. NMFS states in their Response to Comments on Salmonid Travel Time and Survival Related to Flow in the Columbia River Basin:

> NMFS "… consider[s] delayed mortality due to passage through the hydrosystem to be a plausible but untested hypothesis. It cannot be stated as fact. On a related note, flow augmentation may affect survival outside the hydrosystem…"

The White Papers contain numerous references to evidence and potential mechanisms for delayed hydrosystem mortality. The evidence provides numerous links of stress, altered behavior and ecological processes to the development and operation of the hydropower system. While the evidence and mechanisms may not "prove" existence of delayed hydrosystem mortality, the weight of evidence supports this hypothesis for at least a portion of the extra mortality. A summary of these references for each White Paper follows:

D.1 Salmonid Travel Time and Survival Related to Flow in the Columbia River Basin

"These conditions have led to increased travel time for migrating smolts…Through a variety of mechanisms, these flow-related environmental changes have affected the timing of salt-water entry for juvenile migrants…Further, delays in their [juvenile fall chinook] migration due to slack water in impoundments place these juvenile migrants in reservoirs during periods when water temperatures approach chinook salmon's thermal maximum." (p. 1-2)

"Flow and water temperature can affect migrating juvenile salmonids in many ways. Flow influences travel time and consequently duration of exposure to mortality factors in reservoirs. Water temperature affects levels of physiological development and stress and influences factors directly related to mortality (e.g., predator metabolic rates). Flow and water temperature affect characteristics of the estuary and near ocean environment and, through effects on travel time, the timing of estuary arrival of migrating smolts." (p. 7)

"Spill can also reduce smolt travel time." (p. 7)

"Snake River basin fish evolved under conditions where the travel time of smolts through the lower Snake and Columbia Rivers was much shorter than presently exists. Thus, higher flows, while decreasing travel time, may also improve conditions in the estuary and provided survival benefits to juvenile salmonids migrating through the estuary or the Columbia River plume. By reducing the length of time smolts are exposed to stressors in the reservoirs, higher flows also likely improve smolt condition upon arrival in the estuary." (p. 23)

"Thus it appears that a major effect of the dams on subyearling migrants is a shift in rearing from the estuary to reservoirs and extended residence in mainstem rivers." (p. 24)

"[Fall chinook] that migrate under lower flows later in the season may experience passage delays that do not occur early in the season. Hypothesized causes for such delays are disorientation of migrants, reversal of smoltification, disease (Park 1969, Raymond 1988, Berggren and Filardo 1993) and a decreased tendency to migrate under conditions of low turbidity (Steel 1999)." (p. 42)

Figures 17, 18 and 19 show relationships between flow or water travel time and SARs or ln(R/S) for Snake River spring chinook and steelhead and upper Columbia steelhead. Empirical patterns for survival to adult not detectable in direct survival estimates for migrating smolts. (p. 47-52)

"Additionally, since a high proportion of smolts have been transported from the upper Snake River dams to below Bonneville Dam since 1977, an association between SAR and flow for Snake River migrants must reflect either delayed effects of flow conditions experienced upstream from transportation sites of flow conditions experienced in the estuary of Columbia River plume after barge release." (p. 53)

"Yearling chinook salmon and steelhead have evolved to migrate during the spring, suggesting that over the evolutionary time scale, spring conditions, including higher river flows, provide an adaptive advantage for survival. Furthermore, variable flows are a natural part of river ecology, benefiting other riverine processes (ISG 1996)." (p. 54)

"Finally, due to decreased river flows and development of the hydropower system, many migrant salmon (those not transported) likely arrive in the estuary later than under conditions in which they evolved. Efforts to restore the Columbia River plume toward conditions that existed prior to development of the hydropower system would likely benefit salmonids (ISG 1996)." (p. 54)

"This [lack of direct relationship between flow and reach survival] does not preclude benefits of flow augmentation during the migration season because increased flows may improve survival outside the hydropower system as a result of earlier arrival to the estuary, improved estuary conditions, and reduced delayed mortality." (p. 58)

D.2 Summary of Research Related to Transportation of Juvenile Anadromous Salmonids around Snake and Columbia River Dams

"The authors also speculated that an insufficient degree of smoltification, or osmoregulatory or other disturbances associated with transportation, may potentially delay ocean entry (Schreck and Davis 1997)." (p. 10)

"Studies show that collection facilities and procedures increase stress among juvenile salmonids." (p. 14)

"Results of a 1993 study indicated that, even though stress indicators in juvenile salmonids were initially elevated (plasma cortisol, white blood cell levels, composition of white blood cells, diminished avoidance behavior), they decreased as the fish were barged downriver (Shreck and Congleton 1993). Studies in 1994, however, showed that the ability of yearling chinook salmon sampled from a barge at Lower Granite Dam to survive a saltwater challenge was reduced on each of three successive test dates over the course of the juvenile migration (Shreck and Congleton 1994)." (p. 15)

"The highest cortisol concentrations in both groups [wild and hatchery yearling chinook] occurred during peak movement of juvenile salmon into the collection facility migration (Shreck and Congleton 1994). These data suggested that recovery from collection and loading stressors is related to loading density. Mixing species together during collection and transportation may also have been a factor." (p. 15)

"Studies in 1994 and 1995 demonstrated that collection and loading were also stressful to steelhead smolts." (p. 15)

"In confinement [laboratory simulation of transportation practices], the schooling behavior of the chinook did not appear to be compatible with the territorial behavior of the rainbow trout. Physiological studies found that plasma cortisol levels were higher in chinook salmon after rainbow trout were introduced than … in control tanks (no loading) or in tanks loaded with additional chinook salmon." (p. 16)

"However, plasma cortisol levels [in confined yearling chinook] increased 2 hours after the [rainbow trout] odor was introduced (Kelsey 1997; Schreck et al. 1997b)." (p. 16)

"Laboratory cohabitation and waterborne experiments indicated that the causative agent of BKD can be transmitted to healthy chinook salmon smolts during a 48-hour exposure to infected chinook salmon." (p. 16)

"Blood plasma samples taken from yearling chinook salmon in gatewells and barges at Lower Granite Dam, and from fish in the barges after transport, indicated that defenses against disease pathogens are significantly decreased after transportation (Schreck and Congleton 1994)." (p. 16)

"The 1988 through 1992 studies also found that yearling chinook from Snake River hatcheries had a higher prevalence of R. salmoninarum infections when they were sampled at dams than in the hatcheries… Therefore, increases in the prevalence and severity of infection suggest that the infection progressed during the migration… The authors concluded that differences in water temperature and longer migration times caused hatchery fish migrating in the Snake River to experience higher prevalence and severity of R. salmoninarum than did those in the Columbia River (Maule et al. 1996)." (p. 17)

"Comparing the return rates of the fish from different groups indicates that fish [yearling chinook and steelhead] detected at dams apparently had a lower return rate than fish not detected at dams (Fig. 2). While estimates of direct survival differ for fish that pass downstream through nondetection routes and those that pass through bypass systems, the differences are not sufficient to account for the apparent difference in estimated SAR" (p. 19)

Tables 2-5 show NMFS estimate of 'D' to range from 0.63 to 0.73 for wild spring/summer chinook, and from 0.52 to 0.58 for steelhead (i.e., transported smolts survived ½ to ¾ as well as in-river smolts after release). (p. 25-27)

D.3 Passage of Juvenile and Adult Salmonids Past Columbia and Snake River Dams

"By keeping the animals submerged [in collection systems], wet separation is considered less stressful to fish… In addition, recent behavior and physiology studies have indicated that fish hold under the bars for extended periods rather than exit expeditiously from the wet separator unit [J. Congleton, pers. comm.]. This suggests that many fish exit only after they are fatigued as a result of swimming to avoid hydraulic conditions within the unit." (p. 25)

"Stress, generated by external and internal stimuli, induces quantifiable biochemical responses in fish (Hane et al. 1966, Grant and Mehrle 1973). Clinical evaluation of blood plasma has associated stress with changes in concentration of cortisol and adrenaline, which influence levels of secondary indicators including lactate, glucose, liver glycogen, leukocyte count, free fatty acids, and the balance of various electrolytes (Mazeaud et al. 1977)." (p. 47)

"Several stressors related to passage through fish bypass facilities at hydroelectric dams have been shown to alter indicator concentrations in juvenile salmonids under experimental conditions. For example, elevated plasma cortisol and glucose levels have been associated with crowding and handling (Wedemeyer 1976, Congleton et al. 1994), descaling (Gadomski et al. 1994), acclimation temperature (Barton and Schreck 1987a), and confinement (Strange et al. 1978)." (p. 47)

"The relationships between physiological indicators of bypass-induced stress and in-river survival are not as well documented. There is evidence that short-term survival may be directly impaired as a result of stress in poor quality chinook salmon smolts… Indirectly, bypass stress may also contribute to reduced ability to respond successfully to in-river conditions…They [Barton and Schreck 1987b] concluded that even relatively minor events can reduce available energy stores by as much as one-quarter, leaving the animal with substantially fewer reserves to cope with environmental challenges such as temperature adaptation, disease, and demands on swimming stamina." (p. 53)

"These measures of juvenile survival are important for making decisions on how to operate and configure the FCRPS. However, SARs are perhaps a more complete

measure of stock performance, since SARs incorporate both direct and indirect effects of dam and hydropower system passage." (p. 80)

"The cause of this apparent reduction in SARs for fish that passed through bypass systems, and the differences in SARs between individual dam bypass systems and between years (1995 and 1997), is unknown. The reduced return rate is possibly a result of the cumulative effect of stress/injury associated with passing through bypass systems." (p. 81)

"Schaller et al. (1999) provide an analysis of spawner/recruit data that contrasts productivity patterns for yearling chinook stocks from the upper Columbia and Snake Rivers with those from the lower Columbia River. They conclude that differences in productivity between upper and lower river stocks are primarily due to the number of dams each must pass (8 or 9 versus 3 or fewer). The unexplained mortality associated with the Snake River stocks (mortality in addition to the direct loss through the hydropower system) that accounts for the difference in productivity discussed by Schaller et al. is called "extra mortality" (NMFS 1999a). PATH developed three hypotheses to explain the sources of the extra mortality: hydropower system, ocean regime shift, and stock viability degradation (Marmorek and Peters 1998). Hydropower system extra mortality includes any effect of the hydropower system that is not measured during the juvenile or adult migration through the hydropower system corridor." (p. 85)

"The mechanisms of "extra mortality" have not been confirmed. Hypotheses of how the hydropower system could produce extra mortality include the effect of hydro-regulation has on flow and ocean entry timing, the cumulative effect of stress/injury associated with passing through bypass systems or the hydropower system, and the effect of stress, disease transmission, and delay on fish as they pass through bypass systems or fish ladders." (p. 85)

"Clearly, uncertainty exists over whether the source of the extra mortality is caused by the hydropower system or other factors. The actual mechanisms of extra mortality have not been identified. Analyses of hydropower system effects are confounded by changes in ocean productivity, Columbia River hydrology due to increased storage capacity, reliance on hatcheries to meet production goals, and other factors. While is clear that hydroelectric development has played a role in the decline of Columbia and Snake River stocks, isolating the effects of the hydropower system only will be difficult." (p. 85)

" Although direct survival through mechanical screen bypass systems is higher than turbines, fish transiting bypass systems often have increased levels of stress as measured by blood chemistry. This suggests that attention should continue to focus on mechanical bypass system improvements." (p. 101)

" Blood plasma stress indicators can rise dramatically during or after passage through bypass systems, but generally return to pre-exposure levels within several hours. This response does not always occur, and has been observed to vary by species, rearing history, and dam. The response is typical for a fish subjected to a stressor. The

relationship between elevated physiological stress indicators and survival is not well documented. Some evidence suggests bypass induced stress may reduce the ability of juvenile salmonids to avoid predators." (p. 101-102)

Appendix E. Differences between BSM and CRI Metrics

E.1 BSM and CRI Lambdas

Calculating λ with the PATH life-cycle model in a way that was consistent with the CRI turned out to be problematic. After examining the CRI "lambdas" closely, we concluded that the BSM analog of CRI's "λ" could not be easily calculated in a way that was consistent with CRI's lambda.

The CRI defines "λ" in different ways, depending on the particular application, but strictly speaking, λ is any of multiple eigenvalues of a Leslie matrix; the dominant eigenvalue (λ_1) of a Leslie matrix is defined, under specific conditions, as follows (Burgman et al. 1993):

The dominant eigenvalue λ…tells how the population would be changing if the parameters in the model were never to vary and could be fixed for an infinite length of time. λ is often called the finite rate of population increase…In fact, it is only when the population is at its stable distribution that the population's overall growth is measured by λ (p. 132).

In the Ricker context, λ is the density-independent reproductive rate e^r (where *r* is the instantaneous population growth rate of the exponential growth equation (as in $P(t)=P_0 e^{rt}$)),and is calculated from the initial slope of the recruitment curve (N(*t*+1) vs N(*t*)) — i.e., the density-independent portion (Burgman et al. 1993). Note that λ is *not* the initial slope of the curve N(*t*) vs *t* nor would it be appropriate to base lambda on spawner estimates calculated with density dependence, which is not consistent with Ricker's definition of λ.

In order to calculate λ, the density-independent average population growth rate, it appears that it would be necessary to rearrange BSM output to plot N(t+1) vs N(t), and find the density-independent slope (slope at small N). Even then, care would need to be taken to compare equivalent definitions, because the CRI has several definitions, and consequently a range of values, of "λ" (ISAB 1999, Oosterhout et al. 2000, Oosterhout 2000).

E.2 Base period

Any model applied to spawner-recruit data for the SRSSC index populations has to confront the problem that not only spawner counts, but population productivity itself (R/S) has itself been declining. That means that any model that assumes stationarity—as the BSM and CRI models do—will be affected by the period chosen as baseline. Data from earlier in the period will produce higher results; data from later in the period will produce lower results (Appendix C of this report; CRI 2000; Kareiva et al. 2000). For example, λ's for Poverty Flats calculated using the CRI's Leslie matrix model and the Dennis/Holmes model are 14% to 16% higher if the period 1980-1989 is included, than if only the later part of the data are used (see Table E-1).

Table E-1. Sensitivity of Lambda estimates to the time period in which they were calculated.

Baseline period	Leslie matrix l	Dennis/Holmes l

1980-1999	0.949[1]	1.006[2]
1990-1999	0.813[3]	0.847[4]

Notes:
1. From CRI website spreadsheet "POVERTY_july27DraftBiop.xls."
2. CRI 2000, Table B-4.
3. Kareiva et al. 2000.
4. Calculated from reconstructed model.

As another example, Peters et al. (2000a) found for five out of seven index stocks, probabilities of exceeding recovery thresholds over 48 years were lower when only brood year 1980 to 1990 data were used to estimate model parameters, than when the full (BY1952-1990) dataset was used (Table 3-2). Johnson and Poverty, the two stocks that showed a higher recovery probability when only 1980-1990 data were used, are both located on the South Fork of the Salmon River. These stocks experienced severe degradation up until the late 1960's, but habitat conditions have improved since then because of moratoria on timber harvest and road-building and concurrent rehabilitation efforts (Beamesderfer et al. 1997).

Table E-2. Probability of exceeding recovery thresholds over 48 years, using BY1952-1990 data and 1980-1990 data (from Peters et al. 2000a).

Stock	**Probability of exceeding recovery threshold over 48 years**	
	Using BY1952-1990 spawner recruit data[1]	Using BY1980-1990 spawner recruit data[2]
Imnaha	0.358	0.003
Minam	0.236	0.016
Bear Valley	0.310	0.096
Marsh	0.269	0.035
Sulphur	0.226	0.194
Poverty	0.188	0.723
Johnson	0.249	0.418

Notes:
1. From Peters et al. Table 3, Model 3
2. From Peters et al. Table 3, Model 6.

E.3 References

Burgman, M. A., S. Ferson, and H. R. Akcakaya. 1993. *Risk Assessment in Conservation Biology*. Chapman and Hall, UK.

CRI (Cumulative Risk Initiative). 2000. A standardized quantitative analysis of risks faced by salmonids in the Columbia River Basin. Northwest Fisheries Science Center NMFS - NOAA, Seattle, WA.

Dennis, B., P. L. Munholland, and J. M. Scott. 1991. Estimation of growth and extinction parameters for endangered species. *Ecological monographs* 61(2): 115-143.

Kareiva, P., M. Marvier, and M. McClure. 2000. Recovery and Management Options for Spring/Summer Chinook Salmon in the Columbia River Basin. *Science* 290: 977-979.

Oosterhout, G. 2000. Analysis of a decision: A critique of the National Marine Fisheries Service's draft Biological Opinion on the Operation of the Federal Columbia River Hydropower System, from the perspective of the sciences of decision analysis and risk assessment. Decision Matrix, Inc. for Columbia River Inter-Tribal Fish Commission, Trout Unlimited, Save Our Wild Salmon, Earthjustice Legal Defense Fund, and American Rivers, Eagle Point, OR.

Oosterhout, G., P. Wilson, C. Petrosky, P. Budy, N. Bouwes, E. Weber, E. Tinus, G. Thiede, and H. Schaller. 2000. A technical review of the National Marine Fisheries Service Leslie matrix model of Snake River spring and summer chinook populations. STUFA: State, Tribal, and U.S. Fisheries Agencies, Portland, OR.

Peters, C., D. Marmorek and R. Deriso. 2000. PATH-CRI Model Comparison. Memo dated May 25, 2000.

Appendix F. Hatchery effects on Imnaha stock

F.1 Introduction

Subsequent to the analyses described in this report, we discovered an inconsistency in the upriver survival rates of Imnaha stock adults (from the mouth of the Columbia River to the spawning grounds). Observed upstream survival rates (calculated from run reconstruction information) were about 30% lower than what would be predicted by applying estimated conversion rates and inriver harvests for Snake River spring/summer chinook (which is the approach used in BSM to simulate upstream migration), suggesting that we have been overestimating upstream survival rates for this stock and implying that there has been some additional harvest or source of mortality that is not included in our model. This was true only for the Imnaha stock; upstream survival rates for the other six index stocks were consistent with conversion and harvest rates.

Upon investigation, we discovered that beginning in 1982 a proportion of wild returning Imnaha spawners have been removed from annual spawning populations to provide broodstock for a local supplementation program (Beamesderfer et al. 1997). Because these removals have not been accounted for in our forward simulations (i.e., all wild returning adults are assumed to spawn naturally), our base case set of results for the Imnaha stock in essence assumes that these removals are discontinued starting in 1995 and for the duration of the simulation period. This appendix describes some sensitivity analyses of alternative assumptions about the future of the Imnaha removal program.

F.2 Methods

To explore the effects of this assumption on model results, we ran a limited set of runs[16] where we assumed that the removal of natural spawners will continue at a constant rate throughout the duration of the simulation period, without making any contribution to the overall population through supplementation methods. This assumption was implemented by applying, in every simulation year, a constant 30% downward adjustment to upstream survival for the Imnaha stock only. This is a worst-case assumption because a) although we are remove fish that are collected for supplementation of the naturally spawning population, we are not modeling subsequent supplementation of the natural population hatchery-raised progeny of those fish, and b) in reality, the number of wild adult removals is based on a sliding scale so that fewer fish are removed when wild returns are low.

Our modeling representation of the Imnaha removal program could certainly be improved. Both of the assumptions we have used are unrealistic: the base assumption assumes that the removal program is immediately and permanently halted, while the alternative assumption assumes that the removal program continues at a constant rate without modeling the benefits of hatchery supplementation.

F.3 Results

The alternative hatchery assumption (spawner removals continue in the future at a constant rate with no contribution of the progeny of these spawners to the listed population) leads to lower projected Imnaha spawner abundance for both actions A1 and A3 (Figure F-1), but doesn't affect the ranking of actions (A3 still projects higher long-term spawner abundances than A1). Action A1 appears to produce a slight downward trend in spawners with the alternative assumption, compared to a relatively constant trend with the base case assumption (compare the geometric mean spawners in simulation year 2050 with the geomean in 2010 in Figure F-1).

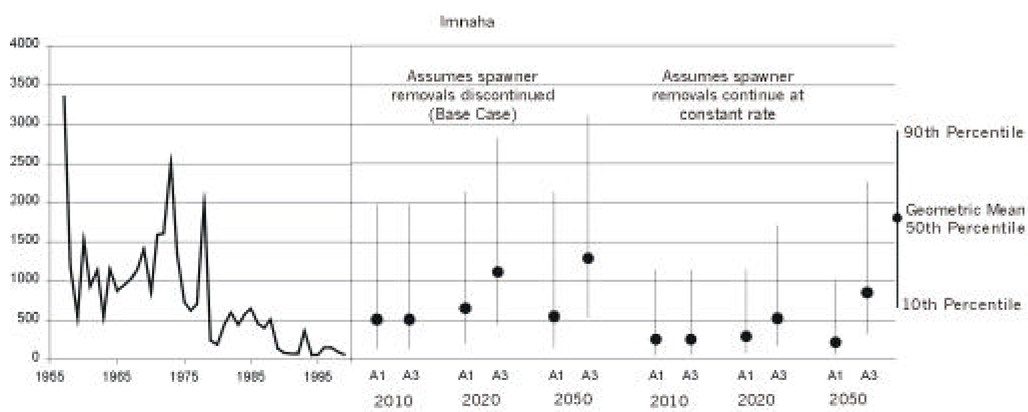

Figure F-1. Effects of alternative spawner removal assumptions on geometric mean, 10th, and 90th percentile of spawners in simulation years 2010, 2020, and 2050 for Imnaha stock, assuming the hybrid

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16 For purposes of this analysis we ran only actions A1 and A3, and used only the FLUSH passage model and 80% hatchery spawning effectiveness.

extra mortality hypothesis, the FLUSH passage model, and 80% hatchery spawning effectiveness (combination 8 from Table 2-2). Actual spawner data goes to 1999.

With the base case assumption, Imnaha was generally one of the stronger of the seven Snake River spring/summer chinook index stocks. With the alternative assumption, however, Imnaha is one of the poorer performing stocks (Figure F-2). Given this effect on the rankings of stocks, we explored the effects of the alternative removal assumption on the NMFS jeopardy standards for the 6th best stock.

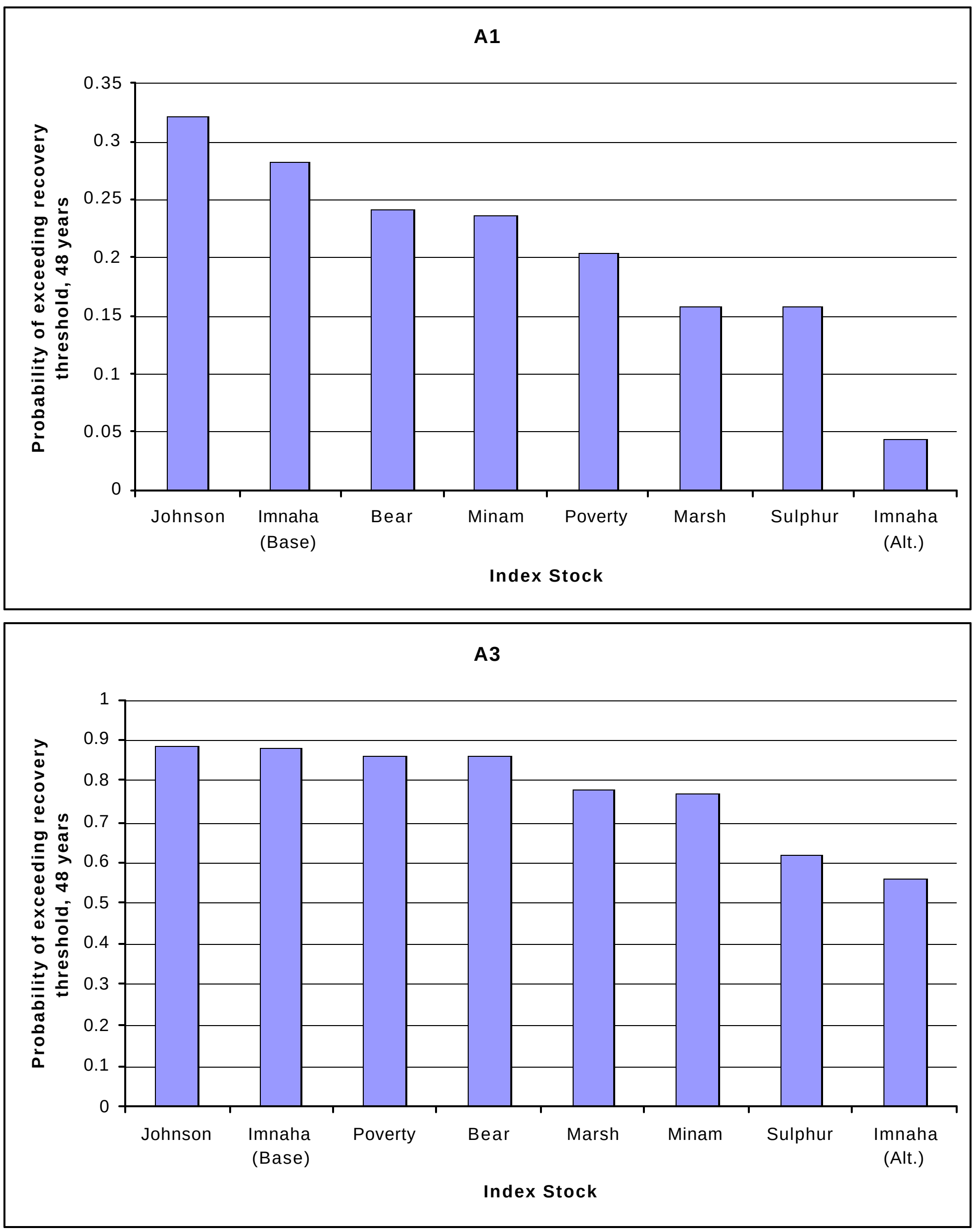


Figure F-2. Probabilities of exceeding 48-year recovery thresholds for each of the seven Snake River index stocks. Results assume the hybrid extra mortality, the FLUSH passage model, and 80% hatchery spawner effectiveness. Base case for Imnaha stock assumes that removal of wild spawners for hatchery broodstock is discontinued in the future. The alternative case assumes that wild spawners continue to be removed at a constant rate. For both actions A1 and A3, Imnaha with base case assumptions has the 2nd highest probability, but Imnaha with the alternative assumptions has the worst.

These effects are shown in Table F-2. In none of the cases did the alternative removal assumption affect either the relative ranking of actions or the ability of the actions to meet the 0.7 survival standard or 0.5 recovery standard from NMFS 1995 Biological Opinion. Because the Imnaha stock goes to 7th best with the alternative removal assumption, the observed differences between removal assumptions essentially amount to the differences between what were the 6th and 7th best stocks with the base case assumption (i.e., the difference between Marsh and Sulphur for A1 in Figure F-2, and the difference between Minam and Sulphur for A3).

Table F-2. Probabilities of exceeding survival and recovery thresholds for the **6th best** stock. Results shown are for each of the extra mortality hypotheses. Results assume the FLUSH passage model and 0.8 hatchery spawning effectiveness. Values that exceed the NMFS standards of 0.7 for survival measures and 0.5 for recovery measures are in **bold**.

	Extra Mortality Hypothesis	Assuming spawner removals discontinued (Base Case)		Assuming spawner removals continue at constant rate	
		A1	A3	A1	A3
Prob. of exceeding survival threshold, 24 years	Hatchery	0.37	0.37	0.37	0.37
	Hydro	0.36	0.46	0.36	0.46
	RS	0.51	0.52	0.52	0.52
	Hybrid	0.39	0.45	0.39	0.45
Prob. of exceeding survival threshold, 100 years	Hatchery	0.49	0.63	0.45	0.61
	Hydro	0.48	**0.82**	0.44	**0.82**
	RS	**0.73**	**0.82**	0.69	**0.81**
	Hybrid	0.53	**0.80**	0.51	**0.80**
Prob. of exceeding recovery threshold, 48 years	Hatchery	0.13	0.38	0.13	0.35
	Hydro	0.13	**0.88**	0.13	**0.79**
	RS	0.25	0.47	0.20	0.38
	Hybrid	0.16	**0.77**	0.16	**0.62**

F.4 Summary and Conclusions

In summary, assumptions about the future of the spawner removal program on the Imnaha stock has significant implications for this stock's projected trend in spawners and probabilities of exceeding survival and recovery thresholds. However, these assumptions did not affect either the relative ranking of actions or the ability of the actions to meet the 0.7 survival standard or 0.5 recovery standard from NMFS 1995 Biological Opinion.

As indicated previously, our modeling representation of the Imnaha removal program could certainly be improved. In principle, the most accurate modeling approach would be something in between these two alternatives: the removal program would continue at some sliding scale and we would account for and include supplemented fish according to some agreed-upon supplementation schedule. We note that the Imnaha Hatchery Master Plan (Ashe et al. 2000) defines broodstock selection and supplementation protocols for these stocks. It also estimates the anticipated contribution of the supplementation fish to the naturally spawning population.

References

Ashe, B., K. Concannon,D. B. Johnson,R. L. Zollman, D. Bryson, G. Alley. 2000. Northeast Oregon Hatchery Spring Chinook Master Plan. April 2000.

Appendix G. Analysis of Alternative Harvest Schedules

G.1 Introduction and Approach

We did some limited BSM runs to explore the effects of alternative spring chinook harvest schedules (Table G-1). We looked at three schedules:

1. Columbia River Fisheries Management Plan ("FMP") – this is the base harvest assumption used in previous PATH analyses and in the All-H analysis.
2. Harvest rates capped at current levels ("CAP") – this was the schedule developed for the All-H analysis to represent harvest restrictions described in the Draft BiOp.
3. An alternative developed by CRITFC ("CRITFC") – a stepped harvest schedule provided by Mike Matylewich of CRITFC (modified slightly to conform to the harvest schedule structure used by BSM)

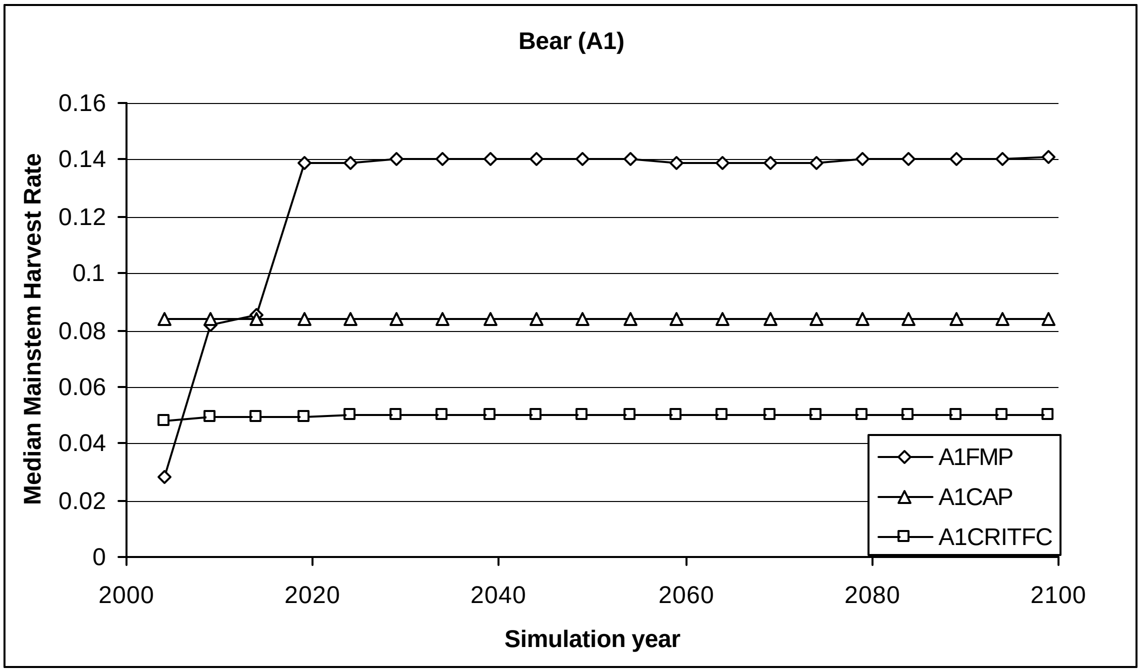
Table G-1. Alternative harvest schedules.

FMP			CAP			CRITFC		
Run Size % of MSP	Mainstem	Tributary	Run Size % of MSP	Mainstem	Tributary	Run Size % of MSP	Mainstem	Tributary
< 22	0.03	0	< 22	0.082	0	<100	0.05	0
22-44	0.082	0	22-44	0.082	0	101-200	0.07	0
45-112	0.14	0	45-112	0.082	0	201-300	0.09	0
113-125	0.25	0.05	113-125	0.082	0	301-400	0.1	0
126-175	0.3	0.15	126-175	0.082	0	401-500	0.11	0
176-200	0.35	0.2	176-200	0.082	0	501-600	0.12	0
>200	0.4	0.25	>200	0.082	0	>600	0.13	0

We looked at these three schedules in conjunction with hydro actions A1 and A3 to assess their effects over a range of low (A1) and high (A3) return sizes. To keep things simple, we limited the analysis to only using FLUSH passage model inputs and assuming 0.8 hatchery spawning effectiveness. The results shown below are for Bear Valley as a representative spring chinook stock (all spring chinook stocks showed similar patterns), and assume the hybrid extra mortality hypothesis.

G.2 Results

Both the CRITFC and the capped harvest schedules are more restrictive than the FMP schedule, particularly at higher return levels (Figure G-1). The CRITFC harvest schedule generally produces median (over the 4000 simulations) harvest rates that are lower than the capped rates at low return sizes as in A1, but the harvest rates of the stepped CRITFC schedule eventually approach and exceed the constant rates of the capped schedule as return sizes increase as in A3.



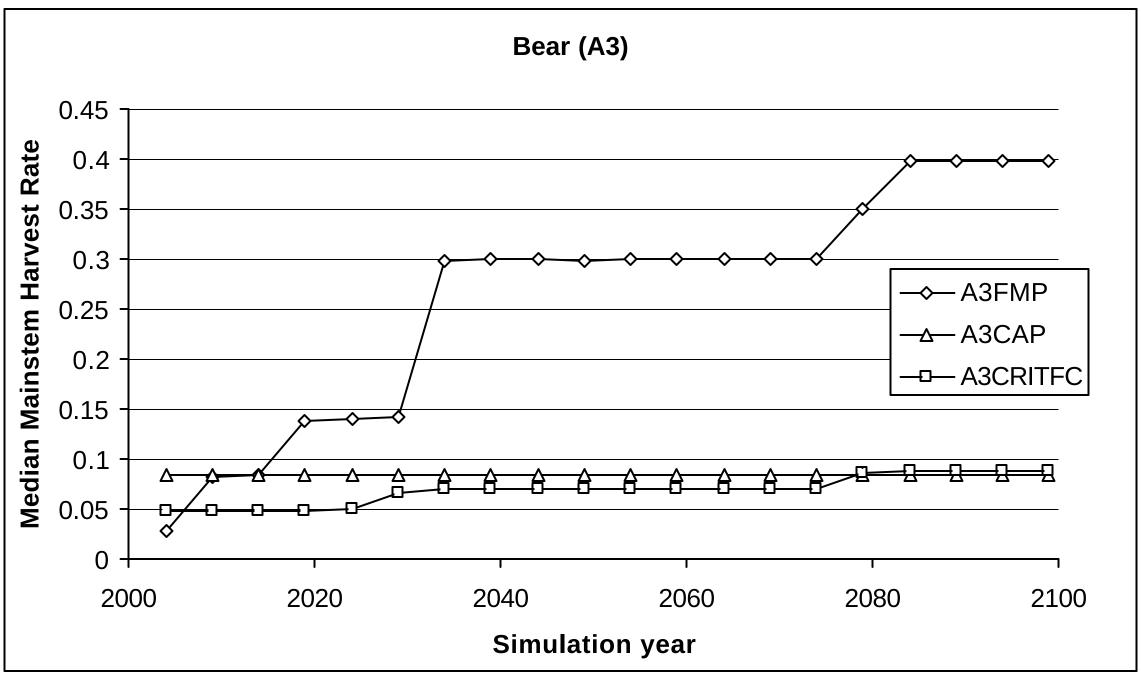


Figure G-1. Projected median harvest rates for three alternative harvest schedules for Bear Valley spring chinook stock and hydro actions A1 and A3. Values shown are medians over the 4000 Monte Carlo simulations in BSM. For these results, we assumed the FLUSH passage model inputs, 0.8 hatchery spawning effectiveness, and the hybrid extra mortality hypothesis.

The projected harvest rates shown in Figure G-1 are reflected in projected median mainstem catches (Figure G-2). The CRITFC harvest schedule produces lower median catches of fish than the capped schedule at low returns (A1), but equal catches at high return sizes. The catches using both the capped and the CRITFC schedules are considerably lower than those obtained when the FMP schedule is used.

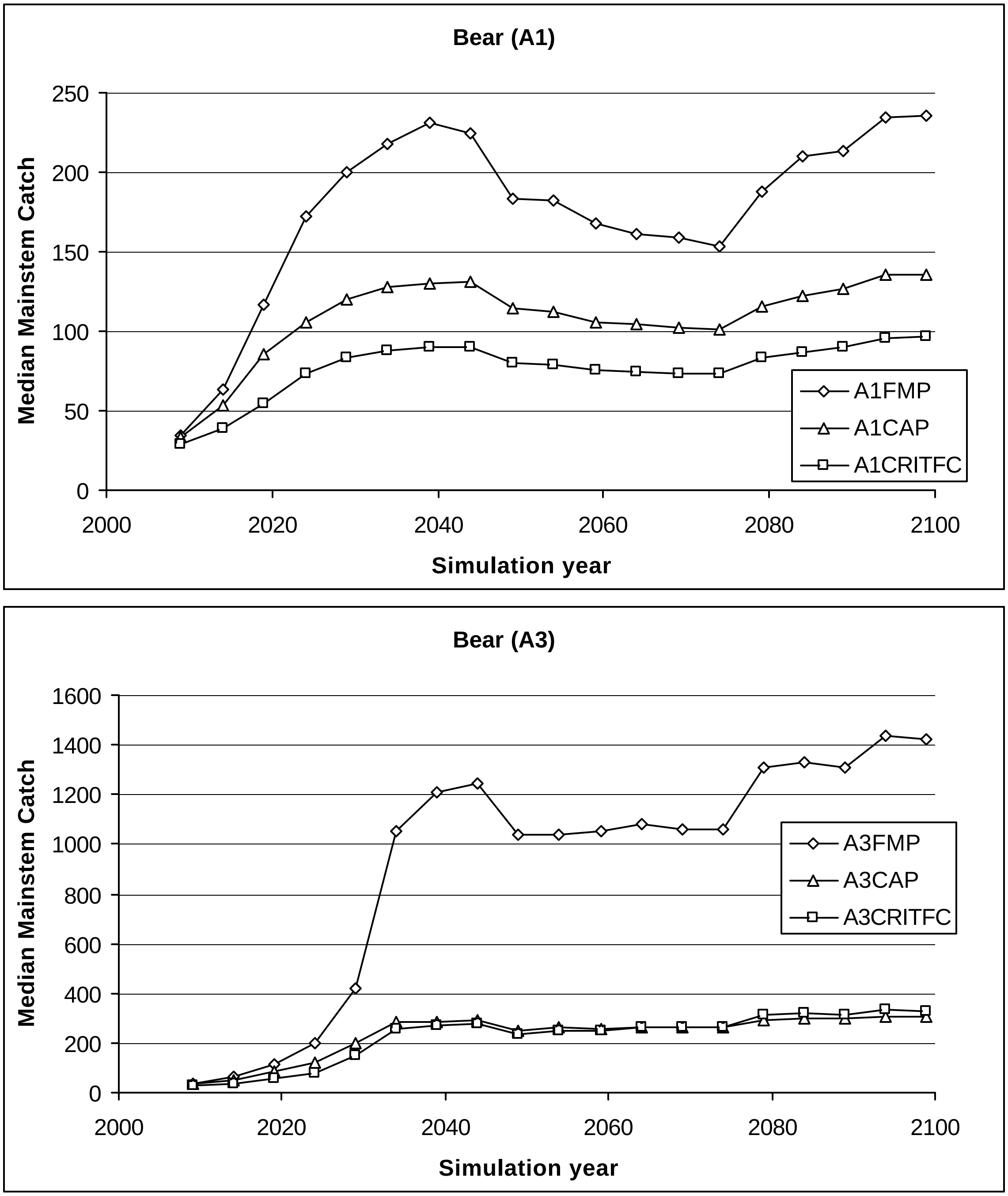


Figure G-2. Projected median catches for three alternative harvest schedules for Bear Valley spring chinook stock and hydro actions A1 and A3. Values shown are medians over the 4000 Monte Carlo simulations in BSM. For these results, we assumed the FLUSH passage model inputs, 0.8 hatchery spawning effectiveness, and the hybrid extra mortality hypothesis.

Ultimately, the reduced harvest rates associated with the capped and CRITFC harvest schedules result in higher numbers of projected spawners (geometric mean over the 4000 simulations) than the FMP schedule (Figure G-3). At low return sizes, projected spawners with the CRITFC schedule are higher than when the capped schedule is used, but about equal at higher return sizes. The same pattern is seen in the 48-year recovery probabilities for the spring chinook stocks (Table G-2) – the CRITFC schedule produce slightly higher probabilities than the capped schedule for A1, but similar probabilities for A3.

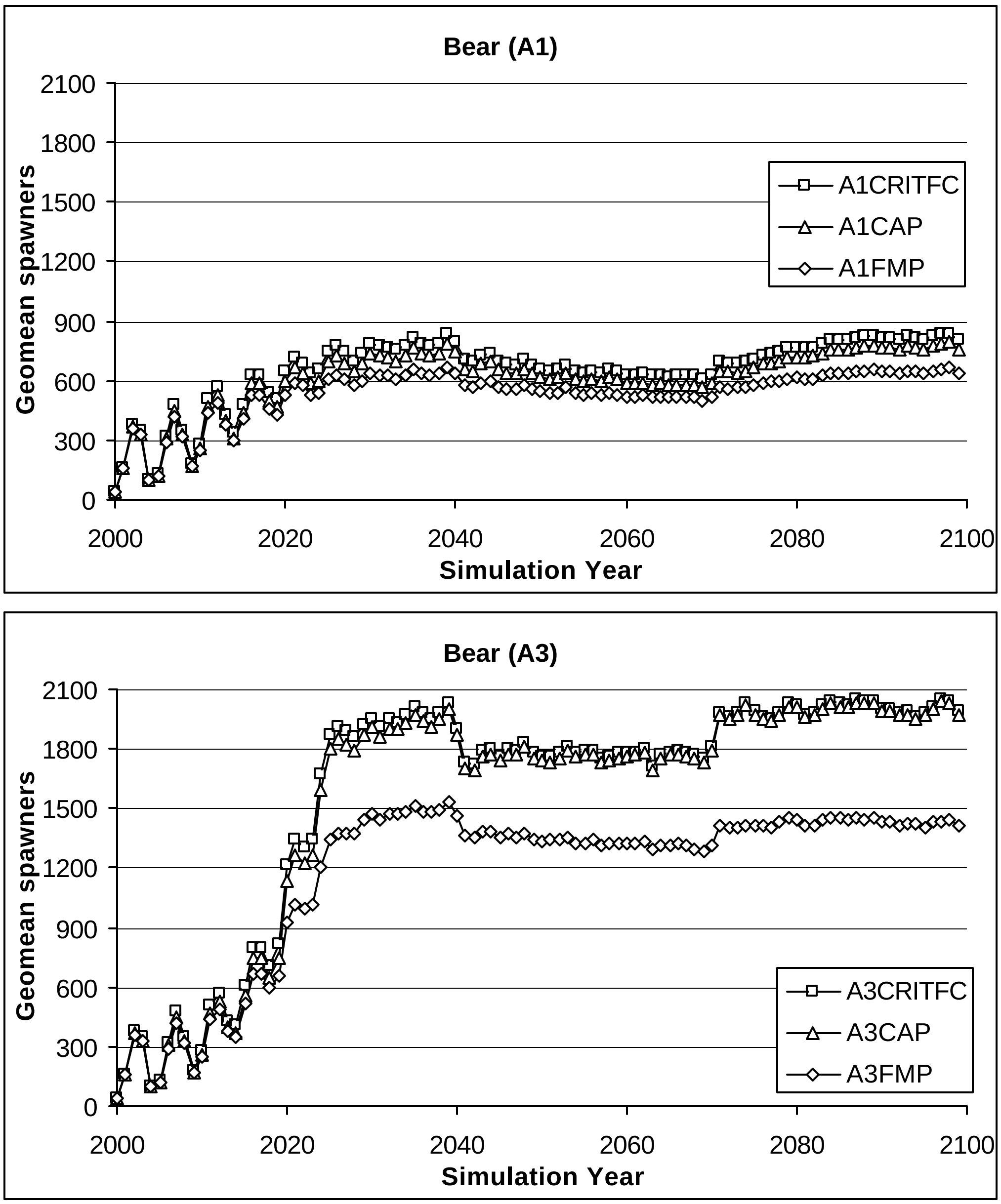


Figure G-3. Projected geometric mean spawners for three alternative harvest schedules for Bear Valley spring chinook stock and hydro actions A1 and A3. Values shown are geometric means over the 4000 Monte Carlo simulations in BSM. For these results, we assumed the FLUSH passage model inputs, 0.8 hatchery spawning effectiveness, and the hybrid extra mortality hypothesis.

Table G-2. Probabilities of exceeding recovery spawning thresholds (over 48 years) for the seven Snake River index stocks using the three alternative harvest schedules. For these results, we assumed the FLUSH passage model inputs, 0.8 hatchery spawning effectiveness, and the hybrid extra mortality hypothesis.

	A1FMP	A1CRITFC	A1CAP
Imnaha (Mixed)	0.28	0.32	0.31
Minam (Spring)	0.24	0.33	0.31
Bear (Spring)	0.24	0.39	0.35
Marsh (Spring)	0.16	0.35	0.31
Sulphur (Spring)	0.16	0.25	0.23
Poverty (Summer)	0.21	0.20	0.20
Johnson (Summer)	0.32	0.31	0.31
	A3FMP	A3CRITFC	A3CAP
Imnaha (Mixed)	0.88	0.88	0.88
Minam (Spring)	0.77	0.85	0.84
Bear (Spring)	0.86	0.91	0.90
Marsh (Spring)	0.78	0.92	0.90
Sulphur (Spring)	0.62	0.74	0.74
Poverty (Summer)	0.86	0.83	0.83
Johnson (Summer)	0.89	0.86	0.86

G.3 Conclusions

Although harvest rate reductions on their own are insufficient for achieving recovery goals, reducing harvest rates when stocks are at critically low levels has a small but positive effect on stock abundance.
The CRITFC harvest schedule produces the lowest harvest rates for Snake River spring chinook at the lower range of spawner abundances, and of the three harvest schedules assessed appears to offer the best opportunity for improving escapements of these stocks.

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MEMORANDUM

To *John Stein, PhD*
Salmon Science Coordinator
Northwest Fisheries Science Center

From Michele DeHart

Date January 30, 2004

Subject Comments on NMFS white paper entitled "Passage of Juvenile and Adult Salmonids at Columbia and Snake River Dams"

Thank you for the opportunity to comment on the White Paper entitled "Passage of Juvenile and Adult Salmonids at Columbia and Snake River Dams" NOAA Technical Memorandum December 2003. We are submitting these comments on January 30, 2004 to meet the February 1, 2004 comment deadline date established in the December 22, 2003 NOAA correspondence to the state and tribal co-managers from Usha Varanasi. The Fish Passage Center, as technical staff for the state and tribal co-managers was requested to review this manuscript and provide comments. We hope these comments will be useful in finalizing the document. Our review might have been more extensive had NOAA provided additional review time.

The purpose of the white paper, as stated in the introduction "This report summarizes the information pertinent to the FCRPS as it is currently configured for each route of passage and life history, and discusses uncertainties associated with the existing database." Overall, we found serious deficiencies in the document, which raise serious questions regarding its adequacy as a basis for development of a Biological Opinion on the operation of the FCRPS. In addition we were discouraged to find that NOAA fisheries ignored several specific technical memorandums that were previously provided to NOAA fisheries regarding specific project passage issues. Specifically:

- It is lacking in breadth of data reviewed, thoroughness of review and consistency and often lacks meaningful syntheses of those data reviewed.
- The list of key uncertainties is incomplete and seems in some ways unrelated to the reviewed data. Also, it is unclear how they were chosen, and whether NOAA

is suggesting that these areas are hopelessly too difficult to study, such as performance measures for individual stocks within the hydro-system.

- We could find only five conclusions identified, as such, in the document. These conclusions are related to turbine passage issues. There are no concluding sections on Spill Passage, Mechanical Bypass, Surface Bypass, Adult Passage.
- Several sections fail to synthesize the available information in any concise way.
- The document is poorly organized and inconsistent in approach. Section by section the format of the review is quite different, with some sections reviewed much more thoroughly, such as "Adult Passage", while others lack meaningful syntheses, such as "Spill Passage" and others contain outdated discussion such as "Surface Bypass".
- The spill and bypass sections have no conclusions, while the turbine section has several bulleted conclusions. In the "Spillway Passage" section very little summary data is available, little mention of how the data are to be used or have been used in previous biological opinions is evident.
- Tables appear to show data from many different studies without indicating the relative merit of the data from different studies. Not all studies could have equal merit. It is impossible to tell whether NOAA technical staff have considered the quality of studies reviewed. Other review such as Coutant and Whitney 2000 (cited in the white paper) discussed the relative merits of data used. NOAA inconsistently indicates poor study designs, good studies, or whether data could be useful and in what capacity.

We suggest that a thorough rewrite of this document might include a more careful and thorough synthesis of data (including updating many sections with current research results), identify appropriate use of data listed in tables, provide solid conclusions that show how NOAA intends to use these data in their Biological Opinion and address specific concerns outlined below.

Specific comments follow and are organized by section and headings within those sections.

Comments on spill section "**JUVENILE PASSAGE THROUGH SPILLWAYS**".

This section is poorly written and consequently hard to follow. NOAA does not consistently identify those research results that stand out as being most reliable, repeatable and useful. Consequently it is impossible to tell what NOAA intends to do with this data. NOAA should indicate which studies are of high quality, showing which are most applicable and rigorous. For example, problems were identified with hose release studies at Ice Harbor Dam. Fish were shown not to be passing at the depth of hose releases, which could seriously bias results let alone interpretation of those results. Yet NOAA treats these data in context of the larger issues of depth of deflector submergence and overall spillway survival just as any other study results. Further, freeze brand studies are listed in same table and presumably given equal weight in terms of applicability and rigor as PIT survival studies. Studies from more recent years should be added.

"**Spill Efficiency and Effectiveness**"

A standardized notation for efficiency and effectiveness should be developed. The fifth paragraph of the section defines the parameters for equation 1 from a PATH analysis as:

"P_f is the proportion of fish passing over the spillway (spill effectiveness)
P_w is the proportion of total river flow passing over the spillway
Spill efficiency is defined as $P_f \div P_w$ ".

The final paragraph of the section states the opposite :
"…(note: definitions for spill efficiency and effectiveness have changed recently where efficiency = P_f and effectiveness = P_f / P_w)…" and then uses this new definition for discussing the final paragraph. This is truly confusing.

NOAA makes no conclusions about the data presented. There appear to be gaps in information such as information at McNary Dam. Changes in configuration and operations at Lower Granite Dam should be included. Such as information on the RSW and it's effects on FPE and survival. There is no clarifying statements regarding the relative importance of spill efficiency and effectiveness in meeting performance standards such as 80% FPE or survival standards.

NOAA should demonstrate how well the equations presented in this section match the radio-telemetry data. Also provide correlation coefficients. NOAA should clarify whether they are recommending their use or not.

Regarding spill efficiency at 3 lower Snake projects NOAA states; "Spill efficiency at Lower Granite, Little Goose, and Lower Monumental Dams can be estimated based on radiotelemetry observations for yearling chinook salmon at Lower Granite Dam (Wilson et al. 1991), because of the similarity of the three projects."
The above quote does not make sense. While those projects were similar in 1991, Lower Granite is not like Little Goose and Lower Monumental dams due to the presence of the RSW, BGS, and SBC at Granite.

The review mentions sensitivity analyses using estimates of efficiency of 1.0 to 2.0, however NOAA is unclear regarding their determination of the appropriateness of that standard. NOAA does not identify whether or not that criterion is utilized by NOAA in the conducting its own sensitivity analysis.

NOAA reviews radio-telemetry studies, as well as hydroacoustic studies in detail with some reservations about mixed species. The section is so disorganized that reviewing it is difficult. For example, discussion of hydroacoustic study results occurs in paragraph 2 on page 8, while further discussion of "sampling assumptions and error" occurs two paragraphs lower in a paragraph that begins discussing (presumably) steelhead spill effectiveness from radio-telemetry studies.

"Seasonal Spill Timing"

This is an important section and is fully covered in two paragraphs. NOAA should provide information, to the best of their knowledge on the migration patterns of various listed stocks of fish. And compare run timing to planning dates. This may warrant status as a key uncertainty if little or no data is available. One potential way to improve knowledge of the timing of wild stocks would be to improve marking (such as adipose clips or coded wire tagging) of hatchery stocks, whether listed or not to be able to discern Snake River wild steelhead, yearling chinook or subyearing chinook timing from hatchery fish. Further efforts in PIT-tag marking wild fish would also be necessary to improve timing information on wild specific wild stocks. NOAA should provide some discussion of the reasons why timing data is not used as a substitute for planning dates such as the calculated 95% passage date that had been proposed by some.

"**Daily Spill Timing**"

NOAA seem to be concluding that 24 hour spill is better than night-time only spill because it decreases delay. This is based on a discussion of data from studies at 3 sites in the Lower Columbia. Other data are available to support this conclusion. NOAA should clarify their recommendations by providing a summary of conclusions in a separate section. A discussion of the trade-offs are involved in 24h v 12h spill such as impacts on spill effectiveness, adult delay, gas production.

"**Forebay Predation**"

NOAA should further elaborate on forebay populations of predatory fish. If there are substantial numbers of predators, provide some evidence of the impacts of predation on the population of juvenile migrant salmonids. Contrast this with impacts of avian predation. Perhaps there is enough uncertainty to include this as key uncertainty also.

"**Tailrace Passage**"

Again, there is little data on this issue, despite some hypotheses that have been proposed as mechanisms for improving egress, this issue is largely not determined. A more rigorous approach, that carefully identifies hypotheses related to tailrace egress, weighs evidence to support the hypotheses and then concludes what the evidence suggests or identifies data needs should be done. Data gaps could be included as a key uncertainty.

"**Spill Survival**"

In this section a large number of study results are presented, but NOAA provides no interpretation of qualitative or quantitative differences either between tag types (such as the difference between freeze brand estimates and PIT-tag survival estimates). Which method best estimates survival through the spillway. Confidence intervals associated with the estimates in table 2 should be provided.

Comments on Section entitled "**JUVENILE PASSAGE THROUGH MECHANICAL SCREEN BYPASS SYSTEMS"**

Comments on Section entitled "**JUVENILE PASSAGE THROUGH SURFACE BYPASS SYSTEMS AND SLUICEWAYS"**

Parts of this section need updating. There are whole paragraphs that seem to be out of date. For example paragraph 4 on page 81 beginning "Tests in 2000 will…" does not reflect an entirely different approach at Bonneville 1.

Also out of date is the section on Bonneville Second Powerhouse Sluice Chute on page 82 **–** This is in need of updating since the Corner Collector has been installed and is being operated in 2004.

Paragraph on page 85 beginning "Lower Granite spillbay…" needs to be updated. The RSW has been installed, operated and tested.

The section beginning in 2nd Paragraph on page 86 beginning "Lower Granite Dam behavioral…" needs to be updated. It is outdated.

Comments on Section entitled "**JUVENILE PASSAGE THROUGH TURBINES"**

Comments on NOAA conclusions regarding turbine passage on page 98

Bullet number 2 states "(comparing)…direct (balloon) estimates to direct and indirect estimates (PIT and radiotelemetry)…, a significant component of …(mortality)…is related to passage through the tailrace."

We strongly disagree with NOAAs reliance on the use of balloon tag estimates for this type of estimation comparison and interpretation. Balloon tags may be useful for identifying relative problems in passage via a specific route, but comparisons to PIT-tag and radio-telemetry estimates is stretching the application of this method beyond its due. We have several concerns regarding the balloon tag methodology that we believe raise serious concern about that methodology (see attached Joint Technical Staff Memorandum). We have attached specific comments regarding the use of balloon tags, (appendix A). that lists several sources of bias within the methodology that we believe bring the methodology in to question. Any use of balloon tags, especially for turbine survival should only be done once uncertainty about the method can be shown to be unlikely to cause bias in results. Furthermore, we question the validity of previous studies especially those summarized by Skalski et al 2002 for questioning the relationship between turbine peak efficiency and peak survival. These concerns regarding the application of balloon tags have been discussed in regional forum meetings such as the System Configuration Team. We are discouraged that NOAA did not address or include any of these concerns of the co-managers in this "white paper".

Concluding bullet number 3 states "A statistical relationship between fish survival and Kaplan turbine efficiency for Snake and Columbia River dams does not exist." This statement is misleading. It suggests that operation outside the peak 1% would not result in decreased survival, but that is not likely the case, and would require careful testing (as is suggested in bullet 5) to justify operation outside 1%. But this statement seems to be based largely on a discussion earlier in the text of the Skalski et al 2002 review that NOAA termed "…the most rigorous review to date of the relationship between salmon survival and turbine operating efficiency." The use of the Skalski et al paper as primary source is troubling since fisheries agencies review found many serious flaws. However, even in the concluding section of that review, Skalski et al stated that the zone of peak operating efficiency was wide and that it "will probably also encompass the maximum turbine passage survival". They went on to say that peak ±1% "…in the broadest sense, is a useful guide for managing turbine operating conditions for the benefit of smolt survival". In fact Skalski et al (2002) provides a basis for maintaining the 1% turbine efficiency. NOAA fisheries was advised of the agencies and tribes technical position and review in a letter dated May 29, 2003 from the joint agencies and tribes technical staffs. That letter is attached. Another review by Coutant and Whitney 2000 (cited by NOAA in this report) summarized the turbine studies they reviewed by stating "Fish survival appeared to follow roughly the efficiency curve of Kaplan turbines, with the highest survival occurring at about the highest efficiency…". Given recent efforts by BPA to operate turbines outside the ±1% of peak efficiency, NOAA should provide a stronger defense of the peak 1% range of operation which is most protective of endangered fish and should require rigorously designed studies that provide a scientifically defensible justification for operating outside this zone. This bullet should include language that qualifies the "statistical relationship" statement recognizing that operations within 1% of peak are likely to provide the highest turbine survival.

Comments on Section entitled " **KEY UNCERTAINTIES RELATED TO JUVENILE PASSAGE"**

Performance measures on a stock specific basis could be more easily accomplished in the hydro-system if NOAA required a more thorough marking program designed to identify hatchery fish distinctly from wild. For example, Snake River wild steelhead could be identified at population trends measured at SMP sites if all hatchery fish were marked in unique ways. This could tell us whether passage timing of run-at-large steelhead is similar to overall run and whether planning dates truly encompass that run. Similar information could be obtained for wild yearling chinook with a comprehensive hatchery marking program.

There is uncertainty as to the level of selective pressures caused by hydrosystem passage, but NOAA could make some hypotheses to encompass the uncertainty, similar to the approach taken in developing the Surface Bypass Premises that lead to Design Criteria on pages 77 and 78. For example the hydro-system likely alters estuary entry timing, due to passage delays. The hydrosystem also alters the riverine environment in several ways such as decreased velocity, increased temperature, and changes in ecosystem species composition all likely to lead to changes selective pressures on juvenile fish. Transportation also is likely to lead to changes in selective pressures on juvenile fish. Other factors that could alter selective pressures could include altered hydrograph, and emphasis upon protection of middle of the run. By operating juvenile bypass systems and providing spill for fish passage from April to August, alternative life-history strategies such as winter migration, are selected against. A more thorough treatment of this key uncertainty may lead to a better understanding of the long-term effects of the hydrosystem by providing hypotheses to test, which may in turn lead to changes in fall and winter operations, for example to benefit diverse life-history strategies.

NOAA should explain why lamprey passage is a key uncertainty for juvenile salmonid passage.

Appendix A

Potential Sources of Bias in Turbine Survival Estimates Using Balloon Tags via Hose Release

The use of balloon tags to determine survival has become fairly common and while several fisheries agencies have objected to their use in survival studies (see attached memo) their use persists as do reviews, which cite balloon tag results for determining relationships between survival and turbine operating efficiency (Skalski et al 2002, Ferguson et al 2003). Balloon-tag studies have been criticized because they do not take into account any indirect effects of turbine passage because the tags inflate and fish are removed from the system shortly after turbine passage so that any effects that may increase predation vulnerability, disease intolerance or other longer term effects are not measured. However, there are likely unmeasured effects of the methodology that affect even the estimation of direct mortality. We term those potentially biasing effects critical uncertainties.

These critical uncertainties should be addressed prior to further use of balloon tags in estimating survival through turbines. It is important that the methodology used to measure turbine survival is representative of conditions actively migrating fish would experience when passing the turbine.

The basic methodology of Balloon Tag studies is well known in the Columbia Basin, since the tag has been used extensively in estimating survival via various routes (Heisey et al 1992). Fish are tagged with the balloon tag and released via hoses into turbines or other passage routes to be evaluated. Our critical uncertainties are related mainly to the evaluation of turbine survival but some aspects may apply, more generally to other types of evaluations as well.

Critical Uncertainties of Balloon Tag Methodology for Estimating Turbine Survival

The Critical Uncertainties are those potential sources of bias in estimation of turbine survival in comparison to the survival of untagged active migrant fish.

Release Location acclimation pressure – Balloon Tagged fish are released from a holding tank at surface and delivered to turbine depth via a hose or pipe. Generally fish are held near atmospheric pressure (1.01 kPa) in shallow water prior to release. This pressure is likely quite different than the pressures to which actively migrating fish would be acclimated, that are destined for turbine passage. Generally, for active migrants, those nearest the surface would encounter the screens and diverted away from the turbines, while those fish deepest in the water, would be entrained in the turbines. Those deep water migrants would be acclimated to hydrostatic pressures in the range of 2 to 3 kPa. Cada et al 1997 cite studies (Harvey 1963, Turnpenny et al 1992, and Muir 1959) in which mortality of salmonids exposed to pressure changes was reported. Cada et al concluded that change from acclimation pressure to exposure pressure (in our case from acclimation to sub-atmospheric pressures in turbine passage) was directly related to mortality rate. In other words, fish acclimated at greater depth (high pressure of 2 to 3 kPa) experienced much higher mortality than those fish acclimated at surface (lower pressures 1 kPa) after both groups were exposed to sub-atmospheric pressures in simulated or direct turbine passage. The use of surface acclimated fish in turbine survival studies probably reduces both direct and indirect affects of turbine mortality due to the smaller change in pressure experienced by experimental fish compared to that of active migrants.

Release location fish orientation to turbine intake —Experimentally released fish that were acclimated to surface pressure would likely swim toward the surface to compensate for pressure difference if given the opportunity and assuming they had the ability to do so. For example, in the balloon tag study conducted at McNary Dam in 2002 (Normandeau et al 2003), fish were released directly below and behind vertical barrier screens in front of turbine intakes some 50 feet or more in front of the stay vanes of the turbines. These fish would likely have attempted to swim upward as they were swept toward the turbines. This would result in net distribution toward the upper portion of the water column in relation to the stay vane (if one assumes the balloon tagged fish can swim). If fish are distributed higher in the water column they would be more likely to pass near the hub of the turbine and these fish have been shown by other tests (Skalski et al 2002) to experience higher survival than those passing mid depth (mid-blade) or deep (blade tip release).

Release location fish orientation to turbine blades – It is unlikely however, that balloon tagged fish can swim with anything approaching normal ability. This has to do with both tagging procedures and release location as well as the center of buoyancy of the fish. In general fish center of buoyancy is below their center of gravity (Cada et al 1997) resulting in fish needing to continually maintain their dorso-ventral orientation in the water. If fish are stunned (as in electrofishing induced tetany), they immediately lose buoyancy control and flip over ventral surface up. The relatively large size of the balloon tag likely accentuates this dorso-ventral imbalance. The deflated balloons would also change the hydro-dynamic profile of the fish, not only increasing drag, but increasing it mainly on the dorsal portion of the fish. This combination of changes probably results in a fish that swims very poorly, that may also struggle to maintain proper dorso-ventral orientation in the water.

Given their delivery through a hose, and their likely difficulty in maintaining orientation, it is likely that balloon tagged fish enter the turbine, and encounter the turbine blades at random orientations. While, it is unknown what the environment within the turbine does to the orientation of actively migrating fish, it is probable that those fish encountering the entraining flows of the turbine intakes, would orient head upstream, or in some cases head downstream (depending on species and smoltification). But in either case body orientation would be parallel to flow net. If these fish maintain this orientation into the turbine it would result in maximum surface area perpendicular to the path of the turbine blade and a higher likelihood of turbine blade strike, than for fish that were randomly oriented in the water (i.e. balloon tag test fish). Fish randomly oriented in the water column would, on average have a smaller profile perpendicular to the turbine blade path, which reduces the likelihood of turbine strike.

Balloon tag effects on drag and inertia—The deflated balloon tags would substantially increase drag in the experimental fish compared to an untagged fish. This would alter the inertia of the fish as related to an untagged fish of the same size, and decrease the likelihood of turbine blade strike. Turbine blades have a pressure wave in front of them as they spine through the water. Small fish, such as fry, having small mass and volume, would likely be pushed away from the blade by this pressure wave, while large fish, such as adult salmon, have much higher inertia based on their mass and would not be moved nearly as much by such a pressure wave and would have a much greater likelihood of being struck by a turbine blade as result (assuming other factors such as orientation, rate of movement etc were equal and also realizing that other factors affect the likelihood of a larger fish being struck by a turbine blade such as total size). However, a balloon tagged fish, of the same size as untagged fish, as a result of its increased drag, would be more likely to be swept around a turbine blade by the preceding pressure wave, than would an untagged fish of the same size. The large external tag decreases the inertia of the tagged fish compared to an untagged fish decreasing the likelihood of turbine strike.

Balloon Tag effects on Draft Tube Passage – In addition to changes in turbine strike probability, the effects of the balloon tag on swim ability may affect fish response to turbulence in the draft tube after passing the turbine. Cada et al 1997 stated that “a turbine imparts a … rotational component” (to the draft tube), and that “fish may sense this whirl as a natural vortex and orient to it in ways that move them rapidly toward the periphery.” In other words actively swimming fish may collide with the draft tube wall attempting to avoid turbulence in the draft tube. This type of behavior would likely increase injuries to these fish, while balloon tagged fish would not be able to orient in similar fashion and would not show a similar effect when passing through the draft tube.

These critical uncertainties may not, individually, greatly change the probability of injury and mortality of tagged versus untagged fish, but in combination, may cause significant bias in the direct survival estimate. it is important that serious consideration be given to these .

REFERENCES

Cada, G., C. Coutant, and R.R. Whitney. 1997. Development of biological criteria for the design of advanced hydropower turbines. Report to the US Department of Energy Advanced Hydropower Turbine System Program. Idaho Falls, ID: 1997.

Ferguson, J., R.L. McComas, R.F. Absolon, D.A. Brege, M.H. Gessel, L.G. Gilbreath, B.H. Monk, and G.M. Matthews. 2003. Passage of Juvenile and Adult Salmonids at Columbia and Snake River Dams.

Heisey, P.G, D. Mathur, and T. Rineer. 1992. A reliable tag-recapture technique for estimating turbine passage survival; application to young-of-the-year American shad (*Alosa sapidssima*). Can. Jour. Fish. Aquat. Sci. 49:1826-1834.

Normandeau Associates, Inc, J.R. Skalski, Mid Columbia Consulting, Inc. 2003. Survival/Condition of Chinook Salmon smolts under different turbine operations at McNary Dam, Columbia River. 2003. Report to U.S. Army Corps of Engineers. Contract DACW68-02-D-0002, 45 p. (Available from U.S. Army Corps of Engineers, Walla Walla, WA.)

Skalski, J.R., D. Mathur, and P.G. Heisey. 2002. Effects of Turbine Operating Efficiency on Smolt Passage Survival. N. Am. J. Fish. Manage. 22:1193-2000.

State, Federal and Tribal Fishery Agencies Joint Technical Staff

US Fish and Wildlife Service

Columbia River Inter-Tribal Fish Commission

Idaho Department of Fish and Game

Oregon Department of Fish and Wildlife

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May 29, 2003

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Dear Mr. Brown, Ms. Kalamaz, Ms. Fodrea and Mr. Peters:

The Bonneville Power Administration has developed and distributed a proposal to the Corps of Engineers Study Review Work Group (SWRG) to discontinue the 1% peak turbine efficiency turbine operating limits included in the NMFS Biological Opinion. We understand and support the ongoing process of evaluating hydrosystem operations and how they relate to fish survival. However, we find that the available evidence strongly suggests that operations outside the 1% of peak efficiency would be detrimental to fish. Therefore we cannot support the draft proposal submitted by BPA to discontinue operations within the 1% of peak efficiency in all mainstem federal projects. We support the implementation of the Biological Opinion (BiOp) measures requiring that turbines operate within 1% of their efficiency range.

State and tribal co-managers have reviewed the proposal and have summarized their comments and concerns below which are presented in detail in the following discussion. In addition we have attached our comments on a specific study proposal presented to the SRWG to study the 1% turbine efficiency operating criteria at McNary Dam in 2003.

- The Our review of historic and recent data only finds evidence that supports maintaining the 1% peak efficiency limits included in the NOAA Biological Opinion.
- BPA proposal shifts the burden of proof of risks to the fishery resource in favor of apparently more certain economic benefits for the hydropower system.
- The BPA proposal abandons the precautionary approach to hypothesis testing which is warranted in an endangered species context.
- The BPA proposal reflects a management priority, which is inconsistent with the fishery management priorities of the state, tribal and federal fishery managers submitting these comments. The BPA proposal to expend effort and limited funds to test fish survival relative to turbine efficiency ranges above levels that are safer for fish is establishing a federal operator priority for increasing hydropower revenue rather than fish protection. A priority established for fish protection would direct expenditures at keeping fish out of turbines and providing alternative passage routes rather than increasing passage of fish in turbines and operating turbines at levels that reduce fish survival. Expenditure of fish mitigation funds for this study is unacceptable to the natural resource managers.
- The BPA proposal does not address the deterioration of conditions in the gatewells and on the vertical barrier screens that will result from higher turbine flows. Gatewell and vertical barrier screen and orifice conditions will deteriorate and result in significantly increased fish injury, stress and mortality.

Our review of historic and recent data only finds evidence that supports maintaining the 1% peak efficiency limits for turbines included in the NOAA Fisheries Biological Opinion.

The NOAA Fisheries 2000 Biological Opinion (BiOp) includes the requirement that turbine operations be limited to within 1% of peak efficiency based upon evidence (both empirical data and expert opinion) suggesting that smolt survival was higher within these limits compared to operations beyond them. In an effort to re-evaluate this BiOp requirement, Bonneville Power Administration (BPA) has submitted a draft proposal (dated May 19, 2003) to discontinue these turbine operating limits. However, in our review of this proposal, historic data, and recent data, we only find evidence that supports maintaining the 1% of peak efficiency limits, and therefore do not support the BPA proposal on turbine operations. Our basis for this conclusion is outlined below.

<u>Milo Bell Compendiums</u>
Bell et al. (1967) and Bell et al. (1981) provided the first basis for the 1% of peak efficiency limits. These reports present published and unpublished data on survival of small fish passing through Kaplan- and Francis-type turbines. The Bell Compendiums provide compelling evidence that fish survival is generally higher when turbines are operated within the 1% limits than when they are operated beyond these limits. In

addition, survival appears to decrease linearly as turbines are operated beyond peak efficiency.

These results make sense from a mechanistic perspective as well. Mechanistically, when turbines are operated beyond peak efficiency, flow fields in the turbines are disrupted, resulting in cavitation and damage to the metal surfaces in contact with the water. Clearly, this is an undesirable condition for fish, and therefore operations that create these conditions (i.e., operations beyond the 1% of peak efficiency limits) are expected to reduce survival. The data provided by the Bell Compendiums clearly support this expectation.

Eicher and Associates (1987)

In a comprehensive review of fish mortality through turbines, Eicher and Associates for EPRI (1987) reported the conclusions of a panel of experts that the maximum survival of fish coincides with the greatest turbine efficiency. Further they noted that turbine efficiency is determined by wicket gate openings and resulting flow qualities and design head in relationship to operation head, and that efficiency falls off after reaching a peak of 60-80% maximum flow into a unit. Eicher and Associates also note that the hydraulic character of the backroll of the turbine discharge into the tailrace is a function of overall flow into the turbine unit. They note as was described by NMFS in Bonneville Dam survival studies (Gilbreath et al. 1993) that the backroll carries fish into heavy predation zones. Eicher and Associates concluded by noting that diverting fish from turbines is probably the most cost-effective way of reducing fish mortality.

Skalski et al. (2002)

The data evaluated in Skalski et al. (2002) provide a second basis for maintaining the 1% efficiency limits. While their analysis was primarily focused on evaluating the academic question of whether peak survival coincides with peak efficiency, they do provide a useful summary of more recent data on the relevant operational question of maintaining the 1% of peak efficiency limits. Based on the data provided in Skalski et al. (2002, Table A.1), mean survival is reduced by 1.13% (for Columbia/Snake River projects) to 1.64% (for all projects) when Kaplan-type turbines are operated beyond the 1% of peak efficiency limits (Figures 1 and 2). In addition, survival decreases linearly as turbines are operated beyond peak efficiency for Columbia/Snake River projects (Figure 3).

Normandeau et al. (2003)

The presence of several study design flaws severely limits the utility of the 2002 McNary turbine survival study results summarized by Normandeau et al. (2003) for evaluating the BiOp turbine efficiency requirement. These flaws stem from both how the study was conducted and how the results can be interpreted given the greater context of fish passage at dams. We condense some of these issues into five main points, below.

First, operations beyond peak efficiency increase turbulence and flow within the gatewells, resulting in screen and orifice clogging, increased current velocities, and fish mortality along the intake and vertical barrier screens. During times of high debris loading, this problem is especially severe. Because fish were released within the gatewells in the 2002 McNary study, the survival estimates do not reflect this known problem. Furthermore, the estimates do not incorporate the changes in fish guidance efficiency that would occur with operations beyond the BiOp regulations.

Second, the sole use of large chinook salmon smolts prevents the application of study results to other species and size classes. As found in Skalski et al. (2002), turbine survival is significantly related to fish size, with smaller fish showing lower survival rates. Species that are more sensitive to turbine passage or are smaller than the large chinook smolts used in the 2002 McNary study will show reduced survival compared with results presented in Normandeau et al. (2003). Therefore using the 2002 McNary study results to overturn the BiOp turbine efficiency operating requirements, which in nature apply to all species and size classes, is inappropriate.

Third, spill operations and sample sizes were not consistent across the treatments in the 2002 McNary study. Treatments outside of the 1% limits (i.e., the 14 kcfs and 16.4 kcfs operations) had no spill during 6 of the 7 study days, whereas the treatments inside of the 1% limits had no spill for 4 of the 9 study days. This inconsistency in spill operations creates the question of whether the differences in survival estimates are the result of differences in turbine operations or of differences in spill. The number of fish released also differed among the treatments. Between 350 and 390 fish were released for 5 of the 6 treatments, but only 270 fish were released for the 14 kcfs treatment. The fact that this treatment also showed the highest survival is curious. Further, based on the results from previous studies, we expect survival to decline linearly as turbines are pushed beyond peak efficiency. Because the survival estimate at the 14 kcfs treatment is well above an interpolation between the 11.2 kcfs and 16.4 kcfs treatment estimates, this casts additional doubt upon the validity of the 14 kcfs survival estimate.

Fourth, we question the use of 48 h survival rates for evaluating delayed turbine mortality. Studies have shown that delayed mortality associated with turbine passage can be significant, and often is not manifested until several days following passage (Kostecki et al. 1987). Without holding the fish for longer periods, we cannot ensure that operations outside the BiOp limits will not jeopardize the long term survival of smolts. Further, forebay and tailrace mortality must be evaluated. Extended holding to assess delayed mortality presents other biases that make this approach difficult experimentally. These delayed and indirect effects may only be understood through studies that evaluate effects on smolt-to-adult survival rates.

Fifth, the efficiency levels chosen for the 2002 McNary study are not informative for comparing fish survival inside and outside of the 1% of peak efficiency operations. The 8 kcfs and 11.2 kcfs treatments lie at the boundary of the 1% limits and the other two treatments are beyond the limits. To evaluate whether operations outside the 1% limits do not negatively impact fish, data must be collected well inside of the 1% limits. Studies operating at the limits and beyond (e.g., the 2002 McNary study) do not provide information on the effects of turbine efficiency on survival because estimates are only collected at operations beyond the efficiency limits. Furthermore it is important to note the fact that Normandeau et al. (2003) report the planned discharges (8, 11.2, 14 and 16.4 kcfs) rather than the actual discharges (7.7, 12, 13.4, and 16.6 kcfs) throughout the document. This was misleading, as was the practice of claiming that the 11.2 kcfs treatment was near peak efficiency when in fact it was at the 1% boundary. We encourage proper and accurate documentation of study outcomes and request the authors of Normandeau et al. (2003) in the future refrain from reporting misleading and inaccurate treatment data and results.

Figure 2. Mean survival and 95% confidence intervals for Kaplan-type turbines operated inside and outside of the 1% of peak efficiency bounds for all projects [Data from Skalski et al. (2002, Table A.1)].

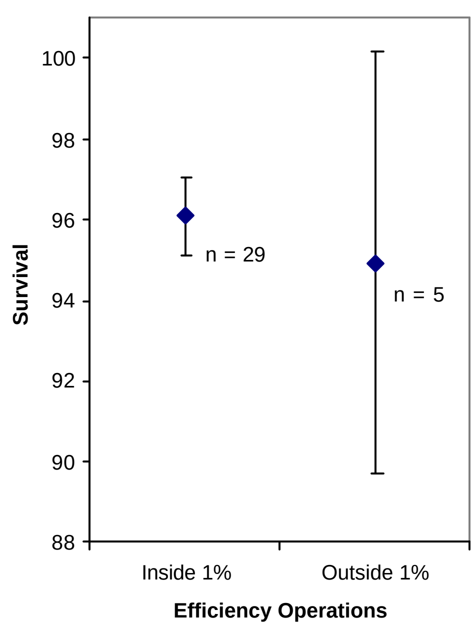
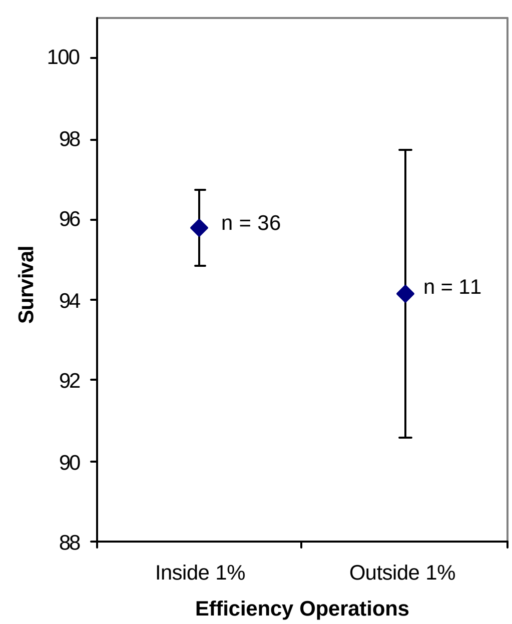


Figure 1. Mean survival and 95% confidence intervals for Kaplan-type turbines operated inside and outside of the 1% of peak efficiency bounds for Columbia/Snake River projects [Data from Skalski et al. (2002, Table A.1)].



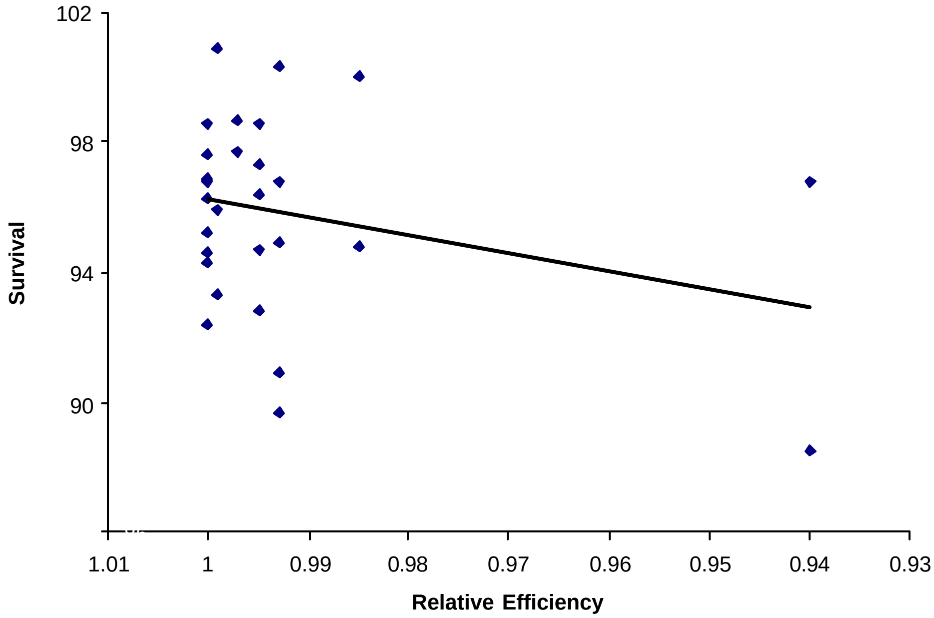


Figure 3. Relationship between survival and relative efficiency of Kaplan-type turbines for Columbia/Snake River projects [Data from Skalski et al. (2002, Table A.1)].

With respect to risks, the BPA proposal shifts the burden of proof to the fishery resource in favor of apparently more certain economic benefits for the hydropower system. The BPA proposal abandons the precautionary approach to hypothesis testing which is warranted in an endangered species context.

The BPA proposal is based upon BPA's decision to place the burden of proof for protection upon the ESA listed salmon, and other anadromous fish resources in favor of anticipated economic benefits to BPA.

The choice of a significance level determines the relative frequency of two kinds of mistakes, either rejecting the H_0 when it is correct making a Type I error, or failing to detect the truth of H_A when it is correct making a Type II error (Snedecor &Cochran, 1989) The failure rate β of not rejecting the null hypothesis when the alternative is "true" is termed the "Type II error" and the failure rate α of rejecting the null hypothesis when the null hypothesis is "true" is termed the "Type I error". In ecological studies, it is often desirable to balance these errors by applying the same failure rates to each type of error or even setting the failure rate such that $\beta < \alpha$.The proposal indicates that BPA is more willing to accept a Type II error than a Type I error. However, there are reasons why a more precautionary approach to hypothesis testing is warranted in endangered species contexts (Peterman 1990, Dayton 1998). Steidl and Thomas (2001) cite investigators who have suggested that Type II errors be considered paramount when monitoring endangered species; or at least that Type I and Type II errors be balanced based on their relative costs. In endangered species recovery activities, if a Type II error is committed, a population could be on its way to extinction before the decline is detected and preventative action is taken. Conversely, if the population is monitored after initiating recovery actions (such as implementing turbine efficiency limitations), and the population is actually increasing, a Type II error would lead to the mistaken inference that the actions are not having the desired effect, perhaps jeopardizing continuance of those actions. The limitations of empirical data and ability to determine small differences in survival should not result in placing listed stocks at additional risk. If the data and methods do not allow differentiation of small differences a precautionary approach to management of endangered species require adoption of the measures that provide conservation and protection of the species.

Proper consideration of the possible detrimental effects of failing to meet turbine efficiency requirements requires acknowledging the limitations inherent in the available empirical data on turbine efficiency and survival. It should be kept in mind, for instance, that it's difficult to accurately characterize exact turbine conditions experienced by individual release groups in the turbine survival studies. The most relevant question we can ask in light of these limitations of data is not whether we can tease out effects on highly variable survival estimates from small variations in turbine operations within a season. Many factors affecting turbine survival probability will always remain outside of management influence. A more relevant question is, over a longer time series, given a representative range of uncontrolled variation in factors affecting survival, are turbine operations within their efficiency ranges associated with higher survival rates?

The BPA proposal does not address the deterioration of conditions in the gatewells, on the vertical barrier screens, and in the tailrace which would result from higher turbine flows. Gatewell and vertical barrier screen conditions would deteriorate and result in fish injury, stress, and direct and delayed mortality.

During 1997 and 1998 studies were conducted (Brege et al. 1998, Brege et al. 2001) to evaluate the vertical barrier screens and outlet flow control devices at McNary Dam. In those studies turbines in the test units were operated at low load 60 MW and high load 80 and 75 MW. Those tests with spring migrants showed that there was significantly higher levels of descaling under high turbine load operations. Under high load conditions descaling averaged 17 % versus 6.7% at low loads.

Present studies indicate that delayed mortality is an important factor in return of adult transported salmon and steelhead. Smolt to adult return data (CSS status report 2001) indicates that smolt to adult return rates for bypassed smolts are lower than spill passage. The BPA proposal to operate turbines at higher loads, given the results of gatewell vertical barrier screen descaling data, will potentially exacerbate and add to delayed morality for transported smolts and reduced survival of bypassed smolts.

The current proposal outlines BPA's justification for operating turbines, specifically at McNary Dam, outside the current 1% efficiency guidelines. The 1% operation was implemented based upon previous research that showed a relationship between peak efficiency of the turbine and maximum survival. BPA has outlined their rationale for believing that this data may not be accurate. Regardless of the debate over operating ranges and juvenile survival through the turbines, operating the turbines outside of 1% percent to increase generation will divert more flow through the turbines. This will likely increase the number of juveniles using this route of passage. As flow through a route increases so does the number of juveniles that use the specific route. This has been shown through countless passage evaluations. Thus, more juveniles will pass via the turbines; only the percent increase is uncertain. Current estimates for passage through the turbines are 86% and 87% from the radio tagged fish evaluation in the 2002 survival study conducted at McNary dam to test the 11.2 and 16.4 kcfs flow rates through the turbines. The project goal is to attain project survival in the high to upper 90's, ideally a route specific survival would be 98%. By increasing the number of juveniles using the turbines, project survival is going in the wrong direction, making it more difficult to attain the goals set out in the 2000 BiOp.

While gatewell releases during the April 2002 evaluation showed no difference in fish condition or survival, the gatewells were clean and operating at an ideal condition. During this time of year, there is little debris and no temperature problems; hence, this evaluation did not test a worst-case situation. By increasing flow through the turbines, more flow will be directed up the gatewell. Peak debris loads normally occur during the spring freshets and during the late summer. As debris and grasses are guided up into the gatewells with the migrating fish, increased head differentials across the barrier screens become evident and normally fish quality/condition problems start to manifest itself at the project. Not only is this hard on the screen mesh and other associated equipment in the gatewells, but fish that are guided into the slots can be injured or worse yet killed as hot spots (increased velocities) along the screen mesh develop. In past years and at present, to best counteract this problem, the project biologists would advise the project to reduce turbine loading to minimum operating levels and where warranted the unit would be taken down and the barrier screens cleaned. Increasing megawatts at McNary for example would only exasperate a "known" condition that currently exists at the project and is counter to improved fish survival goals stated in the 2002 BiOp.

Furthermore, the 2002 spring evaluation measured a much reduced residence time for fish released into the gatewell at 16.4 kcfs. Reductions in gatewell residence have been noted in the past when gatewell conditions become more turbulent and more aggressive hydraulically, which make it more difficult for juveniles to avoid the orifices. Under these condtions the juveniles are more similar to buoyant particles than active swimmers. This situation can be very injurious to fish, even under medium debris loads. This would also likely lead to reduced survival for fish using the bypass system, which would again drive project survival in the opposite direction of the survival goals for McNary as outlined in the 2002 BiOp.

The BPA proposal states that the SIMPASS model showed no difference in project survival. Notably the evaluation is missing the summer component. The evaluation used in the proposal used spring conditions. However the current operation under region discussion will continue through the summer. Current operations at McNary involve daytime involuntary spill. By increasing turbine flow, more fish will be passed via the powerhouse and turbine units as daytime involuntary spill is reduced. Because of the limited powerhouse capacity at McNary, involuntary spill was included in the biological effects analysis during the ESA consultation in 2000. By reducing the involuntary spill, project survival will be decreased and once again the separation between current conditions and the survival targets in the BiOp will be increased.

Table 3 in the BPA proposal, on page 27 describes the SIMPASS assumptions, has questionable values for turbine survival. BPA used balloon tag survival estimates for turbine survival. Balloon tag survival is not an appropriate technique to get a route specific survival due to the interaction of the tag and test animal. Balloon tags only estimate direct survival at best, and do not look at indirect survival post passage. Balloon tags are commonly used to identify areas of concern for passage, not to estimate route specific survival. A radio tag survival study was conducted along with the balloon tag study in 2002. Estimates for survival between the two turbine levels where 86% versus 87% as opposed to the 95% and 93% survival used by BPA in the SIMPASS model. Furthermore, BPA did not model any changes in FGE or FPE as more flow was passed by the turbines, which is questionable when doing a sensitivity analysis for turbine and project survival.

We understand that Bonneville Power Administration's objective is to enhance hydropower production without reducing fish survival. However, the proposal eliminate the 1% turbine efficiency operating criteria included in the NOAA Biological Opinion does not accomplish that objective.

BPAs proposal for operations and study does not represent a prudent expenditure of funds or assignment of priorities from a fish protection standpoint or a Biological Opinion progress check in dates. The BPA proposal is counter to BPA's historical position that turbines should run at peak efficiency during fish migration season. The primary objective of the BPA proposal is to increase hydrosystem revenue.

However, running turbine units outside of 1% peak efficiency will cause cavitation and poor operational conditions that would require more frequent shutdowns of units to repair cavitation damage (Shelton and Loupin 1995). In Europe, turbine units are never operated outside peak efficiency criteria because the costs of shutdowns and repairs are prohibitive. Increased repair costs and unit shutdowns for repairs may actually reduce overall FCRPS hydro revenues, or simply shift anticipated revenue gains to BPA with repairs costs to the Corps.

Precautionary management as anticipated by ESA would place the highest priority on increasing fish survival at the projects which would place the highest priority for expenditure of funds on actions that would reduce injury through the bypass, reduce fish passage through the turbines and provide alternatives to turbine passage. Fish survival is lowest through turbines than any other passage route even within the most efficient turbine operating range, , the BPA proposal will increase the proportion of fish passing through the most lethal project route.

Study design

Studies conducted to date have not shown that survival is improved or unchanged under high load turbine operations. The precision of the balloon tag studies does not support a management decision to eliminate the turbine efficiency requirements of the NMFS Biological Opinion. Please refer to our specific comments (attached) on the BPA,COE proposal to study the 1% turbine efficiency criteria at McNary Dam in 2003.

Conclusions

- Historical and present data does not support the BPA proposal to eliminate turbine efficiency requirements of the BIOP.
- The BPA proposal inappropriately shifts the burden of proof to the fishery resource, placing a higher level of risk on listed and non-listed fish stocks.
- The BPA proposal if implemented is likely to exacerbate issues of delayed mortality on transported fish, and reduced survival of bypassed fish and turbine passed fish due to increased stress, injury and descaling in the gatewells and degraded tailrace conditions.
- Studies of survival relative to turbine operations are turbine operations are a low funding priority in comparison to funding alternatives to turbine passage.
- Funds intended for current fish mitigation programs should not be expended on these proposed studies.
- A proposal to increase fish passage through turbines is counter to the aggressive, non-breach all-H recovery plan that BPA to this point has supported.

Sincerely,

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Tom Lorz, CRITFC

Keith Kutchins, SBT

Shane Scott, WDFW

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