AFR

Mark Walker
Public Affairs
Northwest Power and Conservation Council
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Dear Mr. Walker:

The Fish and Wildlife Service offers the following comments on the Northwest Power and Conservation Council's (Council) Draft Mainstem Amendments to their Columbia River Basin Fish and Wildlife Program (2002-16). We appreciate the opportunity to review the Council's proposed Mainstem Amendment. We are providing general and specific comments that are intended to help the Council ensure that its fish and wildlife and the Mainstem Amendments Program are based on strong science and that it has the support of state, federal, and tribal fish and wildlife managers.

The Fish and Wildlife Service has significant responsibilities for managing anadromous fish, resident fish, and wildlife throughout the Columbia River basin. This includes administering and operating fish hatcheries (about 50 percent of the juvenile salmon and steelhead released above Bonneville Dam), managing over 740,000 acres of fish and wildlife habitat in the National Wildlife Refuge System, serving as a partner in public and private habitat restoration, meeting Tribal trust responsibilities, participating in harvest management, participating in hydropower licensing activities, and consulting with NOAA Fisheries on our activities that may affect listed salmon and steelhead. In addition, we have issued numerous biological opinions (BiOp) throughout the Columbia Basin that are related to federal activities that may affect listed plants and animals. One of the more important of these was our biological opinion for the federal Columbia River Power System (FCRPS) issued in 2000. This BiOp addressed effects of the operation and maintenance of the FCRPS on Kootenai white sturgeon, bull trout, and several species of snails. Over the past several years, we have been working closely with other Federal agencies to incorporate the BiOp requirements into the operation of the FCRPS, and we are committed to working with all our partners in the Columbia Basin to restore important fish and wildlife resources.

Development of the Mainstem Amendments to the Fish and Wildlife Program has initiated considerable debate throughout the Columbia Basin on the issues raised by the Council. Our comments highlight areas of continued debate and discussion. However, there are sections of the Mainstem Amendments that are widely supported and could be adopted by the Council with little or no debate.

General Comments

Throughout the draft Mainstem Amendments, the Council emphasizes their responsibility to balance the needs of all fish and wildlife resources throughout the Columbia River basin and to mitigate for the construction and operation of the FCRPS, as outlined in the Northwest Power Act (NWPA). The Council also recognizes the importance of conserving species listed under the Endangered Species Act (ESA). One of the purposes of the ESA is to conserve the ecosystems on which threatened and endangered species depend. In addition, all Federal agencies are required to conserve listed species and to use their existing authorities to further the purposes of the ESA. This imposes a substantial responsibility on federal agencies. Successful integration of ESA, NWPA, and other statutes requires close coordination among the agencies and entities involved in their implementation. It has been a challenge for the federal agencies, tribes, state fish and wildlife agencies, and other entities to achieve consistency with the ESA, NWPA, and other statutes. However, we are committed to working closely with the Council and our many partners and stakeholders in the Columbia Basin to maintain this balance and to achieve our mutual goals for the basin.

We appreciate the Council's adoption of key components of our 2000 FCRPS biological opinion for Kootenai River white sturgeon and bull trout into the proposed Mainstem Amendment. These key components include the hydrosystem operation objectives for bull trout and the VARQ flood control operations at Libby and Hungry Horse dams. We support other provisions of the proposed Mainstem Amendments and have highlighted our support in our specific comments.

The draft Mainstem Amendments include a number of new restrictions that limit flexibility in hydropower operations, including summer reservoir drafting limits of ten feet from full pool at Hungry Horse and Libby dams, restricting drafting of Lake Roosevelt to elevation 1283 by the end of August, and specific summer/fall elevation targets for Dworshak pool. The result would significantly reduce flows during the spring and summer migration for Pacific salmon and steelhead. The Council indicates the BiOp requirements that limit drafting at these reservoirs in the summer and set downstream flow targets have considerable impacts to resident fish and they are not supported by the available information on survival of anadromous salmonids.

During the ESA consultation which led to the biological opinions for the effects of the FCRPS on Kootenai River white sturgeon and bull trout, we worked closely with NOAA Fisheries, the states, tribes and other entities to meet the needs of all ESA listed species and to balance the needs of other fish and wildlife resources. We believe the existing biological opinions achieve that balance. We are concerned the proposed Mainstem Amendments deviates substantially from the biological opinion requirements for the FCRPS. Adoption of the Mainstem Amendments as proposed has the potential to disrupt that balance.

In general, we are concerned that the draft Mainstem Amendment does not adequately address the needs of listed and non-listed anadromous fish in the Columbia River basin. Specifically, the draft Mainstem Amendment does not support the spring and summer flow targets established for anadromous salmonids, reduces migration flows for Hanford reach fall Chinook salmon, and

removes the requirement that reservoirs meet upper flood control rule curve levels by April 10, which will shift flows from the spring and summer into the winter.

We believe the Council's proposed changes are not supported by compelling scientific or other evidence. It is important that supporting documentation be provided in the Amendments. The effect of the draft amendments on listed species (Kootenai River white sturgeon and bull trout), and other resident fish, including candidate species such as burbot and cutthroat trout, will be to further reduce their survival and long-term persistence. This anticipated reduction in survival will place these populations at a higher risk and reduce the likelihood of achieving the Council's interim biological survival objective for listed Snake River and upper Columbia River salmon and steelhead.

Given the weight of evidence supporting flow/survival relationships, we believe the proposed Mainstem Amendment will reduce overall survival of anadromous salmonids.

We have provided a more detailed response in our specific comments and attachments that present detailed information supporting flow/survival relationships for seaward migrating juvenile Chinook salmon and steelhead (see attachments A, B, and C).

Finally, we are concerned that the draft Mainstem Amendment changes the relationship between the federal, state, and tribal fish and wildlife managers and the Fish Passage Center. We strongly disagree with the proposal to create a new Fish Passage Center oversight board with the Council as the supervisor of the Fish Passage Center manager. Since its creation, the Fish Passage Center has provided critical technical support to the fish and wildlife managers in the day-to-day implementation of fish passage measures and data analysis. The new oversight board and the draft Mainstem Amendment place the Council in the day-to-day role of supervising the Fish Passage Manager. We do not support the Council changing its current critical role from an important policy maker and power/conservation planner in the Columbia Basin to managing fish and wildlife resources and information. The Columbia Basin Fish and Wildlife Authority (CBFWA) have provided supervision and oversight to the Fish Passage Center manager for many years and no problems have been documented that support the proposed changes to that role. We recommend the Council include language in its Mainstem Amendment that retains supervision of the Fish Passage Manager under CBFWA.

<u>Specific Comments</u>

Page 6, Scientific and policy uncertainty, 2nd bullet. We suggest that the Council balance its investigation of scientific uncertainty for all aspects of Columbia River water management. In particular, it appears the ability to measure the benefits gained from resident fish survival from reservoir elevation levels is highly uncertain and therefore the biological value of these actions is debatable. We suggest the Council evaluate not only the benefits of spill and flow, but the benefits of maintaining reservoir levels and how best to rigorously evaluate the trade-offs of these operations.

Page 9, 1st paragraph, line 5. We suggest that the sentence, "*c) allow for adequate levels of mainstem survival to support fish population recovery in the subbasins*," be changed. We

suggest the change should read: c*) allow for adequate levels of mainstem survival (that* explicitly considers direct and delayed mortality components of mainstem passage conditions) *to support fish population recovery in the subbasins.* Delayed mortality is a key uncertainty that needs to be considered in evaluating mainstem measures relative to population recovery.

Page 10, third paragraph, Biological Objectives. We suggest removing the phrase "except where these objectives are inconsistent with specific objectives and strategies included in this mainstem plan" and replacing this phrase with "while integrating the specific objectives and strategies included in this mainstem plan to the extent possible." We make this recommendation because this involves allocation of federal resources, and because federal agencies are obligated first to use their authorities to conserve listed species.

Page 12, Mainstem habitat conditions, bullet 1. We strongly support the Council's recommendations here and elsewhere in the draft Mainstem Amendments regarding the Hanford Reach and the reduction in flow fluctuations associated with operations of the FCRPS and other dams. Currently, the daily and hourly flow fluctuations from the Grand Coulee Project are substantial. The Mid-Columbia hydropower projects (Wells, Rocky Reach, Rock Island, Wanapum, and Priest Rapids) also reshape these flows for power generation purposes (e.g., load following). These combined flow fluctuations have a major adverse effect on juvenile fall Chinook salmon in the Hanford Reach, particularly during April, May, and June, when juvenile fall Chinook are emerging from the gravel. Widely fluctuating flows, sometimes as much as 10 vertical feet, strand and entrap juvenile salmon along the entire 51-mile Hanford Reach. Recent estimates indicate the rate of mortality from these flow fluctuations can be quite high. We believe the reduction in flow fluctuations can greatly improve the habitat and productivity of the mainstem Columbia River for fall Chinook and other anadromous and resident fish. This is consistent with the Council's overall vision for the Columbia River Basin and their Fish and Wildlife Program. We strongly support the Council's efforts to protect and restore fish and wildlife habitat in the mainstem Columbia River, particularly in the Hanford Reach area.

However, we are concerned that other provisions in the draft Mainstem Amendments reduce summer flows that are critical for Hanford reach fall Chinook during their downstream migration. Proposed drafting limits at upstream storage reservoirs would have a negative effect on survival of these fish.

Page 12, Mainstem habitat conditions, bullet 2. We support enhancing connections between tributary and mainstem habitats.

Page 13, Mainstem habitat conditions, bullet 5. We support the general concept of integrated rule curves (IRC) for each project to the extent that they still serve federal project needs, including those of listed and candidate species, listed fish (including flow augmentation for salmon), and consider resident fish to the maximum extent practical.

Page 13, Mainstem habitat conditions, bullet 6. To allow the federal obligations to be fulfilled, we suggest adding "after the needs of listed and candidate aquatic species are met," after the phrase "weighted for the greatest benefit to all species."

Page 14, Mainstem habitat conditions, last bullet. The language indicates that the Federal Energy Regulatory Commission (FERC) should decide whether anadromous fish should be allowed back into historic spawning areas that are currently blocked by hydropower projects under their jurisdiction. FERC has the responsibility under the Federal Power Act (FPA) to determine if it's in the public interest to issue a license for a non-Federal hydropower project under their jurisdiction. However, under section 18 of the FPA, the Secretary of Commerce and the Secretary of the Interior, through the National Marine Fisheries Service and the Fish and Wildlife Service respectively, can prescribe fish passage facilities at non-Federal hydropower projects licensed by FERC. These two agencies will determine whether fish passage is necessary and what type of fish passage facilities are necessary to achieve fishery management goals. Unless these Federal agencies prescribe fish passage facilities under section 18, FERC is unlikely to require them.

With the relicensing of numerous hydropower projects in the Columbia Basin in the near future, the Service and the National Marine Fisheries Service will likely be confronted with the policy issue of whether to prescribe fish passage facilities at FERC-licensed hydropower projects that currently do not have them. We do not believe this decision should be made in isolation by any federal agency, either FERC or the Fish and Wildlife Service. We believe the decision should be made with the input from a wide range of interested parties in the Columbia Basin, including the Council.

We are interested in the Council's views on whether anadromous fish should be allowed to pass mainstem projects (e.g., Hells Canyon Complex) or tributary projects (e.g., Pelton-Round Butte) into habitat that was formerly accessible but has been blocked by dams for the past 50+ years. We believe this should be a public decision made through a public process where the advantages and disadvantages of fish passage can be debated and discussed openly. The Council provides such a forum in their deliberations and we encourage the Council to address this issue in the near future, in cooperation with the federal resource agencies.

Page 15, Migration/passage conditions for anadromous fish, bullet 1. We disagree with the Council's adoption of the standards in Table 9.2-3 of the NOAA Fisheries 2000 FCRPS biological opinion. The footnote to Table 9.2-3 states that the project-by-project survival performance rates "are provided for illustrative purposes only. They are not intended to be interpreted as project-specific standards, or to be used in any way to support curtailment of survival improvement measures at an individual project."

Page 15, Migration/passage conditions for anadromous fish, bullet 5. We support the Council's adoption of an interim objective of 2-6 percent for smolt-to-adult survival rates for listed Snake River and upper Columbia salmon and steelhead.

Page 17, Resident fish/wildlife, bullet 3. Since some of the proposed changes are not minor and are inconsistent with our 2000 FCRPS biological opinion, we recommend removing the last sentence. See our comments below relative to pages 32 and 33 of this draft plan.

Page 17, Resident fish/wildlife, bullet 4. We appreciate the Council's support for mainstem conditions that help to protect and enhance bull trout habitat and the productivity of bull trout populations and the adoption of the Service's 2000 FCRPS biological opinion hydrosystem operations that affect bull trout.

Page 18, Overarching strategies. This section lists a number of actions intended to benefit fish and wildlife. As expected, the list calls for actions that maximize benefits and are the least detrimental to fish and wildlife. There is no reference here to the implementation of strategies based on the best available scientific information. The draft language is vague in the method for picking strategies that meet ESA needs, tribal harvest allocations, benefits to wild fish, cost efficiencies, and system limitations. When properly documented and analyzed, scientific advice is a useful tool in making decisions otherwise influenced by economic, legal, and political factors. The Council needs to propose an objective and reliable mechanism to resolve these differences based on the best available scientific information.

Page 18, Overarching strategies, bullet 3. We have the same recommendation as page ten above with respect to the phrase in italics.

Page 22, Mainstem habitat, bullet 8. Replace the word "stabilize" with "recover and enhance"...white sturgeon. There is public interest in recovering the Kootenai River white sturgeon and removal of protections under the ESA, which may result in once again being able to harvest these fish on both sides of the Canadian/United States border. While the upper Columbia River population of white sturgeon is not listed in the United States, there is international interest in recovering this population to a point where they too may again be harvested.

It is also worthy to note that natural flows effect timing and success of sturgeon spawning. Drafting during the winter and increased draw downs in September would upset the natural regime and decrease the likelihood of higher spring flows necessary to support sturgeon recovery, not only in the Kootenai River, but also in the Upper Columbia-Pend Oreille River below Boundary Dam.

Page 22, Mainstem habitat, last bullet. Replace the word "stabilize" with "recover and enhance"...burbot. There is international interest in recovering and enhancing the Kootenai River burbot to the point where they may again be harvested. Higher winter flows in the draft mainstem amendments may benefit some species by providing additional cover for overwintering, but collectively, fish would expend additional energy maintaining their position in the water column due to higher velocities. This is also a time when burbot spawn under natural conditions. The historic winter flows in the Kootenai River were far less than current flows, and therefore increased winter flows would continue to harm the burbot population.

Page 22, Mainstem habitat. Add a new specific mainstem habitat bullet: Implement recovery actions to recover and enhance bull trout populations in the Flathead, Kootenai, and lower Pend Oreille Rivers and in Lake Pend Oreille and Lake Koocanusa.

Page 25, Spill. We assume that this discussion is limited to the FCRPS dams located in the migration corridor for salmon and steelhead, and this should be noted.

Page 25, bullet 2. We disagree with the statement that "spilling to the maximum gas supersaturation levels of 120 percent may be increasing mortality at some dams when compared to what would occur at lesser volumes of spill." This statement is not supported by the available research and the results from many years of monitoring under the fish spill program.

The Council should support the installation of an additional turbine or spillway flow deflectors at Libby Dam which is consistent with the Service's 2000 FCRPS biological opinion.

Page 29, Water management, bullet 1. Begin with: "Where candidate, threatened, or endangered species are involved with a federal project, these species then automatically become a federal purpose, and they are then considered to be among those physical limitations of these multiple purpose federal projects." This concept is generally understood throughout the nation.

Page 29, Water management, bullet 2. Add "Since these are federal projects, the needs of listed species must be met first. However, every remaining feasible operation which would improve the status of resident species should also be implemented."

Page 29, Water management, bullet 2. Rather than leaving conflict identification up to the federal agencies, we suggest that potential conflicts between listed and non-listed species may be identified by any stakeholder, and those remedies should be sought through the existing regional forum for water management, the Technical Management Team and Implementation Team.

Page 30, Water management, bullet 3. We disagree with the conclusion here that there is a lack of evidence to support the spring and summer flow targets. The Service provided specific comments on the Council's approach for evaluating the evidence pertaining to a flow/survival relationship for spring migrating salmon and steelhead (Appendix A). The following bullets summarize the Service's critique:

1. Based on our interpretation of the Draft Amendment it appears the Council has implicitly formulated a null hypothesis that there is no flow-survival relationship (or more specifically, that providing greater volumes of flow through targets, thus increasing water particle velocity, does not in general lead to increased survival rates).
2. The problems with this approach to hypothesis testing are as follows:
    a. Sets up a hypothesis where deference is given to the 'no flow/survival relationship' hypothesis
    b. Given the high variability in the data and the limited time series used to test this hypothesis, this approach to hypothesis testing places an undue burden on competing hypothesis (i.e., there is a flow/survival relationship). In other words, the Council's conclusions are influenced by their decision about where the burden of proof lies (i.e., that unless meeting flow targets can be proven conclusively to increase survival rates, it should be abandoned in favor of presumably more certain upstream biological and economic benefits).
    c. Claims of no flow-survival relationships are not accompanied by analyses of statistical power estimating the ability to find such a relationship in existing data, if it does in fact exist.

   d. Many of the factors (e.g., degree of smoltification, fish condition, fish size) affecting survival probability will remain largely 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 greater flows *on average* associated with higher survival rates?

3. Reach survival estimates are not primary data and appear to be sensitive to assumptions and methods for calculation. For example, it appears annual survival estimates are sensitive to how tag release groups are combined (e.g., daily blocks, weekly blocks or larger) to estimate reach survivals. This potential error may mask the true underlying relationship.
4. Even given the variability in the estimates (described above), we have found evidence of a flow/survival relationship for Chinook and steelhead. Empirical survival-per-kilometer estimates versus Water Travel Time (WTT) yield significant relationships for the full time series (1970-2001) for yearling Chinook and for the full and short (1994-2001) time series for steelhead (Appendix A).
5. Both historical and recent data provide strong, uncontroversial evidence of a flow-fish travel time relationship for yearling chinook and steelhead.
6. Given that fish travel time appears to be directly related to WTT (and hence flow), the hypothesis that there is 'no flow-survival relationship' necessarily implies that, on average, daily mortality rate increases with flow, since in years with higher flows, fish are traveling faster but experiencing the same total mortality (all else being equal) through the system as at lower flows. The empirical survival and fish travel time data do not support the hypothesis that daily mortality rates are increasing with flow. In addition, for this hypothesis to be true, numerous hypotheses about the interactions of fish with the biological and physical environment would need to be true (see Appendix A).
7. One way to improve upon the Council approach would be to explicitly state competing hypotheses on the subject of flow/survival**, t**hen subject these hypotheses and underlying assumptions to an investigation using the full body of evidence. Lastly, evaluate management alternatives in a formal decision analysis process where competing hypothesis receive equal consideration.

Also see the attached paper, *State, Federal and Tribal Anadromous Fish Managers Comments on the Northwest Power Planning Council Draft Mainstem Amendments as they Relate to Flow/Survival Relationships for Salmon and Steelhead*, for a review of the Service's work in this area and other science (Appendix B and C).

The NWPA includes specific criteria which apply to Fish and Wildlife Program measures. Section 839b(h)(6)(A) states that program measures must complement the existing and future activities of the federal and the regions' state fish and wildlife agencies and appropriate Indian tribes. The draft program measures specifically conflict with the 2000 FCRPS biological opinions. In addition, 839b(h)(6)(B) states that measures must be based on and supported by the best available scientific knowledge. The program draft is based upon the presumption that there is no fish survival and flow relationship. This assumption is not based upon the best available scientific knowledge. The state, federal, and tribal fishery managers presented up-to-date scientific evidence and analysis which represents the most current scientific conclusions regarding the importance of adequate flow, in terms of juvenile survival and smolt to adult returns. In section 839(h)(6)(E)(i)&(ii), the NWPA states that in the case of anadromous fish,

the measures must provide for improved survival of fish at hydroelectric facilities, provide flows of sufficient quality and quantity between such facilities to improve production, migration, and survival of (anadromous) fish as necessary to meet sound biological objectives. The Council's own analysis shows that the draft Mainstem Amendment clearly reduces flow during the spring and summer anadromous fish migration period, while increasing flow during the winter power production period. This clearly conflicts with the Council's stated biological objective of reaching a 2-6 percent smolt-to-adult return rate. During the January 15, 2003, Columbia Basin Fish and Wildlife Authority presentation of the technical analysis to the Council, the fishery managers clearly advised the Council that reducing flows during the migration period would decrease the likelihood of achieving the Council's own biological objective.

These measures do not meet the standards and criteria of the NWPA because of the following reasons:

- The draft Mainstem Amendment would reduce flows during the spring and summer migration period when compared to the biological opinion measures.
- Given the weight of evidence presented by the state, tribal, and federal fish managers supporting a flow/survival relationship, we believe this amendment will result in reduced survival.
- This anticipated reduction in survival will place these populations at a higher risk level and reduce the likelihood of achieving the Council's interim biological survival objective for listed Snake River and upper Columbia River salmon and steelhead.
- The proposed oversight of the Fish Passage Center is inconsistent with the criteria in the NWPA that needs to be consistent with the present and future activities of the federal and state fish and wildlife agencies and appropriate tribes.

Page 32, Hanford Reach/mainstem and estuary spawning, rearing and resting habitat. As we stated in our earlier comments, we support protecting spawning and rearing habitat in these areas, but disagree with the lack of support in the draft Mainstem Amendment for migration flows. There is a strong flow/survival relationship for fall Chinook migrating through the lower Columbia River (see report referred to in previous comment) and only addressing spawning, rearing and resting habitat ignores the critical migration stage in the life history of fall Chinook.

Page 32, Spring reservoir /flow operations, bullet 1. Provision of adequate water for listed fish is of higher priority than is 95 percent probability of refill at federal projects such as Hungry Horse, Libby, Grand Coulee, and Dworshak dams. This paragraph should be changed to accurately represent the current priorities in Federal project purposes.

Page 32, Spring reservoir /flow operations, bullet 2. We disagree. The April 10 upper flood control rule curve requirement should be retained to assure adequate water for conservation of listed anadromous and resident fish. Elimination of the 2000 FCRPS biological opinion requirements for Libby, Hungry Horse, Dworshak, and Grand Coulee reservoirs will have little if any benefit for resident fish in those storage facilities. Lower pool levels may even hamper bull trout, as they start migration in early spring (April) into tributaries because of the degraded condition of stream channels along the shorelines. Bull trout and other resident fish also depend on littoral habitat for foraging and the later refill dates would reduce those opportunities.

Shifting water from spring to winter will also have a negative impact on burbot by increasing flows in the wintertime during burbot spawning.

Page 33, Hungry Horse and Libby Dams, bullet 3. VarQ flood control procedures are now in use at both of these Federal Projects. The adoption of VarQ flood control procedures are Reasonable and Prudent Alternatives in both the Service's and NOAA Fisheries' jeopardy biological opinions on operations of the FCRPS. VarQ flood control procedures are considered by all involved fishery management agencies to be slightly better than the Montana Integrated Rule Curves in achieving the storage for both listed and non-listed fish. The Montana Integrated Rule Curves did not account for summer salmon flow augmentation needs, and they may not adequately consider the needs of Kootenai river burbot. The biological opinions define releases needed for listed species and leave some flexibility for non-listed resident fish. We recommend that you replace this discussion of Montana Integrated Rule Curves with discussions of both VarQ and the Service's and NOAA Fisheries' biological opinions in this section of your final mainstem plan.

Page 33, Operations at Libby Dam to benefit Kootenai River white sturgeon, bullet 3. There is a significant misunderstanding in this section which should be corrected in your final mainstem plan. In the Service's December 2000 FCRPS biological opinion, Reasonable and Prudent Alternative 8.1.c, Table 10 and 8.1.d, Table 11, tiered sturgeon flow targets are clearly identified as "minimums." This has never changed. Note that the tiered volumes were originally adapted from the Montana Integrated Rule Curves where they were also represented as minimums. They are not "specified discharge volumes," nor are they in any way intended to limit the maximum volumes of water which may be released for sturgeon. Rather, they are target volumes developed with the Federal action agencies for operations and modeling convenience. They may be increased at any time for sturgeon, and flows may be increased as needed to preclude spill and possible flooding. The same is true of tiered bull trout flows described elsewhere in this Biological Opinion. They should also be recognized as minimums which may be exceeded for conservation of listed fish or for flood control.

Page 36, Summer reservoir/flow operations, bullet 2, summer drafting limits at Hungry Horse and Libby. We disagree with changing the 20 feet draft limits in the biological opinions. The 20 feet draft limits should remain in effect to provide water for flow augmentation for anadromous and resident fish. We are not aware of any compelling biological justification, or significant biological benefits from limiting the drafting to 10 feet. In the case of Libby the actual draft may be reduced to 10 feet, and possibly less through the "Libby-Arrow Swap" under the Libby Coordination Agreement. There is sufficient flexibility in the biological opinions through in-season management to address concerns about reservoir elevations. Implementation of a strict 10 feet draft limit would limit the ability to meet flows for anadromous and resident fish and reduce their survival.

The draft amendments state that "To the extent IRC operations at these two projects [Libby and Hungry Horse] cannot be accommodated under the Biological Opinions, the Council calls on the federal operating agencies and federal fish and wildlife agencies to reinitiate consultation on the operation of these two projects in an effort to reach that accommodation." When it is not economically feasible for Canada to initiate this swap, there is provision within this agreement for it to be initiated by the United States, and this could be recommended in this draft mainstem plan to assure higher summer levels in Lake Koocanusa. For this reason, we do not believe reinitiating consultation is necessary.

Page 37, Summer reservoir/flow operations, bullet 3, Operate Grand Coulee Dam… We disagree with the proposed draft limit of 1283 feet by the end of August for Lake Roosevelt. This would limit flow augmentation for anadromous fish in the summer and result in reduced survival. There is little scientific information that resident fish populations in Lake Roosevelt would benefit from this recommendation and from maximizing water retention times.

Page 37, Summer reservoir/flow operations, bullet 4, Operate Dworshak Dam… We do not support the very strict minimum monthly summer/fall elevation targets for the Dworshak pool. The 2000 FCRPS biological opinion has sufficient flexibility to balance the multiple needs that are addressed in this section.

Page 39, Monitoring and Evaluation, bullet 1. We agree with the language in the first bullet, that the ultimate goals are to determine whether the biological objectives are being achieved at a basin wide level…. The Service recommends that this particular objective be the focus of the monitoring and evaluation program using rigorous quantitative decision analyses. These analyses should evaluate the trade-offs among resident and anadromous fish with various operational options. We recommend these basin-wide level analyses be conducted by the fish and wildlife agencies and tribes with the assistance of the Fish Passage Center.

Page 39, Monitoring and Evaluation, bullet 2. As we explained in the last paragraph of our special comments, we do not believe that it is appropriate for the Council to engage in the day-to-day role of supervising the Fish Passage Center. Such change in the council's role does not appear to be consistent with the NWPA.

Thank you for the opportunity to comment on the Council's draft Mainstem Amendment.

Sincerely,

Columbia River Basin Coordinator

Attachments:

A - Fish and Wildlife Service review of the Northwest Power and Conservation Council's approach to the flow-survival relationships for spring migrant juvenile salmon and steelhead

contained in the *draft Mainstem Amendments to the Columbia River Basin Fish and Wildlife Program.*

B - State, Federal, and Tribal Anadromous Fish Managers Comments on the Northwest Power Planning Council's Draft Mainstem Amendments to the Columbia River Basin Fish and Wildlife Program as they Relate to Flow/Survival Relationships for Salmon and Steelhead.

C – A letter to Independent Scientific Advisory Board (ISAB) from Fish Passage Center on the answers to the ISAB questions posed for the comments developed by the State, Federal, and Tribal Anadromous Fish Managers on the Northwest Power Planning Council's (NWPPC) Draft Mainstem Amendments as they Relate to Flow/Survival Relationships for Salmon.

cc: Columbia River Fisheries Program Office

Appendix A - US Fish and Wildlife Service review of the Northwest Power and Conservation Council's approach to the flow-survival relationships for spring migrant juvenile salmon and steelhead contained in the *draft Mainstem Amendments to the Columbia River Basin Fish and Wildlife Program*
February 4, 2003

We are concerned about the way the document frames and makes inferences from hypotheses about the existence of a relationship between volume of flow, acting through its effect on water particle velocity, and survival of migrating smolts. The draft mainstem amendments document, as part of the rationale for repudiating the flow targets of the Biological Opinion (BiOp), states that "[r]esearch has not validated the predicted benefits of flow augmentation from upstream storage reservoirs" (p. 31, lines 9-10). This viewpoint, together with the conclusion that available evidence for a flow-survival relationship is lacking, imply that a particular hypothesis test has been set up, and inferences made. Specifics of the test are not provided by the Council, but can be inferred. The document contains no indication that alternatives to the chosen hypothesis test were considered, that alternative methods of analyzing relevant data were considered, or that the vast amount of information about juvenile salmonid migration was factored into the conclusions.

The Council appears to have implicitly formulated a null hypothesis that there is no flow-survival relationship (or more specifically, that providing greater volumes of flow to meet targets, thus increasing water particle velocity, does not in general lead to increased survival rates). The alternative hypothesis is presumably that there is a positive relationship between flow and survival. A formal decision analysis to distinguish the relative likelihood of these hypotheses can be conducted in a number of ways. A statistically appropriate test would at the least explicitly state both the choice for acceptable level of probability of Type I error (incorrectly rejecting the null hypothesis) and the resulting power of the test (= 1 – Type II error probability, where a Type II error is failing to reject the null hypothesis when it is in fact false). The statistical power of the test (the probability of correctly rejecting the null hypothesis, given that the alternative hypothesis is true) will also depend on the natural variability and error in measuring data on survival at different flow levels, as well as the effect size. The effect size in this case is the degree to which survival depends on flow (e.g. the slope of a line relating survival and flow), and should be a biologically significant amount. The Council's position that no flow-survival relationship has been demonstrated is not accompanied by analyses of statistical power estimating the ability to find such a relationship in existing data, if it does in fact exist. Power would likely be low with short data sets, given error and uncertainty in survival estimates and natural variability.

The Council's conclusions are influenced by their decision about where the burden of proof lies, i.e. that unless meeting flow targets can be proven conclusively to increase survival rates, they should be abandoned in favor of presumably more certain upstream biological and economic benefits. Presumably, the Council would be 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. 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.

Shrader-Frechette and McCoy (1992) give reasons why in applied cases, Type I error is often more acceptable than Type II error, whether the null hypothesis is "positive" (no harm) or "negative" (no benefit). Type II error leads to possible harm or loss of benefit, respectively. 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 hard flow targets), 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.

Proper consideration of the possible detrimental effects of failing to meet flow targets requires acknowledging the limitations inherent in the available empirical data on flow and survival. It should be kept in mind, for instance, that it's difficult to accurately characterize exact hydrological conditions experienced by individual release groups in the survival studies: "Identifying and quantifying relationships between environmental variables and travel times or survival of PIT-tagged migrant juvenile salmonid release groups in the Snake River present difficult challenges. Among these is defining the environmental conditions to which a release group is exposed." (NMFS 2000). 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 flow within a season. Many factors affecting 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 greater flows *on average* associated with higher survival rates?

A plot of survival rate under different flows and different uncontrolled factors may help illustrate the difficulties in detecting a true relationship between flow and survival, given that uncontrolled factors also are certain to affect survival rate. Uncontrolled (and unmeasured) factors might be intrinsic, such as smolt physiological condition, or they could be largely external (e.g. predator density-dependent functional response). If we consider a component of survival (or mortality) that is influenced by uncontrolled factors, and one that is influenced by flow, the flow-survival relationship could be obscured by either random or directional variation in uncontrolled survival factors. Variation within a season will tend to obscure an intra-annual flow-survival relationship, and variation between years will tend to obscure an inter-annual flow-survival relationship. In Figure 1, a hypothetical composite factor, which can take values from 0 to 1, is shown on the x-axis, with resulting survival rate shown for low, medium, and high flows. The x-factor survival component varies as a negative exponential function of x-factor value, while flow-induced survival varies as a positive exponential function of flow. We can see from the figure that even though there is positive flow-survival relationship (i.e. at a given uncontrolled factor level, higher flows always result in higher survival), it could be lost in the data if the uncontrolled factors vary within a season or between years. For example, a year with higher flow may have also have a higher x-factor, resulting in lower overall survival than a year with lower flow but lower x-factor.

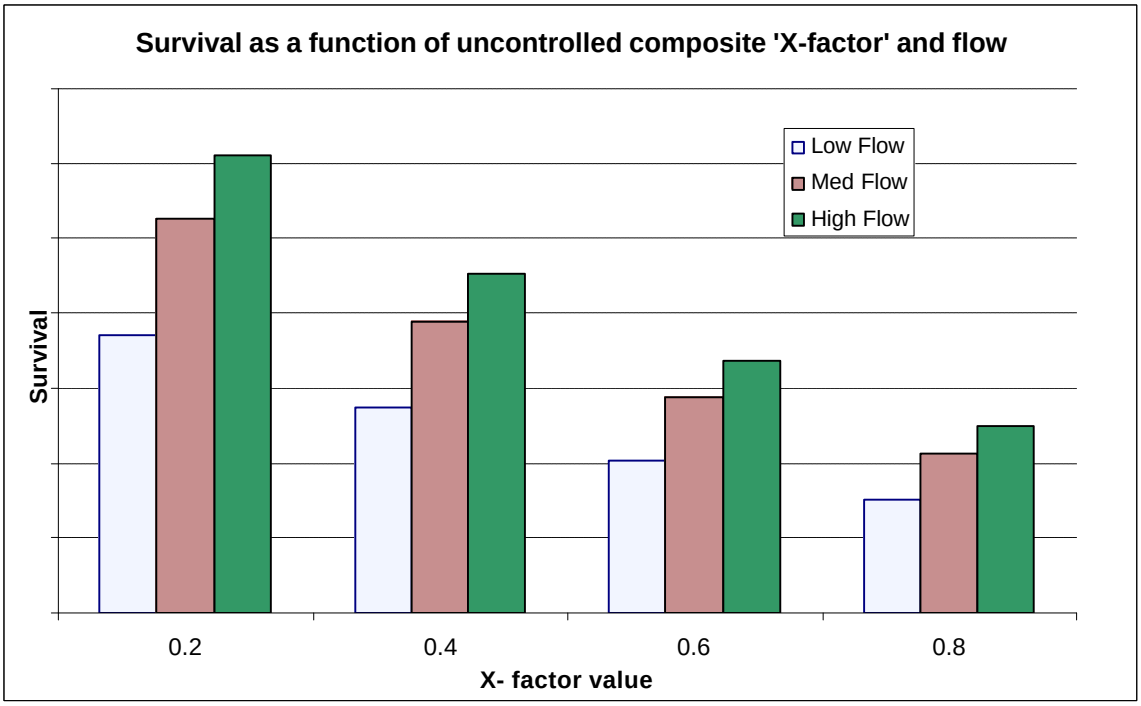

Figure 1. Hypothetical response of survival to composite uncontrolled factors and flow.

Given these caveats, we can look at how estimates of survival rates, from the 1970s through the most recent years, vary with water particle travel time (WTT). WTT is used as a surrogate for flow, since at constant reservoir volumes, there is a strong inverse correlation between flow volume and WTT, and because WTT estimates over reaches which include the Snake and Columbia rivers integrate the effect of flows in the relevant reservoirs. We plotted empirical survival rate-per-kilometer (s/km) estimates from NMFS studies against water travel time. The s/km and WTT values are derived from the longest reach estimate over which NMFS made a survival estimate in that year, and the length in km of that reach. Survival estimates in figures are standardized to the approximate length of hydrosystem (500 km). Flow values corresponding to selected points are shown in parentheses (Snake flow, Columbia flow) to place the variation in flow between years in context. Survival-per-km is a better index than per-project for comparing survival rates among different years and different reach lengths In 2001, for example, per-project survivals for short reaches would have grossly overestimated survival through the entire hydrosystem (FPC 2002). An alternative method of comparing survival among years, using the data sets with consistent reaches over years demonstrated a relationship between flow and reach survival (FPC 2002).

Figure 2 shows data for yearling chinook, from the full time series. With data from the 1970s included, there is a significant survival /WTT relationship.

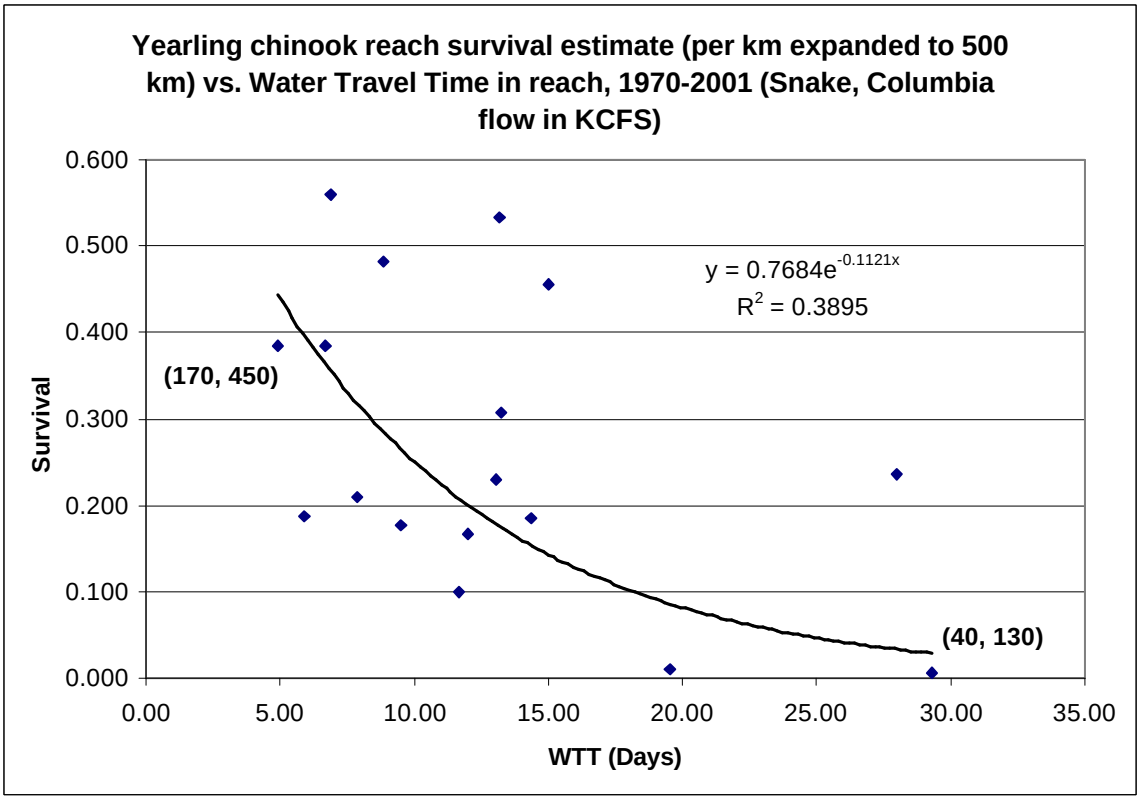

Figure 2.

The inclusion of data from 1970-80 is controversial, as some believe unique conditions in some of those years resulted in some low flow/low survival years that would not occur again. For yearling chinook, with the recent, PIT-tag data only, no survival/WTT relationship is apparent (Figure 3).

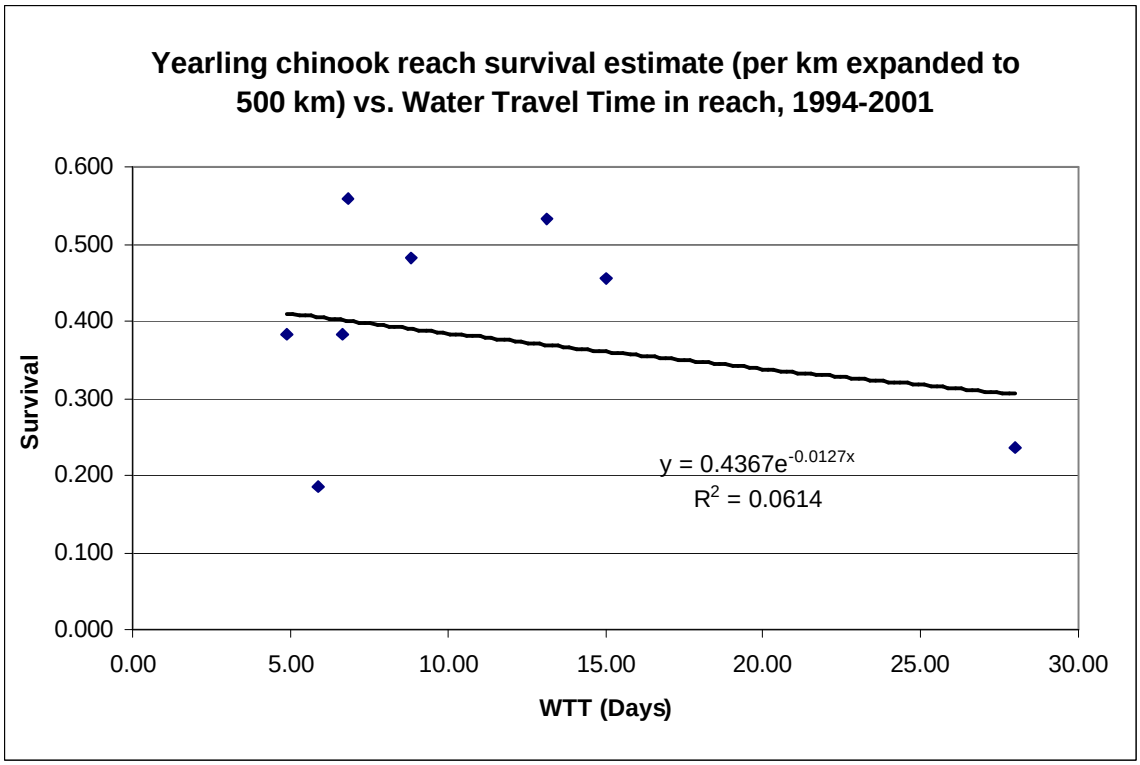

Figure 3.

Figure 4 shows the results for migrating steelhead with the full time series. A strong survival-WTT relationship is indicated.

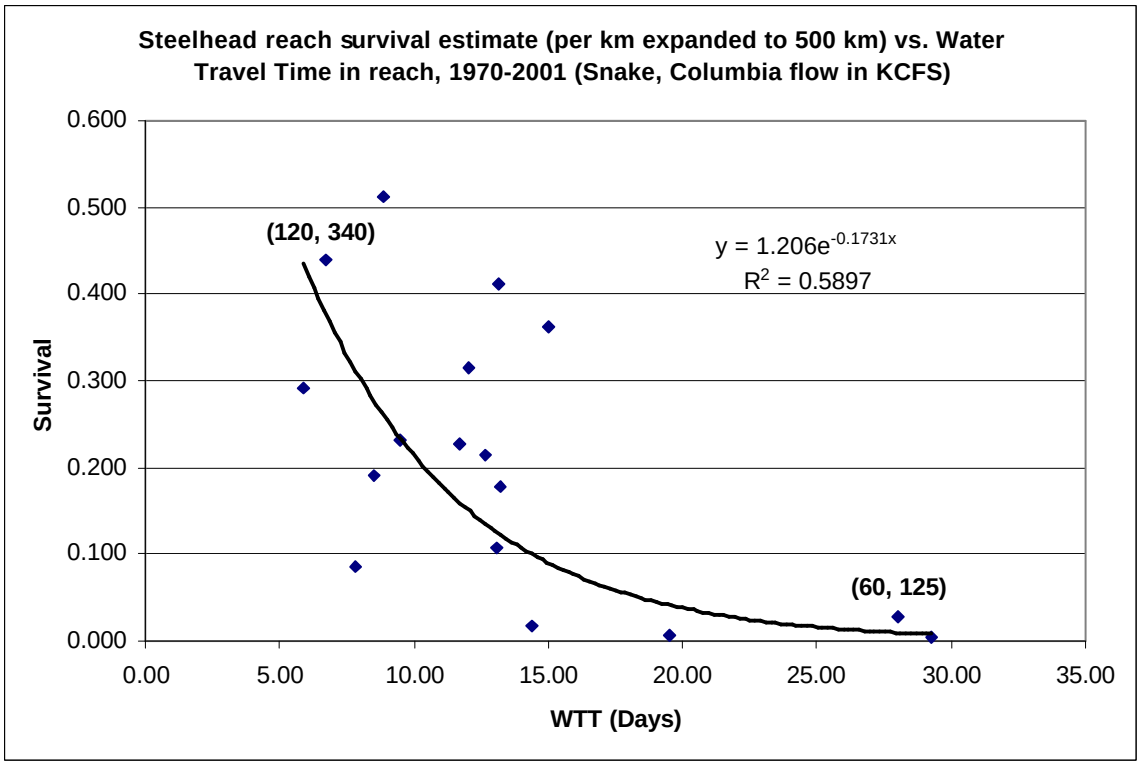

Figure 4.

When we exclude the older data, and use only the PIT-tag data, the survival-WTT relationship for steelhead seems even stronger (Figure 5).

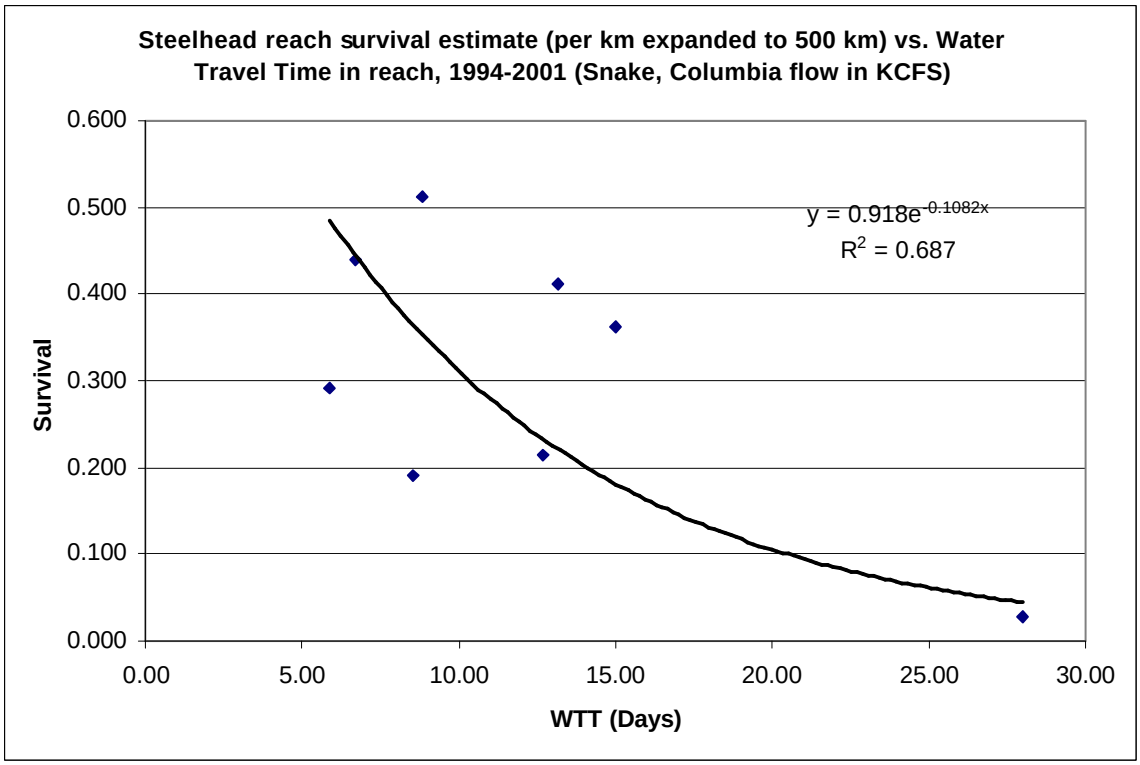

Figure 5.

A formal power analysis can be done for the data presented. Because no relationship was found for chinook using PIT-tag data only (Fig. 3), we perform an analysis of power to detect an exponential survival-WTT relationship on this data set. We assume a one-tailed hypothesis test on the slope of natural log of survival vs. WTT; i.e. the null hypothesis is that $b \geq 0$; and the alternative hypothesis is $b < 0$ (representing a positive relationship between flow and survival). The observed standard deviations of the X and Y values are used, with different levels of "true" underlying values of b. Power for the regression is estimated as in Zar (1984, section 19.4) using the correlation coefficient r (which is directly proportional to b if the ratio of standard deviations of X and Y is held constant). An alpha value (Type I error rate) of .05 is used. The results are shown in Figure 6 for the 8 years of PIT-tag data.

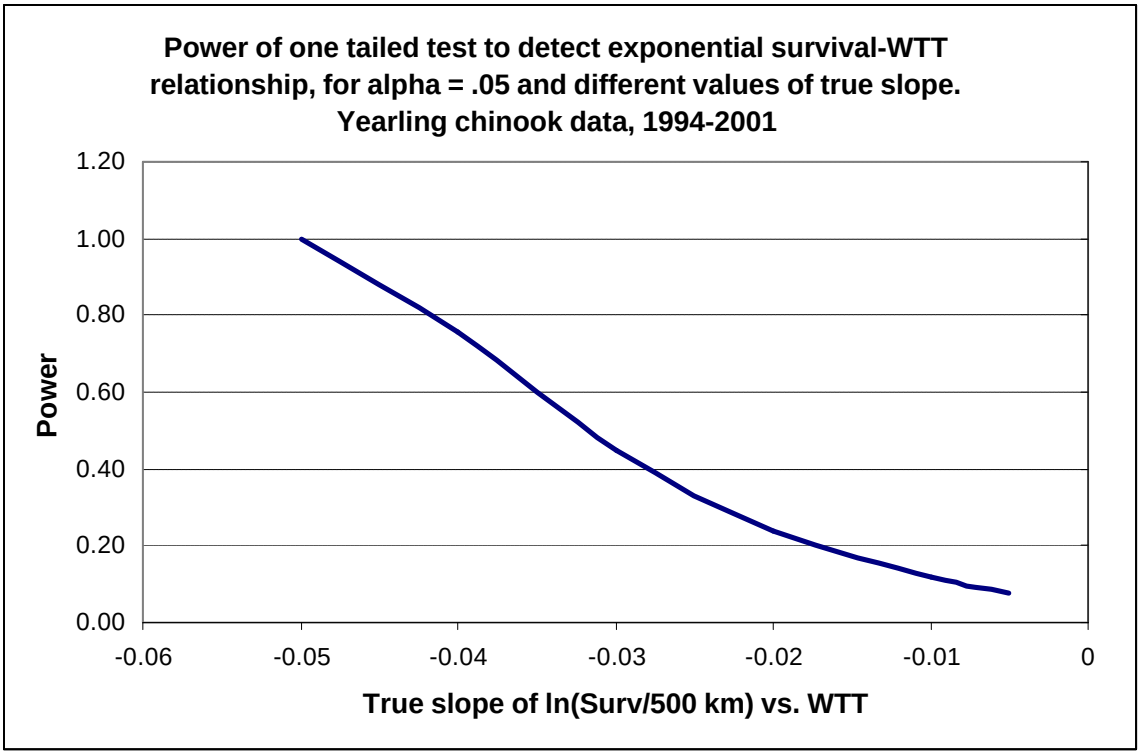

Figure 6.

A commonly accepted target value of statistical power to reject the null hypothesis at alpha = .05 is 80%. Figure 6 shows that this much power would not be expected unless the absolute value of the slope were greater than .04. In other words, there is a substantial chance that a true relationship of as much as -.04 is going undetected in the data. A *b* value of -.04 represents an additional 4% mortality for every additional day of water travel time.

The appropriateness of using data from the 1970s to help inform management of the hydrosystem today is in dispute. However, it is telling that, despite the inherent natural variability, anthropogenic sources of variability, and error in estimation of survival rates, leading to low statistical power to detect flow-survival relationships, three of the four relationships show a significant survival-WTT relationship. We also note that the figures presented fit a simple exponential curve to the data. Using a more realistic and flexible two-parameter curve, such as was used in FLUSH (one of the juvenile passage models used in PATH: Marmorek and Peters 1998), would doubtless result in higher R^2 for the cases where a significant relationship was found.

Another caution applies to the analyses above, and to any inferences made from the reported NMFS annual survival rates. There is a misconception among some in the region that annual reach survival estimates from PIT-tags are “primary data”, not sensitive to assumptions or method of calculation. The Comparative Survival Study (CSS) has calculated reach survival estimates for yearling chinook and steelhead for the years 1994-2002 with a validated survival estimation program using raw PIT-tag data. CSS found that annual PIT-tag survival estimates are sensitive to the way that tag release groups at Lower Granite Dam are blocked within the

season (i.e. daily blocks, weekly blocks, or longer periods). Calculating the season aggregate or using 3-7 time blocks (cohorts) sometimes gives very different values than using daily LGR cohorts, as NMFS does. Uncertainty about the best estimate of annual reach survival may hamper the ability to detect flow-survival relationships, and it should be acknowledged as a possible confounding factor when evaluating evidence for flow-survival relationships in PIT-tag data.

It's useful also to look at evidence for relationships between flow (WTT) and migration rate or travel time of spring migrants. Speeding up the journey through the hydrosystem is a candidate mechanism for increased flow leading to increased survival. Both historical and recent data provide strong, uncontroversial evidence of a flow-fish travel time relationship for yearling chinook and steelhead. For example, both passage models in PATH had strong positive fish travel time-WTT relationships, despite the fact that the survival-fish travel time relationships in the models differed substantially (Marmorek and Peters 1998). NMFS (2000) found "A strong and consistent relationship exists between flow and travel time for spring migrants. Increasing flow decreases travel time." Smith et al. (2002) found that for both chinook and steelhead, travel time strongly correlated with flow volume. These findings that spring migrating smolts appear to rely on swiftly moving water to get downstream is consistent with evolutionary life-history strategies of both species in their natural environment.

Given that WTT (and hence flow) is closely linked to fish travel time, a hypothesis about existence or strength of flow-survival relationship necessarily implies a hypothesis about whether or how much mortality rate (or survival rate) changes with time in the system. In PATH, this was a key point of controversy: disagreement between the two passage models revolved around the rate of mortality. In CRiSP the daily rate of mortality was essentially constant over time while in FLUSH the rate of mortality increased the longer fish are in the river (Marmorek and Peters 1998, Section 4.2, WOE Submission 14). Whether mortality rate increases with time, or stays constant with time, there will be a flow-survival relationship since fish travel time is directly proportional to water travel time. This is because under either assumption, total mortality increases with time, and since over a fixed distance, faster water velocity results in fewer days spent in the hydrosystem, there will be less mortality when flows are higher (all else being equal). In contrast, the hypothesis that there is no flow-survival relationship necessarily implies that, on average, daily mortality rate increases with flow, since in years with higher flows fish are traveling faster but experiencing the same total mortality (all else being equal) through the system as at lower flows.

A graph of the form of the relationship between daily mortality rate and WTT (flow) for the three hypotheses is shown in Figure 7. The FLUSH hypothesis, of course, results in a fairly strong survival-WTT relationship, when the increasing daily mortality rate combines with the fish travel time-WTT relationship. The CRiSP constant mortality hypothesis also results in a survival-WTT relationship because of the fish travel time-WTT relationship, though not as strong as in FLUSH. The hypothesis which reflects the assumption of no-flow survival relationship (No Q-S) requires that daily mortality rate increases with flow.

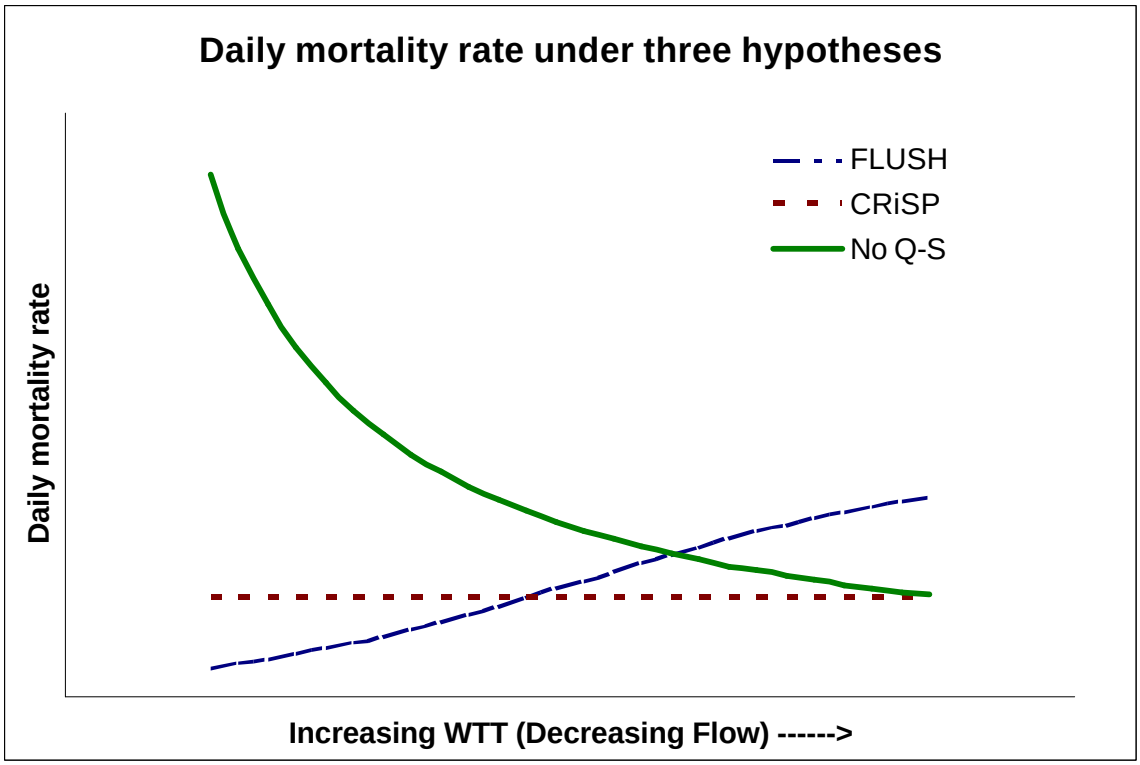

Figure 7.

The "no flow-survival" hypothesis implies specific hypotheses about the interaction of the fish and the biological and physical environment. These hypotheses must be true for survival to be independent of flow, given that fish move faster as flow increases. The overall set of hypotheses has been termed the "gauntlet" hypothesis. For the gauntlet hypothesis to be true, mortality agents the fish face in the hydrosystem must not be, on average, appreciably affected by the amount of flow. This requires that:

- Predator *distribution* is not modified so as to alter consumption rates
- Predator *behavior* is not modified so as to alter consumption rates
- Predator consumption rates are not related to prey migration speed (i.e. encounter time not related to consumption rate)
- Exposure of smolts to increased temperatures under low flows (due to migration extending longer into season) does not affect consumption rates
- Exposure to increased temperatures does not increase smolt mortality from sources other than predation
- Survival per day must be higher in low flow years than in high flow years

Using the available survival and fish travel time data, we can evaluate evidence for the no flow-survival hypothesis, versus for those which imply a positive relationship between flow and survival. To do this, we need to use data from a consistent reach; otherwise variations in the rate of survival (or mortality) per day between years could be attributable to differences in the reaches traversed, rather than any relationship between flow and mortality per day. We use published estimates of annual survival rates and median travel times for primary release groups

from the PIT-tag studies, for both yearling chinook and steelhead. The reach over which survival was estimated has included more projects as PIT-tag detectors have been installed at lower river dams. However, the longest reach (Lower Granite Dam to Bonneville Dam) has been available for only the last few years. From 1995 to 2001, for both chinook and steelhead, survival estimates were made for the reach from LGR Dam tailrace to McNary Dam and this was the reach used (estimates were made from LGR to Lower Monumental Dam in 1994 as in other years; however this reach was judged too short to give relevant information). In years when travel times were estimated from LGR to MCN dam, annual median travel time is estimated by weighting each release group's median by the group's proportion of the total number of PIT-tagged fish released at LGR dam. In the other years (1995 for both chinook and steelhead and 1996 for steelhead), weighted median travel times from Port of Wilma to MCN and from Port of Wilma to LGR were estimated, and the latter subtracted from the former to come up with median LGR to MCN travel time. Survival rate per day was then calculated by taking the tth root of LGR to MCN survival rate, where t is LGR to MCN median fish travel time. Daily mortality rate is 1 – daily survival rate.

Table 1 shows the data sources for survival rate and travel time estimates. The results of the mortality rate calculations plotted against spring migration water travel time estimates are shown in Figures 8 and 9.

Table 1. Sources of data used in mortality per day analysis: reference (table numbers).

Year	Chinook survival rate	Chinook travel time	Steelhead survival rate	Steelhead travel time
1995	1 (2)	2 (D1, D9)	1 (2)	2 (D2, D10)
1996	1 (2)	3 (19, D3)	1 (2)	3 (C1, C5)
1997	1 (2)	4 (11)	1 (2)	4 (9)
1998	1 (2)	5 (25)	1 (2)	5 (23)
1999	1 (2)	6 (26)	1 (2)	6 (28)
2000	7 (1)	7 (27)	7 (10)	7 (31)
2001	8 (1)	8 (27)	8 (10)	8 (31)

1 Williams et al. (2001)
2 Muir et al. (1996)
3 Smith et al. (1998)
4 Hockersmith et al. (1998)
5 Smith et al. (2000a)
6 Smith et al. (2000b)
7 Zabel et al. (2001)
8 Zabel et al. (2002)

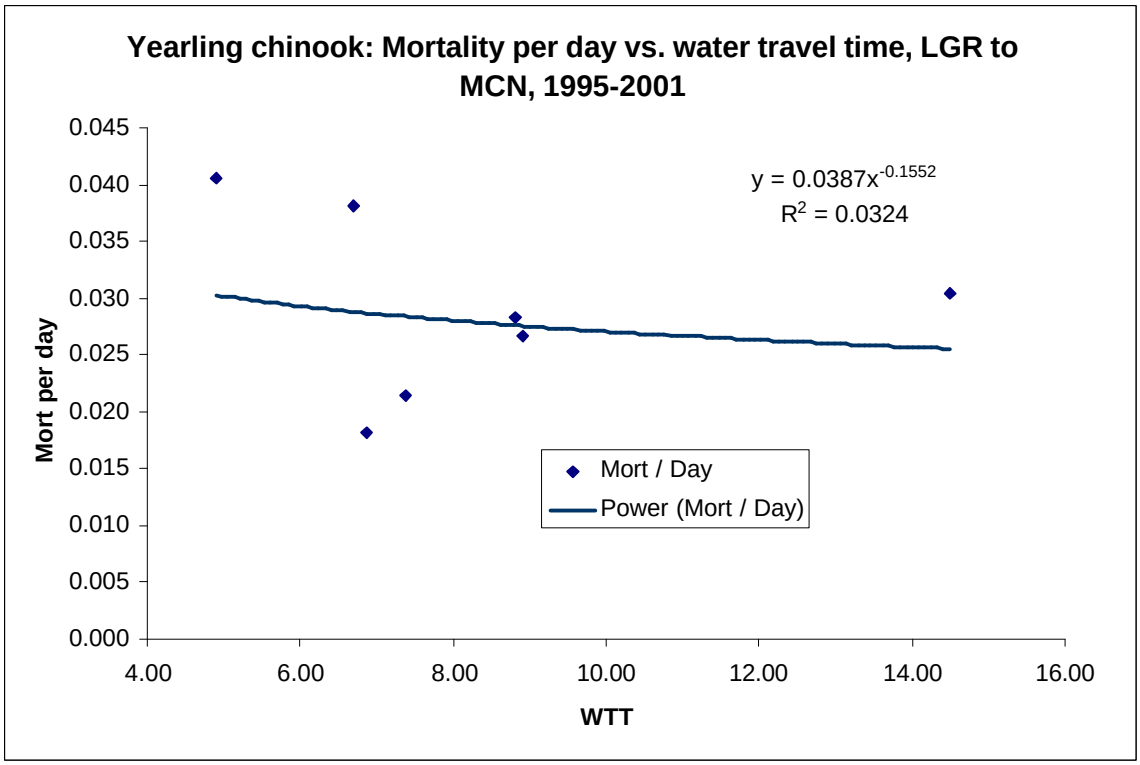

Figure 8.

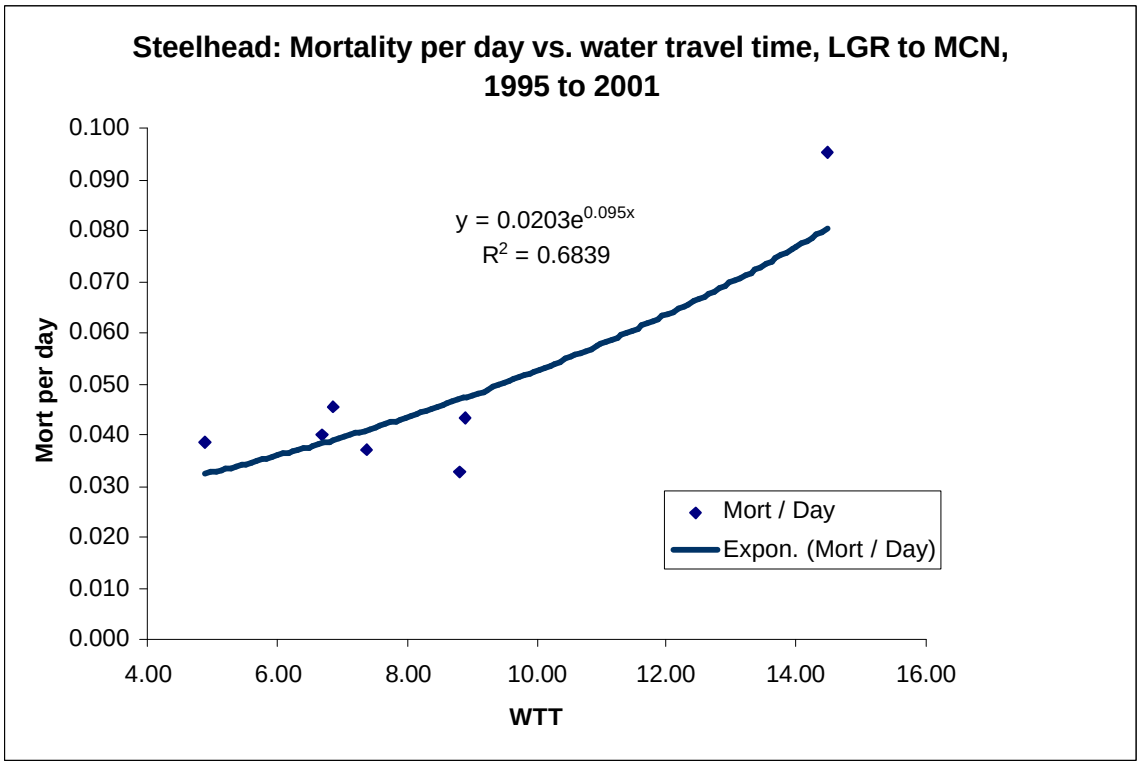

Figure 9.

The trend line fitted for chinook in Figure 8 is a power curve. If the no flow-survival hypothesis were correct, we would expect mortality per day as a function of water travel time to tend to follow a power curve with a negative exponent. The low R^2 suggest that the data do not follow this kind of curve, and the no-flow survival relationship hypothesis is not supported. With steelhead (Fig. 9), fitting a power curve gives a positive exponent. An exponentially increasing trend (shown) fit the data even better. The steelhead data also do not support the no flow-survival hypothesis, and in fact show evidence of mortality rate increasing, rather than decreasing, with time.

A weight of evidence process that compared the evidence for the different hypotheses could be undertaken. This would include any empirical information from the river system under discussion, as well as evidence from the general literature about the mechanisms affecting chinook, steelhead, and related species in other systems. The last bullet point above was examined here using annual survival rates and weighted annual median travel times from the annual reports of NMFS survival studies and CSS PIT tag studies.

Finally, apart from the question of whether there is an observable, or expected, relationship between flow and survival of juvenile migrants within the hydrosystem, there are other reasons to be cautious about abandoning flow targets. These include the appropriate placement of the burden of proof (discussed earlier), effects to survival outside of the hydrosystem (discussed elsewhere), the precautionary principle, and the wisdom of a formal decision analysis removed from the traditional null/alternative hypothesis testing format. A rigorous weight of evidence approach would include findings and considerations from previous work, seen in the context of the species' entire life cycle and the greater management framework. Sample considerations can be found in the NMFS white paper on flow and survival (NMFS 2000):

- "Thus, higher flows, while decreasing travel time, may also improve conditions in the estuary and provide 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."
- "Since a migration rate/flow relationship has been established repeatedly for spring migrants, the focus of flow augmentation in the spring should be to decrease travel times and hence shift arrival timing in the estuary closer to historical timing, with the assumption that arrival timing has been under evolutionary control."
- "Certainly, increased flows, particularly when base flows are low, will not harm spring migrants. Given the critical levels of many spring migrating stocks, continuing the flow augmentation program is consistent with a 'spread the risk' strategy."

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State, Federal, and Tribal Anadromous Fish Managers Comments on the Northwest Power Planning Council Draft Mainstem Amendments as they Relate to Flow/Survival Relationships for Salmon and Steelhead

FINAL DOCUMENT

January 2003

Executive Summary

of the State, Federal, and Tribal Anadromous Fish Managers Comments on the Northwest Power Planning Council Draft Mainstem Amendments as they Relate to Flow/Survival Relationships for Salmon and Steelhead

1. The state, federal, and tribal anadromous fish managers reviewed the NPPC's draft Mainstem Amendments to the Columbia River Basin Fish and Wildlife Program, which are contained in Council Document 2002-16. This review focused on the scientific information, as anticipated in section 839(h)(B) of the Northwest Power Act, regarding the effect of flow on salmon and steelhead survival.

2. The Council draft mainstem amendment document relies heavily on a conclusion from Giorgi et al. (2002) questioning the scientific basis of a flow survival relationship. There was little reliance by the Council on recommendations or comments of the fish and wildlife management agencies, scientific support for flow-survival relationships previously summarized in NMFS (2000) white papers, or recently peer-reviewed articles on chinook summer migrants.

3. The Council did not seem to heed the caution from the ISRP review that the Giorgi et al. (2002) report concerning a flow survival relationship was "…very conservative in drawing statistical conclusions. From a purely statistical standpoint, tests that fail to show statistical significance in data can be definitive in stating *no effect was found*, yet these tests do not definitively prove the absence of an effect."

4. The assessment and conclusions of the state, tribal and federal anadromous fish managers regarding the mechanisms by which flow and water velocity may affect juvenile survival in freshwater and from migrating smolt to adult return have been summarized in this paper. This includes a summary on juvenile migratory characteristics related to flow and spill that also provide evidence of flow-survival relationships, and the supporting empirical evidence from patterns of smolt-to-adult return rates (SARs) and life cycle survival analyses (ratio of recruits to the spawning grounds vs. spawners the previous generation; S/S).

5. The conclusion of the state, tribal and federal salmon managers, based on review of the scientific information regarding the effect of flow on salmon and steelhead are:
    a. **Juvenile steelhead and chinook spring migrants**
        i. A water travel time/ survival relationship exists for spring migrating chinook and steelhead of Snake River and Mid-Columbia River origin.
        ii. A water travel time and fish travel time relationship exists for spring migrating chinook and steelhead.
        iii. Within the management range of the Biological Opinion and the flow spill risk analysis dissolved gas levels of 125% there is minimal risk of reducing survival by increasing spill.
        iv. It is difficult to define a flow survival relationship because survival is the combined result of many interacting variables and the methodology for

estimating survival does not lend itself to identifying each individual environmental or biotic variable individually.

b. **Juvenile fall chinook migrants**
   i. Wild subyearling fall chinook salmon spend from 20 to 42 days in Lower Granite Reservoir primarily during the months of July and August.
   ii. Meeting summer flow targets decreases the time young fall chinook salmon spend in Lower Granite Reservoir by 1 to 5 days.
   iii. Survival of wild subyearling Snake River fall chinook is influenced simultaneously by flow and temperature.
   iv. Meeting summer flow targets increases flow and decreases temperature
   v. Meeting summer flow targets in July and August increases survival of wild subyearling fall chinook migrants.
   vi. Shifting flow augmentation from July and early August to later times in the year would decrease survival of the largest portion of the wild subyearling fall chinook salmon run.

c. Adult return analysis
   i. Numerous mechanisms exist by which flow and water velocity may affect survival from migrating smolt to adult return.
   ii. Juvenile migration conditions and ocean climate conditions were both influential in explaining patterns of adult recruitment of Snake River spring and summer chinook (spawner to spawner ratio).
   iii. The BIOP flow targets appear to represent a minimum needed to maintain the Snake River spring summer chinook populations for average to good ocean conditions and provide inadequate protection for poor ocean conditions.
   iv. The Councils proposed relaxation of spring flow targets would increase water travel time and reduce protection against population declines and the likelihood of rebuilding spring and summer chinook stocks.
   v. Juvenile migration conditions and ocean climate conditions were both influential in explaining patterns of SARs in Snake River spring and summer chinook and steelhead.
   vi. Relaxation of Spring flow objectives would likely decrease the SARs of wild Snake River spring and summer chinook and steelhead.

State, Federal, and Tribal Anadromous Fish Managers Comments on the Northwest Power Planning Council Draft Mainstem Amendments as they Relate to Flow/Survival Relationships for Salmon and Steelhead.

Introduction

The initial recommendations for the Northwest Power Planning Council Fish and Wildlife Program were submitted to the Northwest Power Planning Council under the auspices of Section 4(h) of the Northwest Power Act by the state, federal and tribal salmon managers in November of 1981. Flow and spill for the juvenile out migration of salmon and steelhead were critical facets of those recommendations. The joint recommendations of the salmon management entities were based upon passage and migration data and analysis collected to the date of the initial Fish and Wildlife Program. Over the past decades significant additional study and analysis has taken place.

The Council draft mainstem amendment document relies heavily on a conclusion from Giorgi et al. (2002) questioning the scientific basis of a flow survival relationship. There was little reliance by the Council on recommendations or comments of the fish and wildlife management agencies, scientific support for flow-survival relationships previously summarized in NMFS (2000) white papers, or recently peer-reviewed articles on chinook summer migrants. The Council did not seem to heed the caution from the ISRP review that the Giorgi et al. (2002) report was "…very conservative in drawing statistical conclusions. This fact needs to be understood for proper interpretation of the report. From a purely statistical standpoint, tests that fail to show statistical significance in data can be definitive in stating *no effect was found*, yet these tests do not definitively prove the absence of an effect." See Peterman (1990) for a review of this problem in fisheries research and management.

This paper briefly summarizes the assessment and conclusions of the state, tribal and federal anadromous fish managers regarding the mechanisms by which flow and water velocity may affect juvenile survival in freshwater and from migrating smolt to adult return. This includes a summary on juvenile migratory characteristics related to flow and spill that also provide evidence of flow-survival relationships, and the supporting empirical evidence from patterns of smolt-to-adult return rates (SARs) and life cycle survival analyses (ratio of recruits to the spawning grounds vs. spawners the previous generation; S/S). The document is organized in terms of juvenile migration characteristics and adult analysis. The conclusion of the state, tribal and federal salmon managers, based on review of the scientific information as anticipated in section 839(h)(B) of the Northwest Power Act, regarding the affect of flow on salmon and steelhead are:

Juvenile steelhead and chinook spring migrants

- A water travel time/ survival relationship exists for spring migrating chinook and steelhead of Snake River and Mid-Columbia River origin.
- A water travel time and fish travel time relationship exists for spring migrating chinook and steelhead.

- Within the management range of the Biological Opinion and the flow spill risk analysis, there is minimal risk of reducing survival by increasing spill up to dissolved gas levels of 125%.
- It is difficult to define a flow survival relationship because survival is the combined result of many interacting variables and the methodology for estimating survival does not lend itself to identifying each individual environmental or biotic variable individually.

Juvenile fall chinook migrants

- Wild subyearling fall chinook salmon spend from 20 to 42 days in Lower Granite Reservoir primarily during the months of July and August
- Summer flow augmentation decreases the time young fall chinook salmon spend in Lower Granite Reservoir by 1 to 5 days
- Survival of wild subyearling Snake River fall chinook is influenced simultaneously by flow and temperature
- Summer flow augmentation increases flow and decreases temperature
- Summer flow augmentation in July and August increases survival of wild subyearling fall chinook migrants
- Shifting flow augmentation from July and early August to later times in the year would decrease survival of the largest portion of the wild subyearling fall chinook salmon run

Adult return analysis

- Numerous mechanisms exist by which flow and water velocity may affect survival from migrating smolt to adult return.
- Juvenile migration conditions and ocean climate conditions were both influential in explaining patterns of adult recruitment of Snake River spring and summer chinook (spawner to spawner ratio)
- The BIOP flow targets appear to represent a minimum needed to maintain the Snake River spring summer chinook populations for average to good ocean conditions and provide inadequate protection for poor ocean conditions
- The Councils proposed relaxation of spring flow targets would increase water travel time and reduce protection against population declines and the likelihood of rebuilding spring and summer chinook stocks.
- Juvenile migration conditions and ocean climate conditions were both influential in explaining patterns of SARs in Snake River spring and summer chinook and steelhead.
- Relaxation of Spring flow objectives would likely decrease the SARs of wild Snake River spring and summer chinook and steelhead

Background of Flow Related Effects on Salmonid Smolt Travel Time, Rate of Seaward Movement, and Survival and Adult Returns

The analyses are approached in three components, the Snake River from Lower Granite to McNary Dam, Mid-Columbia from Rock Island to McNary and Lower Columbia River reaches from McNary to Bonneville tailrace. The following assessment focuses on the migration characteristics of juvenile salmonids including; travel time (migration speed), rate of seaward

movement, survival and migration timing, addressing these migration characteristics and the suite of biotic and abiotic factors that affect them.

Increases in flow in the hydrosystem are thought to be beneficial to migrating young salmonids for several reasons. These species evolved in systems without dams and were dependent on the river current to aid in their migration to the ocean. The migration of spring/summer and fall chinook and steelhead was timed with periods of high spring runoff. During a free-flowing condition Snake River yearling chinook and steelhead migrated to the ocean in about $^{1}/_{3}$ to ½ the time that is now observed with the dams in place. Dam construction changed juvenile fall chinook salmon life history in the Snake River basin by shifting production to areas with relatively cool water temperatures and comparatively lower growth opportunity. Consequently, young fall chinook salmon do not attain migratory status until late spring and the majority of the wild fish are present in lower Snake and Columbia River reservoirs in July and August after spring runoff is complete (Connor et al. 2002). Increases in the time spent in the reservoirs increases the exposure time to higher temperature and predators, now more abundant in the reservoir system than in pre-dam riverine conditions. (Poe et al 1991, Poe et al 1994) In addition to the direct effects of increases in flow on downstream passage of smolts, there are several other flow related mechanisms that manifest in life history constraints hence smolt survival. Increases in flow are associated with decreases in temperature and increases in turbidity. When flow falls to low levels, the accompanying increases in temperature increase the energetic demands for migrating smolts, increase their susceptibility to disease, disrupt smoltification, and increase the energy demands of predators hence predation on smolts. Low turbidity increase the susceptibility of smolts to visual predators such as fish and birds. Studies also suggest that the extended time smolts spend in freshwater affect marine survival by depleting energy reserves before the smolts arrive at the ocean. This phenomenon is especially prevalent under low flow conditions (Congelton, ACOE Delayed Mortality Workshop). A delay in seawater entry might also disrupt physiological changes necessary for adapting to saltwater. Decreased flows may also form greater physical barriers with the freshwater/saltwater interface (Schreck and Stahl 1998).

Travel time is one of the key migrational characteristics reflecting the dynamics of the migration of juvenile salmonids. The physiological condition of smolts changes over time and arrival at the estuary during the “biological window” determines the success of the smolts transition to seawater. Studies conducted since 1998 (Congleton et al., 2000, 2001 and 2002) have observed the rate of energy use and the blood chemistry changes that occur in fish as they migrate from hatcheries above Lower Granite Dam to Bonneville Dam In general, the juvenile chinook salmon studied were in negative energy balance throughout the downstream migration. The low flows in 2001 caused fish to undergo a migration that was significantly longer and the low flows and extended travel times resulted in the exhaustion of lipid reserves at points further upstream and greater use of protein reserves than in earlier years. The use of protein reserves means that muscle mass is metabolized and the activities of critical rate-limiting enzymes involved in metabolism, saltwater adaptation, and other vital functions may be reduced (Congleton, 2002).

Giorgi et al. (2002) points to these life-history constraints as rationale for flow augmentation. They provided information supporting increased migration rates with increases in flow for yearling chinook and steelhead (Sims and Ossiander 1981, Berggren and Filardo 1993). Most of

these analyses demonstrate increasing migration speeds by increasing flows provides the greatest benefits at lower flows. Regardless of flow level, several studies have produced equivocal results with respect to the relation between flow and seaward movement of summer migrating subyearling chinook salmon. Berggren and Filardo (1993), Giorgi et al. (1997), and Tiffan et al. (2000) studied ocean-type chinook salmon passing downstream in Columbia River reservoirs. Berggren and Filardo (1993) concluded that seaward movement of summer migrants increased as flow increased, thus flow augmentation helps to mitigate dam-caused passage delays. Tiffan et al. (2000) concluded that flow was weakly related to seaward movement. Giorgi et al. (1997) concluded that there is no evidence for a relation between downstream migration rate and flow. A recent study, however, showed that wild subyearling fall chinook salmon progress through a series of complicated migrational behaviors during which their response to changes in flow varies (Connor et al. In press a). Subyearling fall chinook salmon respond to increases in flow as they pass downstream from the free-flowing Snake River to Lower Granite Dam. The Connor et al. analysis, however, failed to find evidence for a flow-migration rate relation as fish passed downstream between Lower Granite and Little Goose dams probably because of limitations on their study. This does not suggest a downstream relationship does not exist, rather that different degrees of smoltification will result in different rates of migration and therefore, complicate such relationships.

Giorgi et al. (2002) reiterate a concern by several researchers that many environmental variables may be responsible for patterns of survival through the hydrosystem. Flow and spill are unlikely the only variables affecting survival; however, many of the variables of concern are a result of changes in flow. Turbidity and temperature, for example, have been suggested to be driving survival patterns, but these are often dependent on flow, flow is not dependent on turbidity and temperature. These factors may make flow/survival patterns more difficult to observe but they should not be used as evidence that flow is not an important driver to relationships that we do observe.

A large proportion of Snake River spring/summer chinook and steelhead have been removed from the river for transportation since Snake River dam construction, yet their subsequent survival may also be influenced by the environmental conditions (flow and spill in particular) experienced prior to collection and transportation (Budy et al. 2002; Mundy et al. 1994). Examples of mechanisms by which flow or water travel time may influence post-transport survival of smolts include effects of delayed migration on energetic condition (reduced lipids), exacerbated by stress at the collection projects, holding facilities and in transportation.

As with transportation and spill, considerations to the impacts of flow outside the hydrosystem, including delayed mortality to both transported fish and those that migrated in-river (Budy et al. 2002), must be taken into consideration. Flow may be important below Bonneville where fish and avian predators are most abundant and survival is not currently estimated as fish and avian predators are most abundant in this area. As stated above, smolts undergo dramatic physiological changes to cope with entry into the estuary and saltwater. Changes in flow can greatly affect the physiological timing of this transition. For example, Schreck and Stahl (1998) have documented that smolts that are stressed (from barging or migrating in-river) avoid entry into saltwater by remaining on the floating freshwater lens at the saltwater-freshwater interface. This forces smolts to the surface where they are susceptible to avian predation. Increased flows

out of the Columbia enhance mixing of freshwater and saltwater and aid migrating salmon into the transition to saltwater decreasing this delayed hydrosystem mortality. Through these mechanisms both transported and in-river fish can be greatly affected by the flow regime. How this and other factors in the hydrosystem affect survival back to adults is of prime importance. Giorgi et al. (2002) does not evaluate the impacts of flow on these other life stages but evidence can be found for this in NMFS white papers, and in previous fish and wildlife agency comments to the Council.

Methods of Travel time and Survival Data Analysis for Juvenile Steelhead and Chinook Springs Migrants

Travel time and survival

The juvenile migrants considered for these analyses represent groups for which travel time and survival was estimated for the entire Snake River (Lower Granite Dam to McNary Dam) reach using PIT tag technology. The first year that PIT tag data was available for survival estimation in the entire Lower Granite to McNary reach was 1995, however, not until 1998 when installation of full bypass PIT tag detection at John Day Dam was completed did we begin to obtain reliable estimation of survival to McNary Dam. Although survival studies using PIT tags were initiated as soon as the PIT tag detection units were installed at the projects, the reaches covered were limited in the early years. In 1993 survival studies could only be conducted between Lower Granite and Little Goose dams. This was expanded in 1994 to the Lower Granite to Lower Monumental river reach when PIT tag detectors were installed at additional projects. In 1995 to 1997, direct estimates of survival in the Lower Granite to McNary Dam reach were possible; however, due to limited detection capability at John Day Dam (detection of sampled fish from one gatewell slot out of 48) and moderate detection capability at Bonneville Dam due to operational spill levels at that facility, the resulting reach survival estimates had low precision. The detection limitations of the early years necessitated the extrapolation of the shorter river reach survival estimates to the longer reach (Lower Granite to McNary). It is now known that these earlier estimates using extrapolation resulted in a miss-representation of survival when applied to the longer reach. Consequently, we have chosen not to include these estimates in our analysis. Reliable estimation of survival to McNary Dam was not possible until installation of bypass detectors at John Day in 1998. For these reasons we have chosen to use survival estimate from 1998 to 2002 in creating the bivariate and multiple regression models. The above detection limitations below McNary Dam do not impact the quality of the travel time data from Lower Granite Dam to McNary Dam and therefore, travel time analyses use data from 1995 to 2002 for yearling chinook and 1996 to 2002 for steelhead. All juvenile yearling chinook and steelhead marked using PIT tags at hatcheries and fish traps above Lower Granite Dam and subsequently recaptured at the initial site, as well as those fish marked and released at Lower Granite Dam, were used in our analysis.

For the analyses pertaining to the Mid Columbia River, travel time and survival was estimated from Rock Island to McNary dams for releases of yearling chinook and steelhead marked and released at Rock Island Dam from 1998 to 2002. The Mid-Columbia fish used in our analysis were marked at Rock Island as part of the Fish Passage Center's Smolt Monitoring Program.

For the Snake River this study used all juvenile yearling chinook and steelhead marked using PIT tags at hatcheries and fish traps above Lower Granite Dam and subsequently recaptured at the initial site, as well as those fish marked and released at Lower Granite Dam. In the Mid Columbia the fish used were marked at Rock Island Dam as part of the Fish Passage Center's Smolt Monitoring Program. The accuracy and precision associated with any estimate of survival or travel time will be dependent on the number of fish in a release group (N) and the number of fish subsequently recaptured. The intent of the analysis was to relate the dependent variables (travel time and survival) to a series of independent environmental variables. As fish migrate through the hydrosystem the initial release group disperses over time making the description of an average environmental condition difficult. The best chance of describing the environmental variable for each group was to limit the time frame over which the variable was estimated before groups became too dispersed and to reduce the overlap among groups. Consequently, when grouping daily releases of PIT tagged groups together over longer periods of time to provide the most accurate and precise estimate, it is important to not group too large a time period to mask the effect of environmental variables. For smolts originating in the Snake River basin, travel time and survival estimates were developed for each weekly release block in the available years of data. Each year was divided into eight weekly periods for wild and hatchery yearling chinook and into six weekly periods for steelhead. For the Mid Columbia migrants, the season was divided into three two-week blocks for each year.

Smolt travel time is amount of time needed for juvenile migrants to transit the river system between any two points. For each temporal block, an estimate of median travel time was calculated from the smolts transiting the entire reach of interest.

Survival is estimated using the Cormack-Jolly-Seber (CJS) tag-recapture methodology. This method estimates survival components between each dam within the index reach having PIT tag detection equipment such as Little Goose, Lower Monumental, and McNary dams (additional detections at John Day and Bonneville dams downstream of McNary Dam also contribute to process of estimating survival in the upstream reaches. In the case of the Snake River reach, the survival estimate is the product of survival from Lower Granite Dam tailrace to Little Goose Dam tailrace, Little Goose Dam tailrace to Lower Monumental Dam tailrace, and Lower Monumental Dam tailrace to McNary Dam tailrace. In the case of the Mid-Columbia River reach, the survival estimate is the single estimate from Rock Island Dam tailrace to McNary Dam tailrace. The Snake River reach includes four reservoirs and dams and the Mid-Columbia River reach includes three reservoirs and dams.

Because the recovery of the PIT tags is dependent on being observed in a bypass system at downstream hydroprojects, the river and project operations exert considerable influence on the ability to obtain sufficient tag recoveries to obtain a valid estimate. Several criteria were employed to distinguish among the resulting estimates to assure their validity. Any temporal blocks which contained less than 300 smolts in the release group provided too few recoveries to

make valid estimates of survival. Consequently, no estimates of survival and travel time were made when less than 300 smolts were available. In addition, another criterion was applied to the estimates of survival. When the coefficient of variation (standard error divided by estimate) of any component survival estimate exceeded 0.25, the full reach survival estimate was excluded from the analysis. This check was made prior to multiplying the several component survival estimates to create a full reach survival estimate, as was the case in the Snake River basin. Whenever a component survival estimate was greater than 1, then the standard error divided by 1 was used as the threshold criteria. In the years 1998 to 2002, only one wild chinook, two hatchery chinook, and one steelhead temporal block needed to be excluded due to the minimum coefficient of variation criterion. In the Snake River reach, the final survival data set contained 66 estimates of survival for yearling chinook (hatchery and wild combined) and 26 estimates for steelhead. In the Mid Columbia, the final survival data set contained 13 estimates for yearling chinook and 15 estimates for steelhead. All survival estimates were accompanied with associated environmental variables.

Environmental Variables: Water transit time, spill proportion, and water temperature

Predictor variables of in-river survival were considered that are related to how flow or velocity may affect the survival of smolts migrating in-river through the hydro system in specific reaches of the Snake and Columbia rivers. The final set of predictor variables included a water velocity related variable, a spill related variable, and river temperature.

Water Transit Time

Previous analyses suggested that changes in flow produced changes in water velocity, which determined how quickly smolts migrated through the hydrosystem. The actual flow regime experienced by a group of migrating juvenile fish is difficult to quantify. Past analyses have used an index of flow through a specific reach for a period of time around the median passage dates of the migration or an average flow over the entire passage period. Because of the discrete relation between flow and water transit time (WTT) (also known as water particle travel time) and the implication of velocity as the important determining factor, the flow variable was quantified as the summation of water transit times for each reservoir incorporated in a reach (Figures 1 and 2 showing relation between WTT and average flow in the Snake River and McNary Dam reservoir).

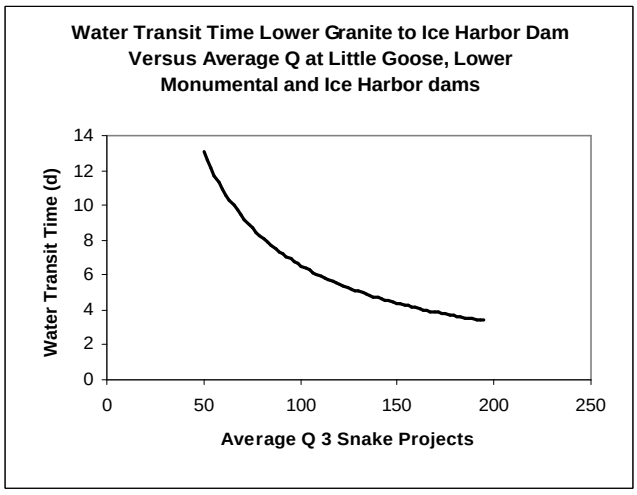

Figure 1. Relation between water transit time flow in Lower Snake River.

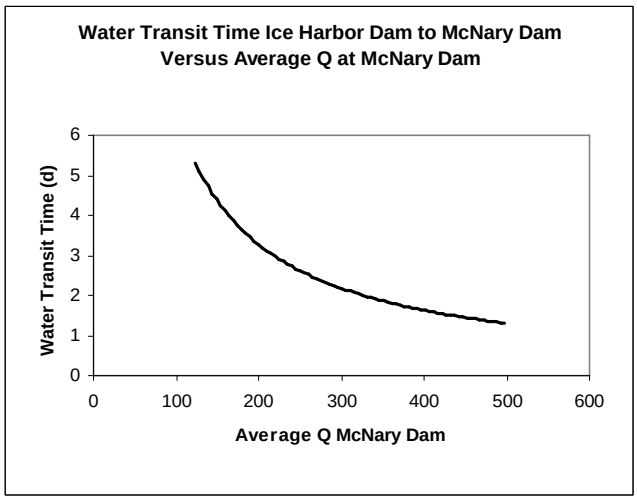

Figure 2. Relation between water transit and average time and average flow in McNary Pool.

The water transit time is the estimated amount of time required for a water particle to travel the fixed distance from the start of the reach to the end of the reach (WTT = distance / average water velocity). This fixed distance was 140 miles for the Snake River reach from Lower Granite Dam tailrace to McNary Dam tailrace and 161 miles for the Mid-Columbia River reach from Rock Island Dam tailrace to McNary Dam tailrace. The median travel time was estimated to each down stream project for each weekly block. The mid-date of release from LGR was used and to it was added median travel time for the release group to the downstream project. For each day, WTT is computed by dividing each reservoir volume by its corresponding daily average flow to determine the water particle transit time for that day. Reservoir volumes are obtained using COE tables and current reservoir elevations. For each reservoir, an average WTT is computed over a 7-day window of WTT's around the date of median passage of the fish of interest at the reservoir's downstream dam. These average WTT are then summed over the number of reservoirs in the reach of interest. The dates of median fish passage at each dam are obtained from PIT tagged smolts released from or passing during weekly blocks of time at Lower Granite Dam. This process is repeated for each weekly release group of PIT tagged smolts at Lower Granite Dam. Each weekly (7-day) release, starting April 1 for yearling chinook and April 17 for steelhead, was numbered sequentially from first through last week for each year to create a variable for week of entry into the reach.

Spill Proportion

For each reservoir and dam segment of the reach, survival may be viewed as the product of two components, a reservoir survival component and a dam passage component. In the dam passage component, survival may be viewed as the weighted average survival across each passage route, such as spillway route, turbine route, and bypass channel route (if present), where the weight is equal to the population of smolts using each route. Because the spill passage route has been shown to be the safest route of passage (except during periods of excessively high flows when gas may be a problem), increases in the amount of spill and numbers of fish passing through that route will have a direct effect on the reach survival estimate. Therefore, it is essential to include

a spill related variable in all multiple regression models, otherwise the effect of spill will be confounded within the parameter estimates of the other variables in the model (*i.e.*, a case of model misspecification). The variable representing spill at Little Goose, Lower Monumental, Ice Harbor, and McNary between April and June of 1998 and 2002 was the percentage of daily spill to total discharge. It was calculated using daily average spill and daily average total discharge at each project. Each daily percent Spill/Total Discharge was averaged over a seven-day passage window (centered around the median passage date) for each species and project. The average spill proportion is denoted as SPILLPROP in the subsequent text and tables.

Water Temperature

The dates of median fish passage at each dam are obtained from PIT tagged smolts released from or passing during weekly blocks of time at Lower Granite Dam. From these same 7-day windows around the dates of median smolt passage at each dam of interest, averages of river temperature are generated. Initially, a variable for the week of entry into the reach was considered, however, it was felt that the river temperature variable would already include the effect of this temporal variable in two ways. First, the general timing of the smolts at Lower Granite Dam is highly influence by river temperature. In years of warmer winters and earlier warming of the river, the smolts begin their migration earlier, whereas in years of cooler winter and later snowmelt, the smolts begin their migration later. Second, river temperature increase over time during the migration period, and so any effects of week of entry into the reach is already confounded within the river temperature variable. Therefore, week of entry into the reach was not used in the multiple regression analyses. The water temperature variable is denoted simply as TEMP in the subsequent text and tables.

Results of Travel Time Analysis

Snake River Reach: Lower Granite Dam to McNary Dam

Bivariate relations between smolt travel time and WTT were modeled using linear regression (Table 1). Relations for smolts originating above Lower Granite Dam and migrating between the tailrace of Lower Granite Dam and McNary Dam are shown for wild yearling chinook in Figure 3, hatchery yearling chinook in Figure 4, and steelhead (wild and hatchery) in Figure 5.

Table 1. Summary of linear regressions of median travel time versus water transit time for wild and hatchery yearling chinook and steelhead.

Group	Regression Equation	R^2
Wild Chinook	y = 1.245x + 0.8745	0.51
Hatchery Chinook	y = 1.107x + 2.3327	0.58
Steelhead	y = 1.250x - 1.2075	0.87

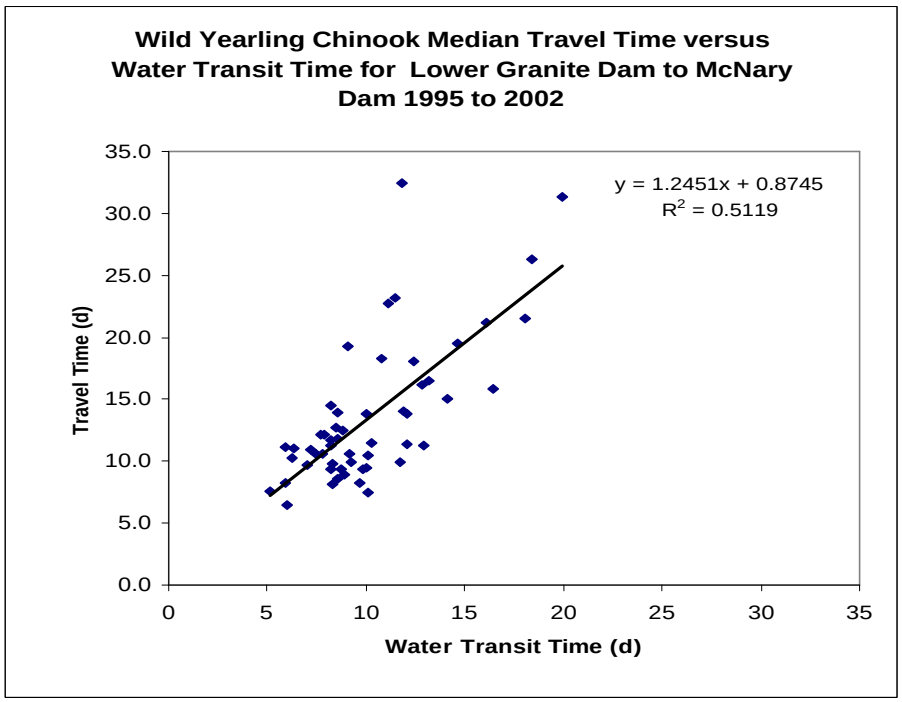

Figure 3. Wild yearling chinook travel time versus water transit time.

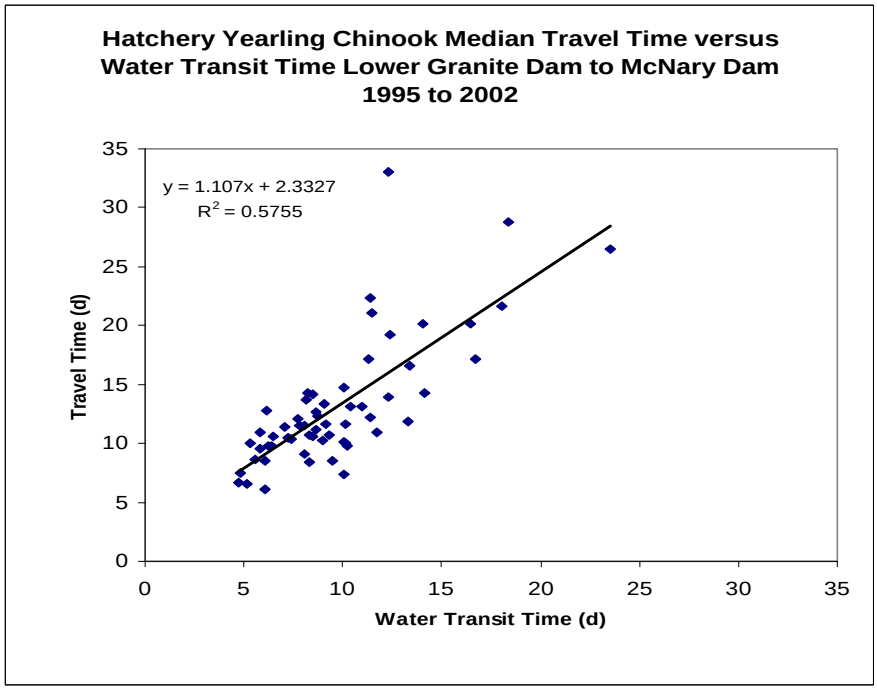

Figure 4. Hatchery yearling chinook travel time versus water transit time.

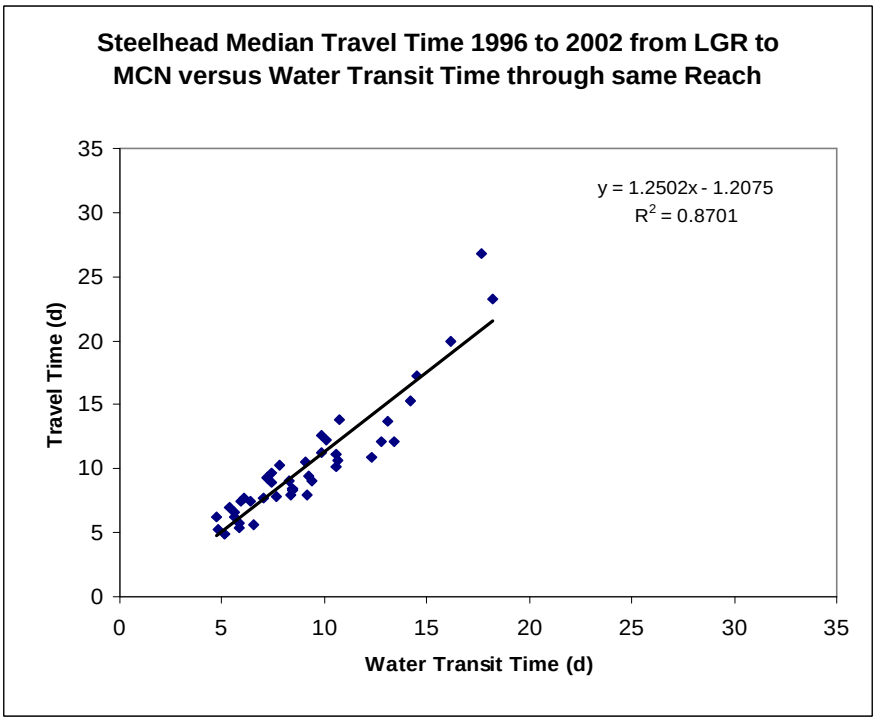

Figure 5. Steelhead travel time versus water transit time.

Mid-Columbia River Reach: Rock Island Dam to McNary Dam

Bivariate relations between smolt travel time and WTT were modeled using linear regression (Table 2). Relations for smolts originating above Rock Island Dam and migrating between the tailrace of Rock Island Dam and McNary Dam are shown for yearling chinook in Figure 6 and steelhead in Figure 7. For each species, the data is a mixture of wild and hatchery smolts.

Table 2. Summary of linear regressions of median travel time versus water transit time for wild and hatchery chinook and steelhead.

Group	Regression Equation	R^2
Yearling Chinook	y = 2.0797x - 1.8816	0.55
Steelhead	y = 1.8899x - 3.5432	0.93

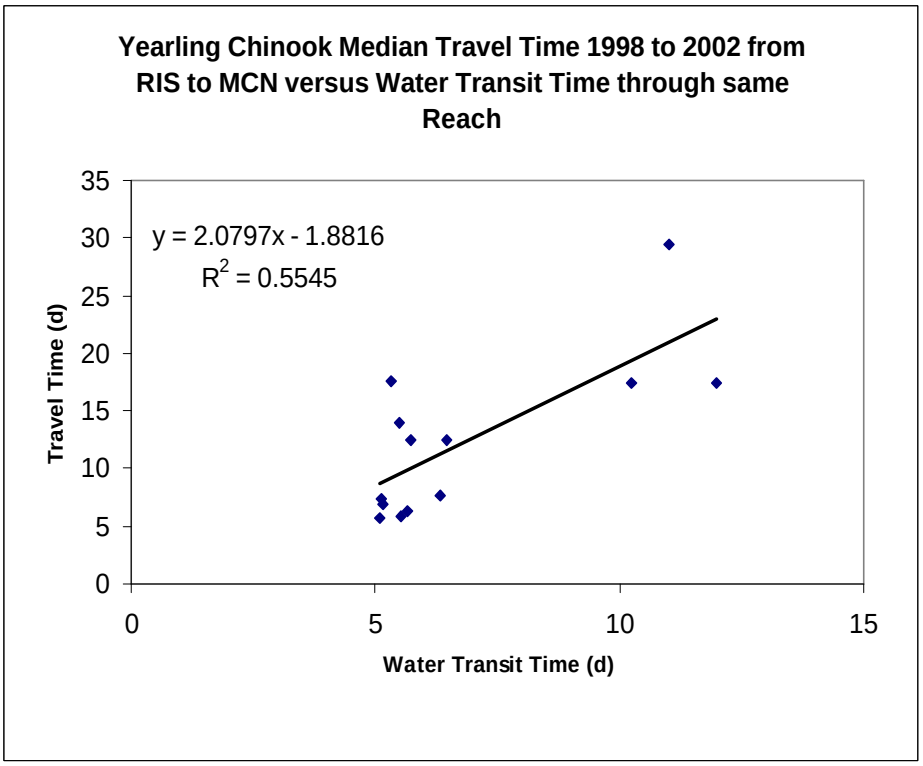

Figure 6. Yearling chinook travel time versus water transit time.

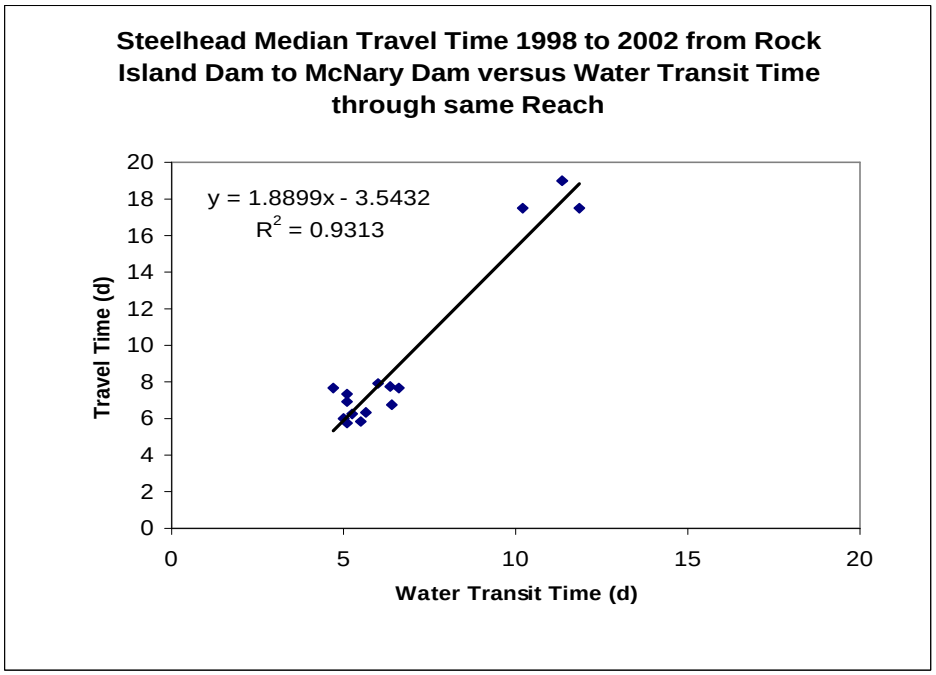

Figure 7. Steelhead travel time versus water transit time.

Results of Survival Analysis

Snake River Reach: Lower Granite Dam to McNary Dam

Survival Analysis for steelhead

The water transit time (WTT) and spill proportion (SPILLPROP) variables both had high correlation with the dependent variable survival (Table 3). Correlation between WTT and SPILLPROP was r = -0.81, a level low enough so that multicollinearity is not a problem. The square root of the variance-inflation factor, sqrt[1/(1-R^2)] provides a measure of the extent to which the standard error of the regression coefficients will be inflated due to high correlation between the predictor variables in a model. In the case of our model with WTT and SPILLPROP, the regression coefficient standard error will be inflated by a factor of approximately 1.7. Myers (1990) and Fox (1991) show that multicollinearity doesn't become a problem until the variance-inflation factor exceeds 10, which triples the standard error of the regression parameters. A plot of estimated survival of steelhead from the tailrace of Lower Granite Dam to the tailrace of McNary Dam relative to WTT shows a linear relation in Figure 8.

Table 3. Correlation matrix for variables related to steelhead.

	SURVIVAL	WTT	SPILLPROP
WTT	-0.914		
SPILLPROP	0.869	-0.809	
TEMP	-0.430	0.300	-0.464

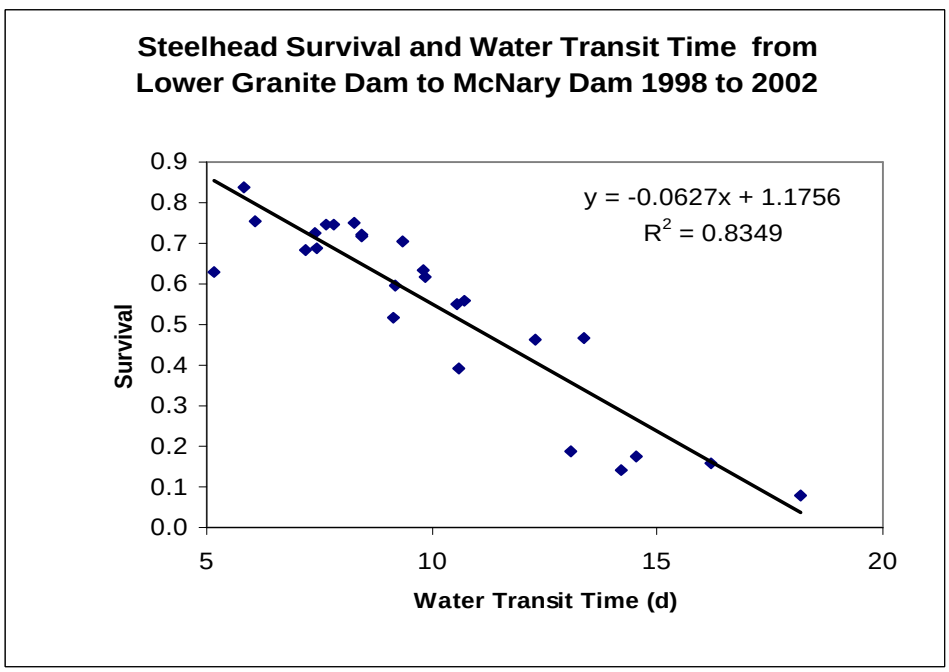

Figure 8. Steelhead survival versus water transit time

In the multiple regression analysis for steelhead, WTT and SPILLPROP were both significant variables in explaining variation in the dependent variable survival (Table 4). In the presence of these two variables, water temperature (TEMP) did not significantly explain any variation in survival. Since the various routes of passage, each with differential rates survival for passing fish, at a particular dam is an integral component of any reach "true" survival rate, it is encouraging to see a spill-related variable remain in the model. Any mechanistic model should always include the influence of spill, and it does so in the steelhead regression model. The joint model of WTT and SPILLPROP provides the best model for predicting steelhead survival in the Snake River reach.

Table 4. Multiple regression models for predicting survival of steelhead salmon in the Snake River from the tailrace of Lower Granite Dam to the tailrace of McNary Dam.

	Variable	Coefficient	SE	P	MSE	R^2
N = 26	Constant	0.79901	0.13203	0.00000	0.00639	0.87
	WTT	-0.04184	0.00831	0.00004		
	SPILLPROP	0.00527	0.00117	0.00508		

Survival for Yearling Chinook

Analysis of covariance was used to determine whether hatchery and wild chinook differed in survival response as a function of the predictor variables. Wild and hatchery chinook did not significantly differ with any of the predictor variables (Table 5). Plots of estimated survival of yearling chinook from the tailrace of Lower Granite Dam to the tailrace of McNary Dam relative to WTT shows similar linear relations for hatchery and wild fish (Figures 9a and 9b, respectively). All further analyses were conducted on the combined set of wild and hatchery chinook data.

Table 5. Analysis of Covariance comparison of hatchery and wild yearling chinook survival when all covariates are accounted for in the model.

	Variable	SS	df	MSE	F-ratio	P
N = 66	RearType	0.00191	1	0.00191	0.32314	0.57182
H = 32	WTT	0.05225	1	0.05225	8.81804	0.00426
W= 34	SPILLPROP	0.04096	1	0.04096	6.91232	0.01082
	TEMP	0.06892	1	0.06892	11.63241	0.00115
	Error		61	0.00593		

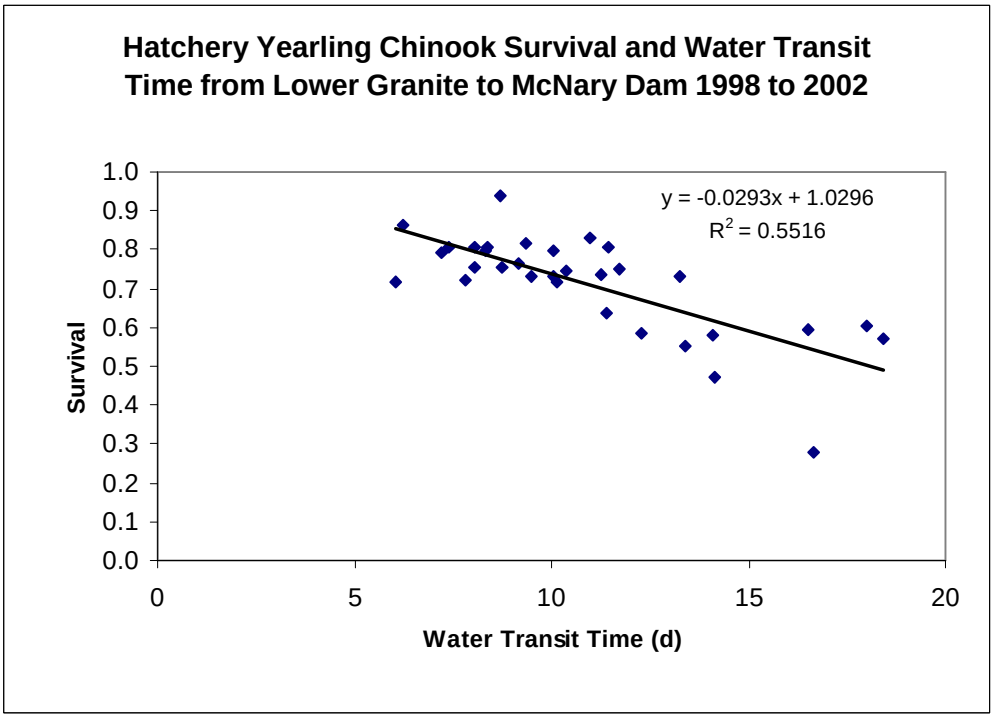

Figure 9a. Hatchery yearling chinook survival versus water transit time.

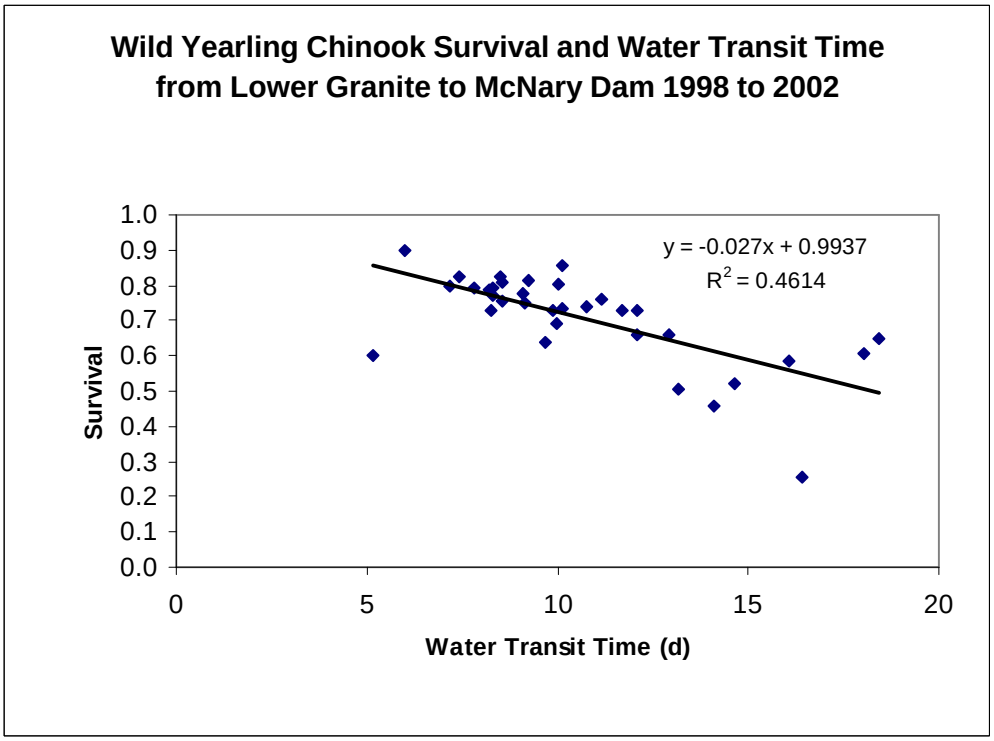

Figure 9b. Wild yearling chinook survival versus water transit time.

For the combined wild and hatchery yearling chinook, the WTT and SPILLPROP variables both had high correlation with the dependent variable survival (Table 6). As was observed with steelhead, the correlation between WTT and SPILLPROP for yearling chinook was r = -0.81, a level low enough so that multicollinearity is not a problem

Table 6. Correlation matrix for variables related to wild and hatchery yearling chinook salmon.

	SURVIVAL	WTT	SPILLPROP
WTT	-0.70898		
SPILLPROP	0.75498	-0.80546	
TEMP	-0.46136	0.16461	-0.34821

In the multiple regression analysis for yearling chinook, WTT and SPILLPROP were both significant variables in explaining variation in the dependent variable survival (Table 7). In the presence of these two variables, TEMP also was significant in explaining variation in survival. The joint model of WTT, SPILLPROP, and TEMP provides the best model for predicting yearling chinook survival in the Snake River reach.

Table 7. Multiple regression models for predicting survival of combined hatchery and wild yearling chinook salmon in the Snake River from the tailrace of Lower Granite Dam to the tailrace of McNary Dam.

	Variable	**Coefficient**	**SE**	**P**	**MSE**	**R^2**
N = 66	Constant	1.09264	0.13901	0.00000	0.0586	0.65
	WTT	-0.01497	0.00504	0.0042		
	SPILLPROP	0.00281	0.00106	0.01027		
	TEMP	-0.02624	0.00765	0.00109		

Mid-Columbia River Reach Rock Island Dam to McNary Dam

Survival Analysis for steelhead

For steelhead in the Mid-Columbia River reach, WTT had the highest correlation with the dependent variable survival, while both SPILLPROP and TEMP had similar moderate levels of correlation with survival (Table 8). The correlation between WTT and SPILLPROP for steelhead was r = -0.87, a level still low enough so that multicollinearity is not a problem. A plot of estimated survival of steelhead from the tailrace of Rock Island Dam to the tailrace of McNary Dam relative to WTT shows a linear relation in Figure 10.

Table 8. Correlation matrix for variables related to steelhead salmon.

	SURVIVAL	WTT	AVGSPILLPROP
WTT	-0.808		
AVGSPILLPROP	0.647	-0.870	
AVTEMP	-0.587	0.312	-0.193

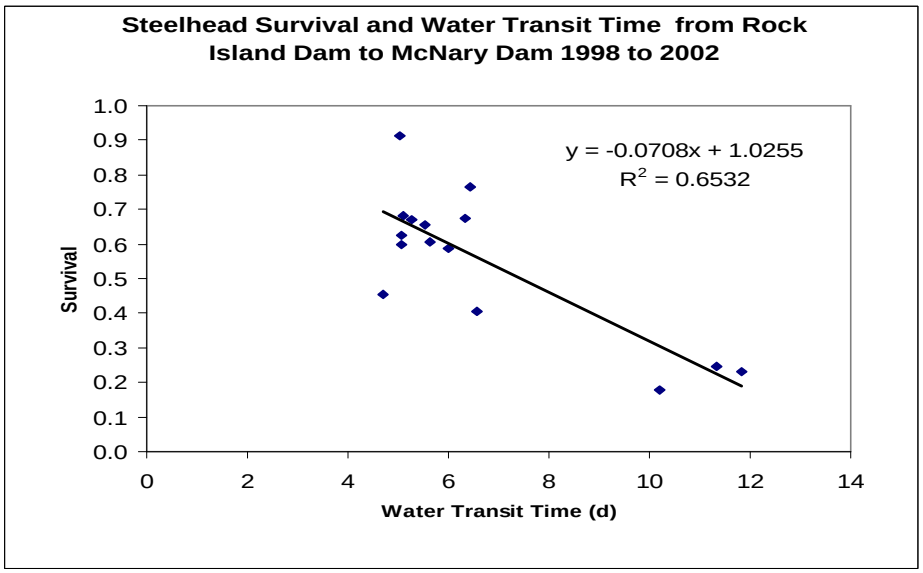

Figure 10. Steelhead survival versus water transit time.

In the multiple regression analysis for steelhead, WTT and TEMP were both significant variables in explaining variation in the dependent variable survival (Table 9). In the presence of these two variables, SPILLPROP did not significantly explain any variation in survival. Since the level of spill at Wanapam and Priest Rapids dams remained fairly constant over the years covered in the analysis, it is not surprising that SPILLPROP did not explain additional variation in survival. However, this finding does not reduce the intrinsic benefits of spill. Any mechanistic model should always include the influence of spill, and when it doesn't, the effect of spill becomes confounded within the coefficients of the other parameters in the model. For survival prediction purposes, the joint model of WTT and TEMP provides the best model for predicting steelhead survival from the tailrace of Rock Island Dam to the tailrace of McNary Dam.

Table 9. Multiple regression models for predicting survival of steelhead salmon in the Mid-Columbia River from the tailrace of Rock Island Dam to the tailrace of McNary Dam.

	Variable	Coefficient	SE	P	MSE	R^2
N = 15	Constant	1.6135	0.2425	0.00002	0.01136	0.74
	WTT	-0.06065	0.01256	0.00041		
	TEMP	-0.0553	0.02138	0.02383		

Survival for Yearling Chinook

For yearling chinook in the Mid-Columbia River reach, WTT and SPILLPROP had similar moderate correlation with the dependent variable survival (Table 10). The correlation between WTT and SPILLPROP for steelhead was r = -0.83, a level low enough so that multicollinearity is not a problem, but higher than observed for yearling chinook in the Snake River reach. A plot

of estimated survival of yearling chinook from the tailrace of Rock Island Dam to the tailrace of McNary Dam relative to WTT shows a linear relation in Figure 11.

Table 10. Correlation matrix for variables related to yearling chinook salmon.

	SURVIVAL	WTT	AVGSPILLPROP
WTT	-0.543		
AVGSPILLPROP	0.461	-0.828	
AVTEMP	-0.230	0.421	-0.211

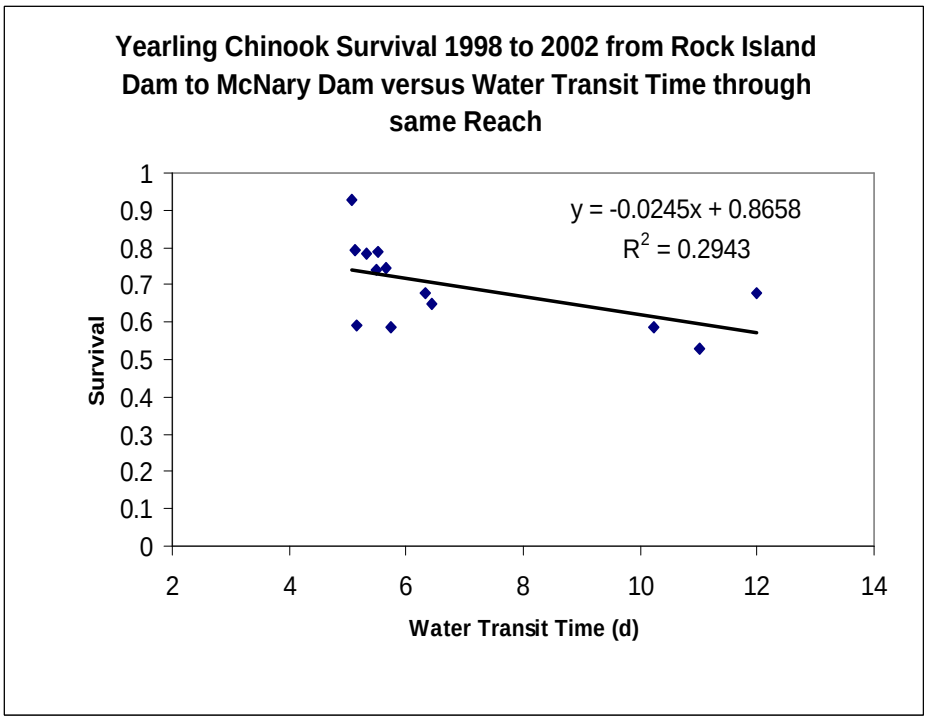

Figure 11. Yearling chinook survival versus water transit time.

In the multiple regression analysis for yearling chinook, only WTT was moderately significant in explaining variation in the dependent variable survival (Table 11). In the presence WTT, SPILLPROP did not significantly explain any variation in survival. Since the level of spill at Wanapam and Priest Rapids dams remained fairly constant over the years covered in the analysis, it is not surprising that SPILLPROP did not explain additional variation in survival. For survival prediction purposes, the simple bivariate model of WTT provides the best model for predicting yearling chinook survival from the tailrace of Rock Island Dam to the tailrace of McNary Dam.

Table 11. Multiple regression model for predicting survival of yearling chinook salmon in the Mid-Columbia River from the tailrace of Rock Island Dam to the tailrace of McNary Dam.

	Variable	Coefficient	SE	P	MSE	R^2
N = 13	Constant	0.86052	0.08282	0.00000	0.00956	0.23
	WTT	-0.02446	0.54250	0.05543		

Lower Columbia River Reach: McNary Dam to Bonneville Dam

Survival Analysis for steelhead

For combined hatchery and wild steelhead, the water transit time (WTT), spill proportion (SPILLPROP), and water temperature (TEMP) variables each had high correlation with the dependent variable survival (Table 12). Correlation between each pair of predictor variables was also very high, which lead to problems of multicollinearity when trying to include more than one predictor variable in the model. Thus, a model with only one predictor variable was obtained. Since WTT had the highest correlation with steelhead smolt survival, it entered into the bivariate model that explained the most variation in the dependent variable survival (Table 13). A plot of estimated survival of steelhead from the tailrace of Lower Granite Dam to the tailrace of McNary Dam relative to WTT shows a linear relation in Figure 12. Although a multiple regression model was not attainable, one must keep in mind that SPILLPROP still has a direct influence on the resulting magnitude of the survival estimate. This is because, as stated earlier, the survival of smolts that pass through the spill route is typically higher than any other passage route at a dam.

Table 12. Correlation matrix for variables related to steelhead.

	SURVIVAL	WTT	SPILLPROP
WTT	-0.959		
SPILLPROP	0.871	-0.969	
TEMP	-0.948	0.985	-0.930

Table 13. Bivariate regression model for predicting survival of steelhead salmon in the lower Columbia River from the tailrace of McNary Dam to the tailrace of Bonneville Dam.

	Variable	Coefficient	SE	P	MSE	R^2
N = 4	Constant	0.97747	0.10775	0.0119	0.00518	0.92
	WTT	-0.06481	0.01358	0.0412		

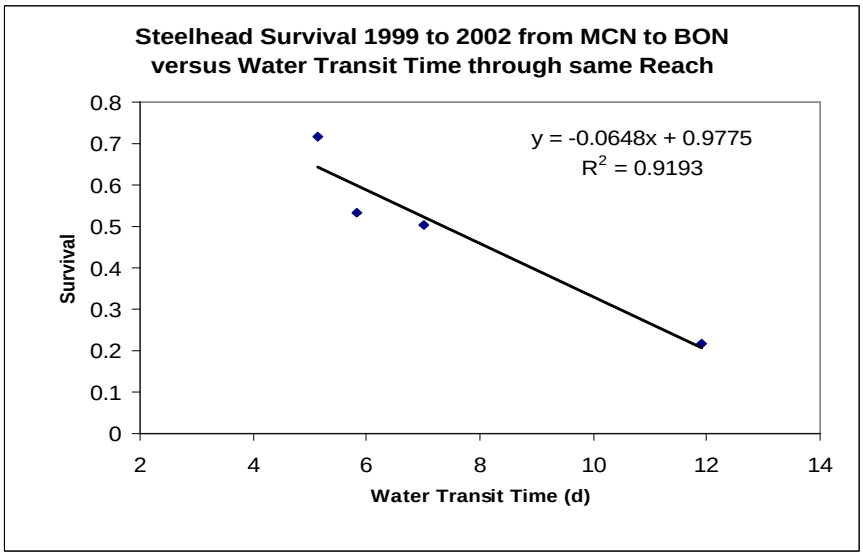

Figure 12. Steelhead survival versus water transit time

Survival for Yearling Chinook

For combined hatchery and wild yearling chinook, both WTT and SPILLPROP variables had high correlation with the dependent variable survival (Table 14), whereas AVTEMP had only a moderate correlation. Correlation between WTT and SPILLPROP was not high enough to create multicollinearity problems, but it was high enough to both variables from remaining together in a multiple regression model.

Table 14. Correlation matrix for variables related to yearling chinook salmon.

	SURVIVAL	WTT	SPILLPROP
WTT	-0.771		
SPILLPROP	0.870	-0.882	
TEMP	-0.433	0.431	-0.341

Since SPILLPROP had the highest correlation with yearling chinook smolt survival, it entered into the bivariate model that explained the most variation in the dependent variable survival (Table15). This is not to say that WTT is less important than SPILLPROP with regards to yearling chinook survival though. But it does show a major weakness in using regression techniques to pick the most important “causative” factors from the set of factors being considered in the modeling exercise. Although SPILLPROP has a direct influence on the resulting magnitude of the survival estimate, it level in the hydro system operation does not occur independent of the prevailing flows. Thus flows have a direct influence on WTT and so both variables must be considered as key elements affecting the inriver survival of smolts thorough the hydro system. A bivariate plot of estimated survival of yearling chinook from the tailrace of McNary Dam to the tailrace of Bonneville Dam is shown in Figure 13 relative to WTT and in Figure 14 relative to SPILLPROP.

Table 15. Bivariate regression models for predicting survival of yearling chinook salmon in the lower Columbia River from the tailrace of McNary Dam to the tailrace of Bonneville Dam.

	Variable	Coefficient	SE	P	MSE	R^2
N = 11	Constant	0.37096	0.05513	0.00009	0.00272	0.76
	SPILLPROP	0.87267	0.16458	0.00049		

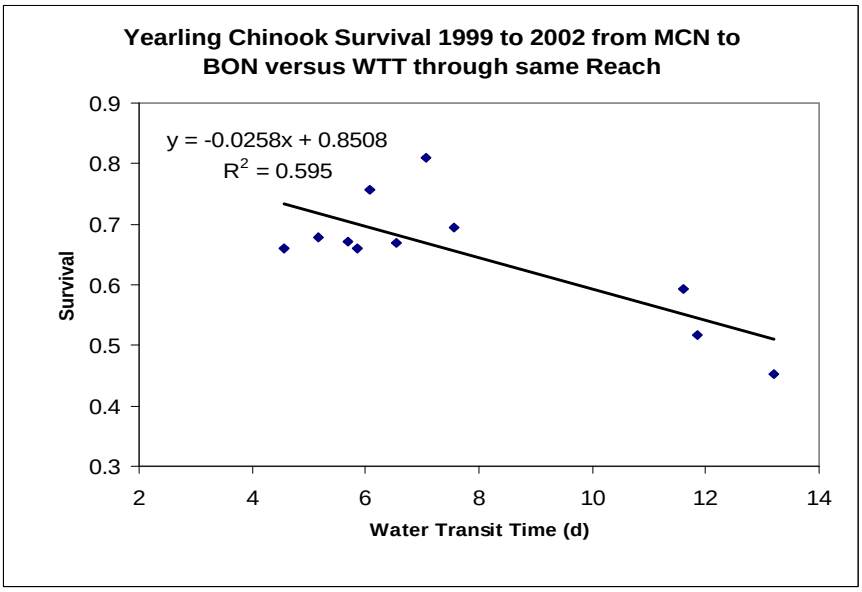

Figure 13. Yearling chinook survival versus water transit time.

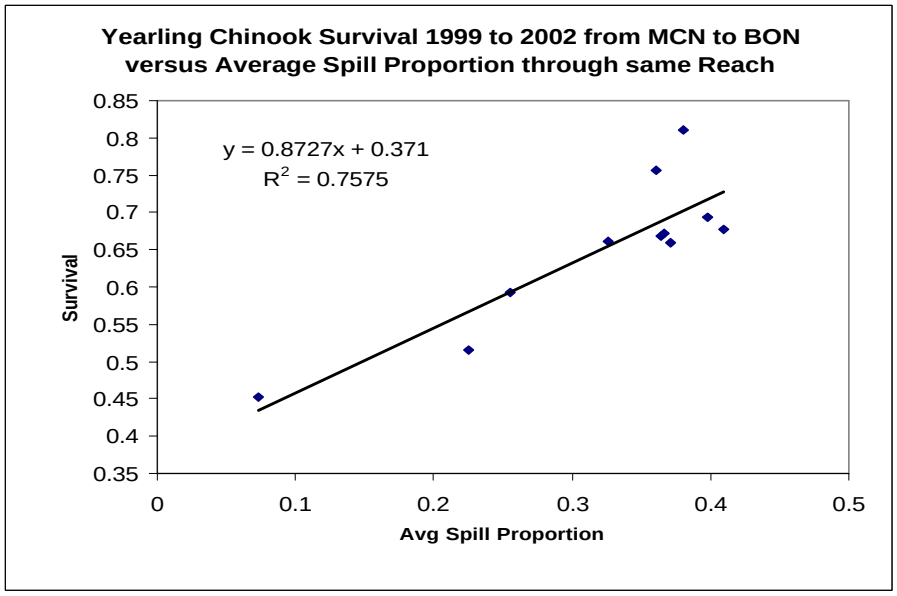

Figure 14. Yearling chinook survival versus average spill proportion.

Migration Timing in the Lower Columbia River as measured at John Day Dam

The population of juvenile salmon is not homogeneous throughout the entire migration season. Consequently, the concept of migration timing is extremely important in fish management. Some fish migrate in discrete time periods that may be significantly different from the timing displayed by the migration as a whole. We observed PIT tagged yearling chinook and steelhead at John Day Dam in 2001 and quantified their timing in the Lower Columbia River. Yearling chinook and steelhead stocks that originated in the Walla Walla, Umatilla and John Day rivers are the earliest stocks to pass John Day Dam in 2001. In 2001, the percent of PIT tagged yearling chinook from the John Day and Umatilla rivers detected at John Day Dam in April was approximately 53% and 13%, respectively (Table 16), whereas virtually no PIT tagged yearling chinook from the Snake and Mid-Columbia River basins were detected until May. The percent of PIT tagged steelhead from the John Day and Umatilla rivers detected at John Day Dam in April was approximately 31% and 11%, respectively (Table 17), and again virtually no PIT tagged steelhead from the Snake and Mid-Columbia River basins were detected until May.

Table 16. Proportion of PIT tagged yearling chinook detected at John Day Dam over specific periods of the 2001 migration season.

Dates of PIT tag detections at John Day Dam	Snake R basin	Mid-Columbia R basin at/above Rock Island Dam[1]	Yakima R basin	Umatilla R basin	John Day R basin
Total detections	14,086	2,091	4,041	1,291	1,743
3/30 – 4/30	0.0002	0.0000	0.0084	0.1332	0.5295
5/1 – 5/24	0.3369	0.1836	0.3606	0.7854	0.4509
5/25 – 6/15	0.5422	0.6738	0.5048	0.0736	0.0132
6/16 – 9/15	0.1207	0.1425	0.1262	0.0077	0.0063

[1] PIT tagged hatchery chinook released on alternating days at Rock Island & Rocky Reach dams in large numbers for specific studies were omitted because they do not represent the timing of the run-of-the-river fish.

Table 17. Proportion of PIT tagged steelhead detected at John Day Dam over specific periods of the 2001 migration season.

Dates of PIT tag detections at John Day Dam	Snake R basin	Mid-Columbia R basin at/above Rock Island Dam	Walla Walla R basin	Umatilla R basin	John Day R basin
Total detections	440	59	23	1,005	97
3/30 – 4/30	0.0045	0.0000	0.0000	0.1124	0.3093
5/1 – 5/24	0.4841	0.1525	0.8696	0.7532	0.6082
5/25 – 6/15	0.3886	0.5254	0.0870	0.1085	0.0825
6/16 – 9/15	0.1227	0.3220	0.0435	0.0259	0.0000

Rate of Seaward Movement of Subyearling Fall Chinook Summer Migrants Measured from Release in the Free-flowing Snake River to Passage Lower Granite Dam

Fall Chinook Rate of Seaward Movement Methods

From 1992 to 2001, U.S. Fish and Wildlife Service personnel used a beach seine to capture juvenile fall chinook salmon in the free-flowing Snake River (Connor et al. In press a). Sampling typically started in April soon after fry began emerging from the gravel. Sampling was conducted at permanent stations 1 d/week in the upper reach of the Snake River, and 2 d/week in the lower reach. Supplemental sampling was conducted 1 or 2 d/week for three consecutive weeks at additional stations within each reach once the majority of fish were at least 60-mm fork length. Sampling was discontinued in June or July when the majority of fish had moved into Lower Granite Reservoir. Passive integrated transponder tags were inserted into fall chinook salmon 60-mm fork length and longer. Data were pooled the data across reaches and years (1992-2001) to increase the range of the predictor variables (Berggren and Filardo 1993; Giorgi et al. 1997).

Tagged fish were released at the collection site after a 15-min recovery period. Some of the PIT-tagged fish were detected after they passed into the fish bypass systems of Lower Granite Dam. Rate of seaward movement for PIT-tagged fall chinook passing downstream from initial tagging sites to Lower Granite Dam was calculated as the distance traveled to Lower Granite Dam (located 173 km from the Snake River mouth) divided by travel time to Lower Granite Dam.

The predictor variables analyzed included: flow, the mean stream discharge (m^3/s) measured by U. S. Army Corps of Engineers personnel at Lower Granite Dam between initial tagging of a PIT-tagged fall chinook salmon and its detection at Lower Granite Dam; temperature, the mean temperature (^oC) measured by U. S. Army Corps of Engineers personnel in the forebay of Lower Granite Dam between initial tagging and detection at Lower Granite Dam; tagging date, day of year a fish was initially tagged; fork length, fork length (mm) measured on at initial tagging; and, riverine distance, the distance (km) traveled in the free-flowing Snake River before entering Lower Granite Reservoir.

Rate of seaward movement was natural-log-transformed to improve linearity and remedy heteroscedasticity of residuals, and bivariate and multiple regression models were fit from every possible combination of predictor variables. The slope coefficients of each predictor variable in every model were examined for sign change, and for inflated standard errors (hence, failure to reject H_o: $B = 0$). Sign changes and large standard errors are indications of problematic multicollinearity (Dielman 1996). A Pearson correlation matrix was calculated to examine the level of collinearity between each factor. Models with problematic multicollinearity, or that included factors with non-significant ($P > 0.05$) slope coefficients, were removed from further analysis. Fit was compared among the remaining regression models based on the coefficient of determination (R^2). The three regression models that had the highest R^2 values were reported.

Residual plots were made for flow and temperature as described for flow in the following example. Natural-log-transformed rate of seaward movement was regressed against fork length and riverine distance. The residuals from this regression were then plotted against flow. A line

was then fit to the residuals by regressing them against flow. The resulting residual plots provided a better graphical representation of the relation between flow and rate of seaward movement because the variability in downstream migration rate attributable to fork length and riverine distance had been removed.

Fall Chinook Rate of Seaward Movement Results

A total of 2,808 observations were available (years 1992-2001) to describe the factors affecting rate of seaward movement of PIT-tagged fall chinook salmon from initial tagging to detection at Lower Granite Dam. After pooling the data across reaches and running every possible regression model, the slope coefficient for flow changed from being positive to negative when flow and temperature were entered into the same regression models. The correlation coefficient for the relation between flow and temperature was $r = -0.77$ ($P < 0.0001$). The slope coefficient for tagging date changed from being negative to positive when tagging date and temperature were entered in the same regression models. The correlation coefficient for the relation between tagging date and temperature was $r = 0.60$ ($P < 0.0001$). All models containing both flow and temperature, and tagging date and temperature, were removed from the analysis because of problematic multicollinearity.

The regression model with the best fit included the predictor variables temperature, fork length and riverine distance (Table 18). The slope coefficients for each of the three factors differed significantly from zero, and together the three factors explained 73% of the variability observed in natural-log-transformed rate of seaward movement (Table 18). Natural-log-transformed rate of seaward movement generally decreased as temperature increased, and increased as fork length and riverine distance increased, as shown by the sign and *P* values of the slope coefficients (Table 18). The slope in the residual plot indicates that rate of seaward movement decreased as temperature increased throughout the range of 9 to 21°C (Figure 15).

The regression model that had the second-best fit included the factors flow, fork length, and riverine distance (Table 18). Flow, fork length, and riverine distance explained 66% of the variability observed in natural-log-transformed rate of seaward movement. Natural-log-transformed rate of seaward movement generally increased with increases in each of the three factors based on the slope coefficients, all of which differed significantly from zero (Table 18). The slope in the residual plot shows that rate of seaward movement increased as flow increased over the entire range of observed flows (Figure 15).

The regression model that had the third-best fit included the factors tagging date, fork length, and riverine distance (Table 18). Natural-log-transformed rate of seaward movement generally decreased with increases in tagging date, and increased as fork length and riverine distance increased, as shown by the signs and *P* values of the slope coefficients (Table 18). Together, these three factors explained 58% of the variability observed in natural-log-transformed rate of seaward movement (Table 18).

Table 18. Results from multiple regression models fit to describe rate of seaward movement of PIT-tagged wild subyearling fall chinook salmon from initial tagging in the Snake River and detection at Lower Granite Dam, 1992 to 2001.

Variable	coefficient	SE	t value	Probability	R^2	*P*
Constant	0.81598	0.07490	10.89	≤ 0.0001	0.726	≤ 0.0001
Temperature	- 0.15190	0.00382	- 39.73	≤ 0.0001		
Fl	0.02773	0.00060	46.16	≤ 0.0001		
Km	0.00798	0.00018	44.42	≤ 0.0001		
Constant	- 2.07197	0.05627	- 36.82	≤ 0.0001	0.659	≤ 0.0001
Flow	0.00024	0.00001	26.73	≤ 0.0001		
Fl	0.02498	0.00066	37.66	≤ 0.0001		
Km	0.00876	0.00020	43.88	≤ 0.0001		
Constant	-1.17620	0.10755	-10.94	≤ 0.0001	0.575	≤ 0.0001
Date	-0.00304	0.00083	-3.68	0.0002		
Fl	0.02568	0.00090	28.64	≤ 0.0001		
Km	0.01061	0.00022	49.56	≤ 0.0001		

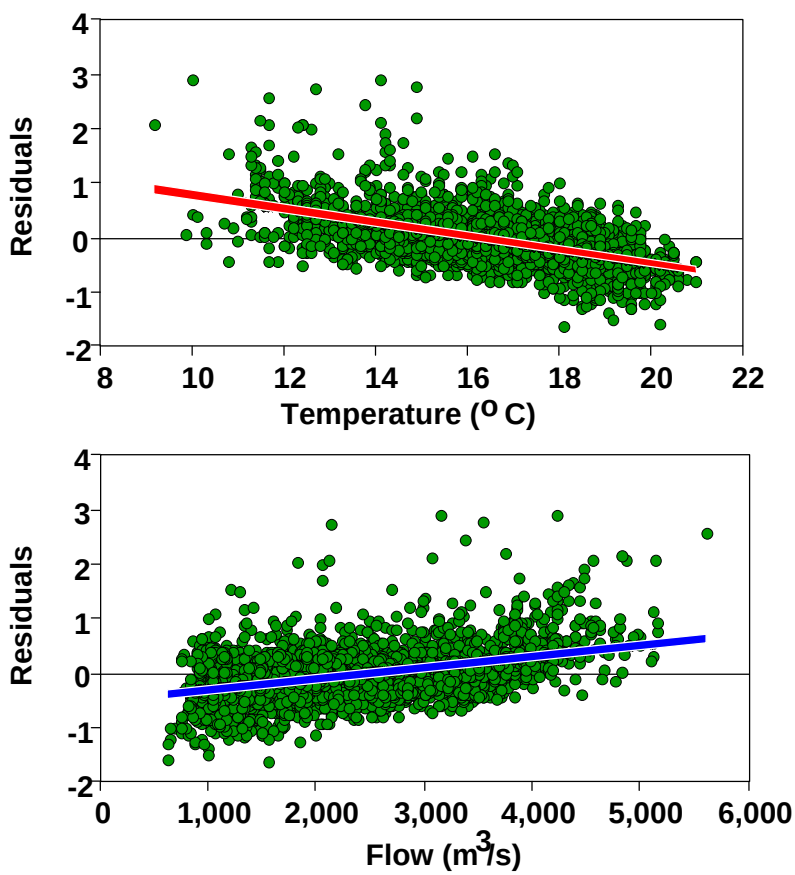

Figure 15. Wild subyearling chinook rate of seaward movement versus temperature and flow.

Fall Chinook Rate of Seaward Movement Discussion and Conclusions

Though the regression model that predicted natural-log-transformed rate of seaward movement from the predictor variables temperature, fork length, and riverine distance had the best fit of all models tested, Connor et al. (In press a) concluded that it is unrealistic to expect an inverse relation between temperature and rate of seaward movement over the entire range of temperatures studied (9 to 21°C). Fall chinook salmon that are exposed to mean temperatures of 20°C and above before they become smolts would be expected to move seaward at slower rates than those that experience cooler temperatures because of a reduced likelihood of successful smoltification (e.g., Marine 1997). However, rate of seaward movement should have increased as temperature increased up to at least 17°C as a result of increased growth and normal patterns of smolt development (Banks et al. 1971; Boeuf 1993; Marine et al. 1997; Connor and Burge in press). Connor et al. (In press a) concluded that the decrease in rate of seaward movement as temperature increased to 17°C was most likely caused by the accompanying decreases in flow.

The regression model with the second-best fit included the predictor variables flow, fork length, and riverine distance. This regression model showed that the relation between rate of seaward movement and flow was positive consistent with the results of other studies (Berggren and Filardo 1993; Tiffan et al. 2000). Higher rates of seaward movement at higher flows (or vice versa) can be explained by the relation between discharge and water velocity. Water velocity in reservoirs is proportional to the ratio of discharge to channel volume. Since the length of Lower Granite Reservoir presumably changes little over time, the change in volume can be described by changes in pool elevation. Lower Granite Reservoir was held at minimum operating pool elevations ranging from approximately 223 to 224 m above mean sea level during the summer (U. S. Army Corps of Engineers, unpublished data). Therefore, the flow values Connor et al. (In press a) used in their regression modeling were proportional to velocities in Lower Granite Reservoir upstream of Lower Granite Dam forebay suggesting that rate of seaward movement increased as velocity increased. These results support a flow-migration rate relation.

Rate of seaward movement from release in the Snake River to passage at Lower Granite Dam decreased as tagging date increased according to the results of the regression model with the third-best fit. Tagging date (a.k.a., release date) is used as a surrogate for time-based physiological, behavioral, and environmental processes when describing seaward movement of juvenile anadromous salmonids (e.g., Berggren and Filardo 1993; Giorgi et al. 1997; Connor et al. 2000). There was no significant tagging date effect when flow and tagging date were entered into the same regression model. Problems with multicollinearity were encountered when tagging date and temperature were entered into the same regression model. In the Connor et al. In press a) analyses, tagging date apparently functioned as a surrogate for flow and temperature. To a lesser extent, increases in date also reflected the decreased potential for successful smoltification of fish initially tagged late in the seining season.

Connor et al. (In press a) concluded that the increases in flow and decreases in temperature resulting from summer flow augmentation increases the rate of seaward movement of fall chinook salmon in Lower Granite Reservoir (where fish spend prolonged periods of time) provided that augmentation occurs when the fish have moved offshore in the free-flowing river and are behaviorally disposed to being displaced downstream. The regression model that

included flow predicts an increase in rate of seaward movement of approximately 0.1 km/d with each increase of 100 m^3/s in flow when fork length and riverine distance are held at 74 mm and 40 km (the overall 1992-2001 medians). At temperatures above 17^oC, the regression model that included temperature predicts an increase in rate of seaward movement of approximately 0.2 km/d with each decrease of 1^oC when fork length and riverine distance are held at 74 mm and 40 km. Increasing the rate of seaward movement by 0.1 to 0.2 km reduces travel time to Lower Granite Dam by 1 to 5 d (Connor 2001).

Survival of Wild Subyearling Fall Chinook Summer Migrants Measured from Release in the Free-flowing Snake River to Passage at Lower Granite Dam and Passage Timing at the Dam

Fall Chinook Survival Methods

Data collected on fall chinook salmon from 1998 to 2000 were analyzed. Data for these years were selected because sample sizes of tagged fall chinook salmon were large, and tagged fish were not handled as they passed Lower Granite Dam. Field personnel captured and PIT tagged fall chinook salmon by using a beach seine as described for analyses on rate of seaward movement . After detection at Lower Granite Dam, the PIT-tagged smolts were routed through flumes back to the river. Smolts then had to pass seven more dams to reach the Pacific Ocean. Little Goose, Lower Monumental, McNary, John Day, and Bonneville dams were also equipped with monitoring systems that recorded the passage of PIT-tagged smolts that used the bypass systems, and then routed the bypassed fish back to the river.

The first step in the analysis was to divide the annual samples of PIT-tagged fall chinook salmon into four sequential within-year release groups referred to as cohorts. The annual samples into cohorts based on estimated fry emergence dates. Fry emergence date was estimated for each fish in two steps. First, the number of days since each PIT-tagged fish emerged from the gravel was calculated by subtracting 36 mm from its fork length measured at initial capture, and then dividing by the daily growth rate observed for recaptured PIT-tagged fish (range 0.9 to 1.3 mm/d; Connor and Burge in press). The 36-mm fork length for newly emergent fry was the mean of the observed minimum fork lengths. Second, emergence date was estimated for each fish by subtracting the estimated number of days since emergence from its date of initial capture, tagging, and release. The data in ascending order by estimated fry emergence date, and then divided it into four cohorts of approximately equal numbers of fish. The single release-recapture model (Cormack 1964; Skalski et al. 1998) was used to estimate survival probability to the tailrace of Lower Granite Dam for each cohort. Three assumption tests described by Burnham et al. (1987) and Skalski et al. (1998) were applied to insure that the single release-recapture model fit the data.

Cohort survival was the dependent variable for the analysis. The predictor variables were: tagging date, median day of year fish from each cohort were captured, tagged, and released; fork length, mean fork length (mm) at capture, tagging, and release for the fish of each cohort; flow, a flow (m^3/s) exposure index calculated as the mean flow measured at Lower Granite Dam by U.S. Army Corps of Engineers personnel during the period when the majority of smolts from

each cohort passed the dam; and temperature, a water temperature (^{o}C) exposure index calculated as the mean temperature measured in the tailrace of Lower Granite Dam by U.S. Army Corps of Engineers personnel during the period when the majority of smolts from each cohort passed the dam.

To determine when the majority of smolts passed Lower Granite Dam, the PIT-tag detection data were used to calculate a passage date distribution for each cohort including the 25th percentile, median, 75th percentile, range of non-outliers, and mild outliers. The date cutoffs for mild outliers were calculated as the 25th percentile minus the inter-quartile range multiplied by 1.5 (i.e., the lower fence; Ott 1993), and the 75th percentile plus the inter-quartile range multiplied by 1.5 (i.e., the upper fence; Ott 1993). All but the mild outliers were considered to be in the majority. See Connor et al . In press b for more details on calculating flow and temperature exposure indices.

A Pearson correlation coefficient (r) was calculated to test for collinearity among the predictor variables. Predictor variables that were correlated ($r \geq 0.6$; $P \leq 0.05$) were not entered into the same model. Multiple regression models were fit from every combination of non-collinear predictor variables. Fit was compared among models based on Mallow's Cp scores (Dielman 1996), Akaike's information criteria (AIC; Akaike 1973), and the coefficient of determination (R^2). The final (i.e., best) regression model had a Mallow's Cp score similar to the number of parameters, the lowest AIC value, the highest R^2 value, and predictor variables with slope coefficients that differed significantly ($t \geq 2.0$; $P \leq 0.05$) from zero. Only the top three models are reported.

We made residual plots for each predictor variable in the final regression model as described for flow in the following example. Estimated survival was regressed against temperature. The residuals from this regression were then plotted against flow. A line was then fit to the residuals by regressing them against flow. The resulting residual plots provided a better graphical representation of the relation between survival and flow because the variability in survival attributable to temperature had been removed.

We assessed the effect of summer flow augmentation on cohort survival to the tailrace of Lower Granite Dam by comparing two predictions. First, we predicted cohort survival to the tailrace of Lower Granite Dam by entering the observed mean flow and water temperature exposure indices for each cohort into the final regression model. Cohort survival was then predicted a second time by entering mean flow and water temperature exposure indices into the final regression model that were recalculated to remove effects of summer flow augmentation.

The flow exposure index was recalculated after subtracting the daily volume of water released for summer flow augmentation. The water temperature exposure index was recalculated using temperatures that were simulated for the tailrace of Lower Granite Dam under the flow conditions had the summer flow augmentation not been implemented. Water temperatures were simulated using a one-dimensional heat budget model developed for the Snake River by the U.S. Environmental Protection Agency (Yearsley et al. 2001). Past model validation showed that daily mean water temperatures simulated for July and August were within an average of 1.1^{o}C of those observed (Yearsley et al. 2001).

Fall Chinook Survival and Passage Results

During the 3 years, 5,030 fall chinook salmon were captured, PIT tagged, and released along the free-flowing Snake River. Annual sample sizes of PIT-tagged fall chinook salmon were 2,060 in 1998, 1,761 in 1999, and 1,209 in 2000. The number of fall chinook salmon in the resulting 12 cohorts ranged from 302 to 515 (Table 19). Emergence dates, tagging dates, fork lengths, and water temperature exposure indices generally increased from cohort 1 to 4 (Table 19). Flow exposure indices and survival estimates decreased from cohort 1 to 4 (Table 19).

Tagging date and fork length were negatively correlated (N = 12; r = -0.76; P = 0.004). Therefore, tagging date and fork length were not entered into the same multiple regression model. Fork length and flow (N = 12; r = 0.47; P = 0.12), fork length and temperature (N = 12; r = -0.54; P = 0.07), and flow and temperature (N = 12; r = -0.45; P = 0.15) were non-collinear.

The model that predicted cohort survival from flow and temperature had a Mallow's Cp score one less than the number of parameters, the lowest AIC value, and an R^2 of 0.92 (Table 20). The models that included fork length or tagging date had Mallow's Cp scores that equaled the number of parameters, relatively low AIC values, and R^2 values of 0.92 (Table 20), but the slope coefficient for fork length (t = 0.05; P = 0.96) and tagging date (t = 0.07; P = 0.94) did not significantly differ from zero.

Table 19. Emergence dates, predictor variables, and estimates of survival probability (%±SE) to the tailrace of Lower Granite Dam for each cohort of wild subyearling fall chinook salmon, 1998 to 2000. Predictor variables: Tagging date, median day of year of tagging; Fl, mean fork length (mm) at tagging; Flow, a flow (m^3/s) exposure index calculated as the mean flow measured at Lower Granite Dam during the period when the majority of smolts passed the dam; and Temperature, a water temperature (^oC) exposure index calculated as the mean temperature measured in the tailrace of Lower Granite Dam during the period when the majority of smolts passed the dam.

Cohort	*N*	Emergence date	Tagging date	Fl	Flow	Temperature	Survival
				1998			
1	515	7 April	140	80	2,344	17.6	70.8±2.9
2	515	15 April	141	75	2,021	18.7	66.1±3.3
3	515	23 April	153	73	1,898	19.0	52.8±3.1
4	515	7 May	167	70	1,299	19.8	35.6±2.9
				1999			
1	441	20 April	147	80	2,378	16.3	87.7±4.6
2	440	30 April	153[A]	77	1,963	17.1	77.0±3.8
3	440	5 May	152[A]	70	2,116	16.7	81.2±5.8
4	440	13 May	167	68	1,353	18.3	36.4±3.5
				2000			
1	303	6 April	130	77	1,510	16.7	57.1±4.1
2	302	15 April	144	77	1,296	17.6	53.4±4.2
3	302	22 April	146	77	1,274	17.8	44.4±3.6
4	302	29 April	158	71	859	18.5	35.7±4.3

[A] Fish from cohort 2 emerged earlier than fish of cohort 3, but they were initially captured, tagged, and released later than fish of cohort 3.

Table 20. Mallow's Cp scores, Akaikes information criteria (AIC), and coefficients of determination (R^2) used to compare the fit of multiple regression models describing the survival of cohorts of wild subyearling fall chinook salmon from tagging in the Snake River to the tailrace of Lower Granite Dam, 1998 to 2000. Predictor variables: Tagging date, median day of year of tagging; Fl, mean fork length (mm) at tagging; Flow, a flow (m^3/s) exposure index calculated as the mean flow measured at Lower Granite Dam during the period when the majority of smolts passed the dam; and Temperature = a water temperature (^oC) exposure index calculated as the mean temperature measured in the tailrace of Lower Granite Dam during the period when the majority of smolts passed the dam.

C(p)	AIC	R^2	Variables in model
2	44	0.92	Flow, Temperature
4	46	0.92	Fl, Flow, Temperature
4	46	0.92	Tagging date, Flow, Temperature

The final multiple regression model was: Cohort survival = 140.82753 + 0.02648 Flow -7.14437 Temperature. The final model was significant (N = 12; $P \leq 0.0001$) as were the coefficients for flow (t = 6.81; $P \leq 0.0001$) and temperature (t = - 3.96; P = 0.003). Flow and temperature explained 92% of the observed variability in cohort survival to the tailrace of Lower Granite Dam. Cohort survival generally increased as flow increased, and decreased as temperature increased (Figure 16).

The majority of fall chinook salmon passage occurs in July and August (Figures 17-19). Water releases for summer flow augmentation in 1998, 1999, and 2000 were generally timed to coincide with the passage of smolts from mid-July through August at Lower Granite Dam (Figures 17-19). Therefore, these later migrants were usually predicted to accrue greater survival benefits than the earlier migrants cohorts (Table 21). For all cohorts, estimated survival to the tailrace of Lower Granite Dam was predicted to be higher when summer flow augmentation was implemented than when it was not implemented (Table 21; Figure 20). Notably, eliminating flow augmentation in early July and August would likely decrease survival of a large portion of the smolts.

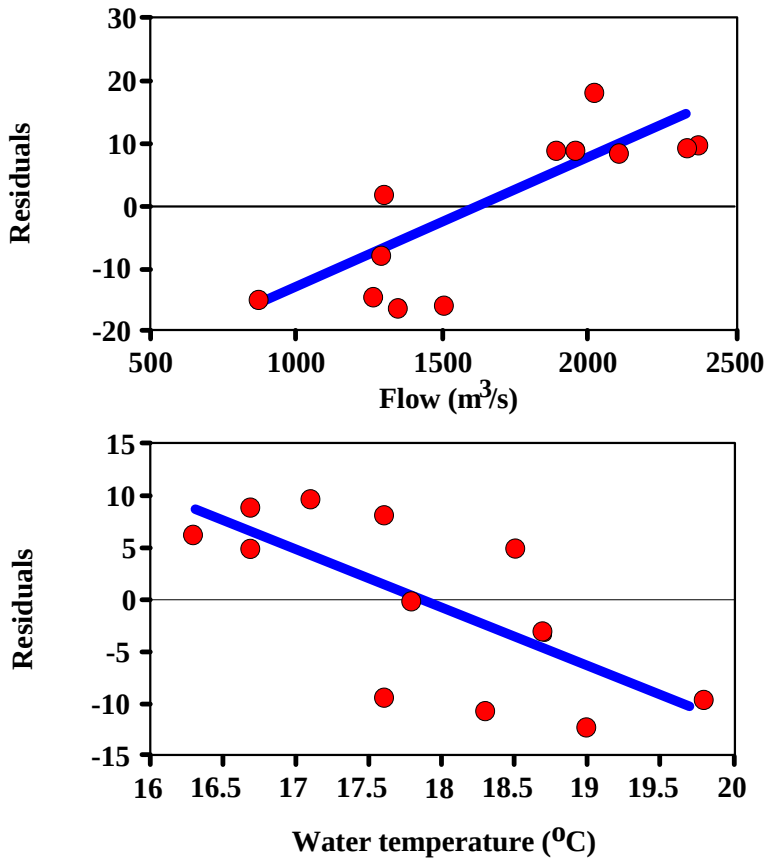

Figure 16. Residuals plots for flow and temperature. Residuals are from ordinary least-squares multiple regression models fit to predict cohort survival from the predictor variables that is not on the X-axis. The line in each plot was predicted by regressing the residuals against the predictor variable on the X-axis.

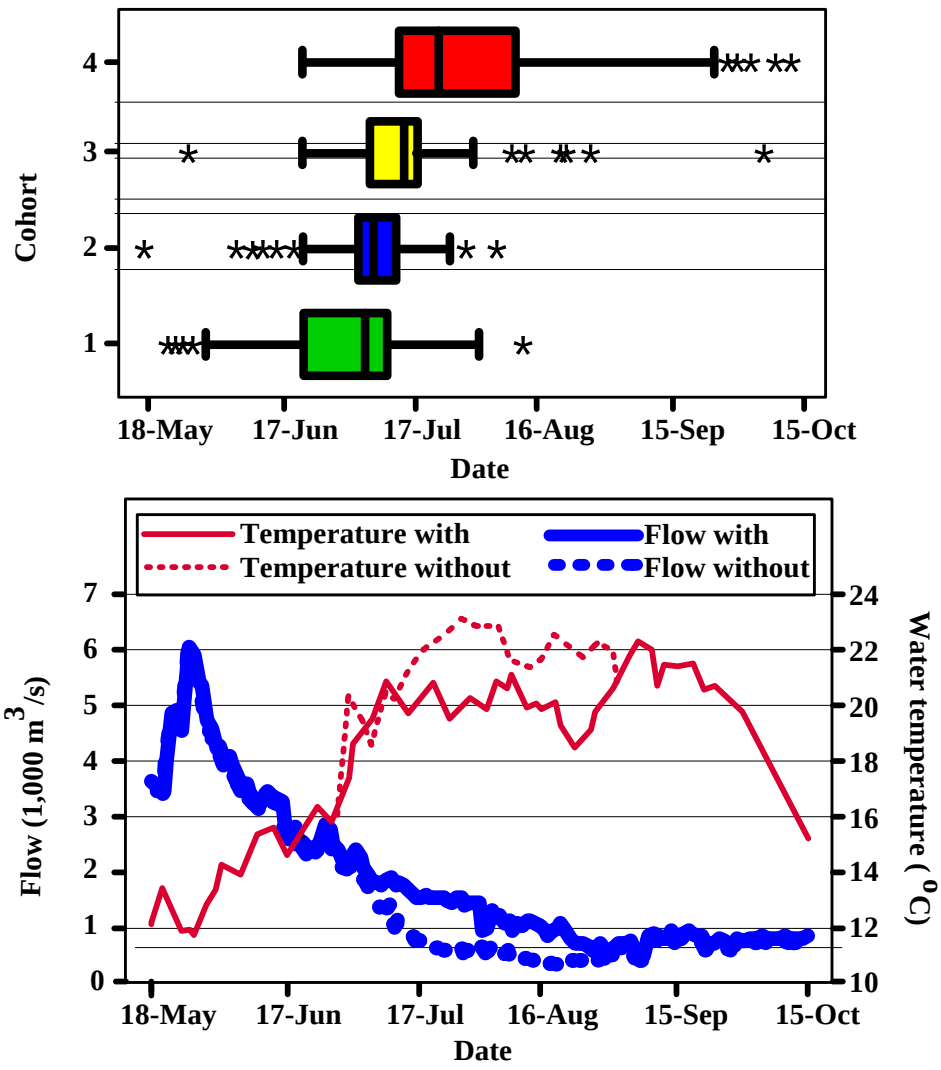

Figure 17. Box plots showing passage timing at Lower Granite Dam for PIT-tagged wild subyearling fall chinook salmon from each of four cohorts in 1998 (top), and the mean daily flows and water temperatures observed in Lower Granite Reservoir when flow was augmented (with) compared to those that may have occurred if flows had not been augmented (without; bottom).

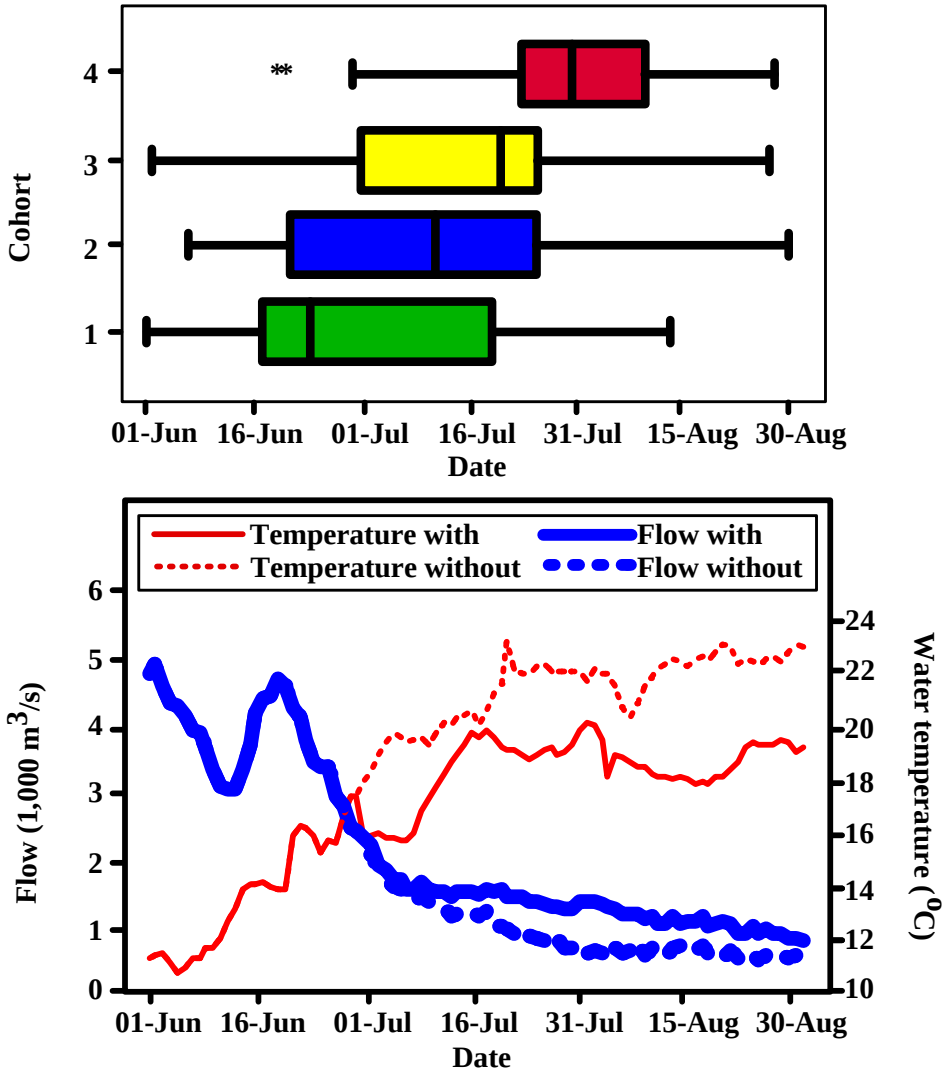

Figure 18. Box plots showing passage timing at Lower Granite Dam for PIT-tagged wild subyearling fall chinook salmon from each of four cohorts in 1999 (top), and the mean daily flows and water temperatures observed in Lower Granite Reservoir when flow was augmented (with) compared to those that may have occurred if flows had not been augmented (without; bottom).

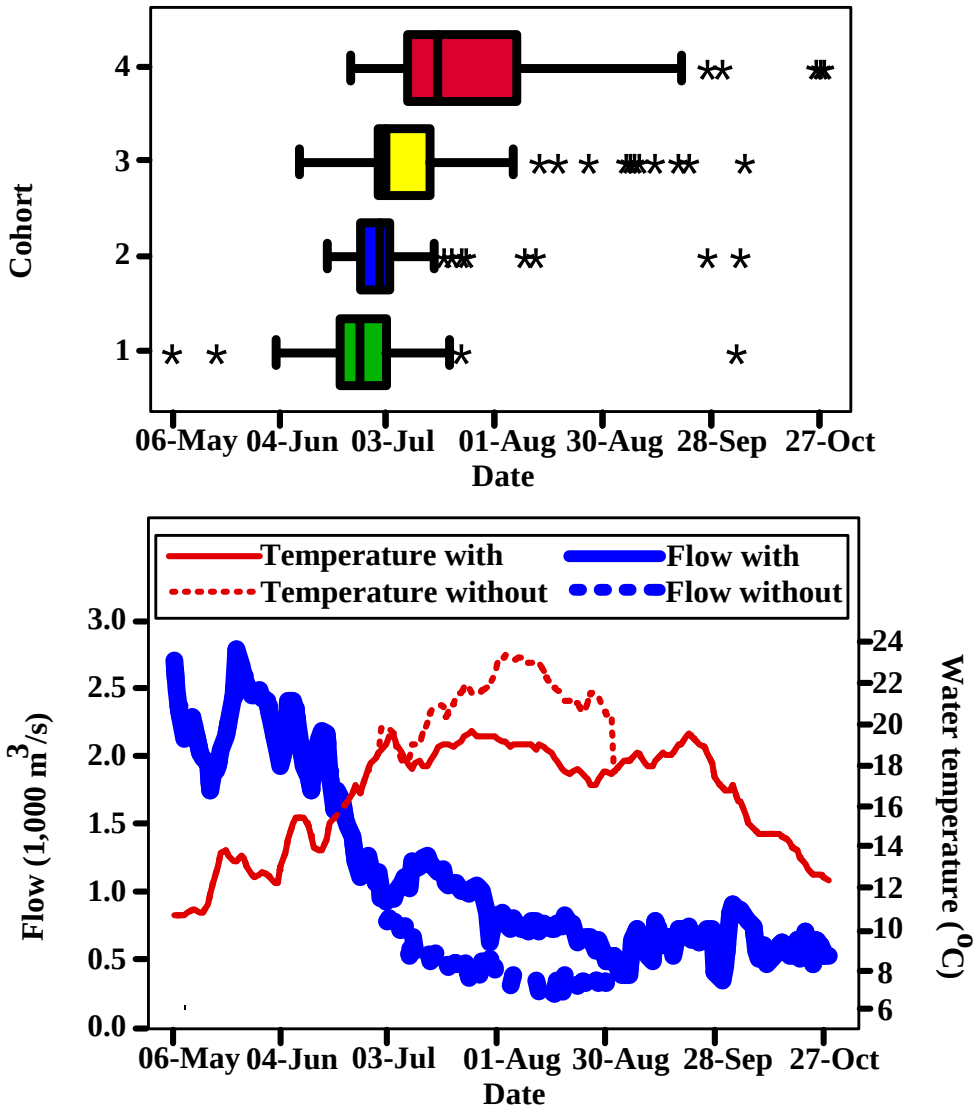

Figure 19. Box plots showing passage timing at Lower Granite Dam for PIT-tagged wild subyearling fall chinook salmon from each of four cohorts in 2000 (top), and the mean daily flows and water temperatures observed in Lower Granite Reservoir when flow was augmented (with) compared to those that may have occurred if flows had not been augmented (without; bottom).

Table 21. Predicted survival (%±95% C.I.) to the tailrace of Lower Granite Dam for cohorts of wild subyearling fall chinook salmon tagged in the Snake River from 1995 to 1998. Predictions were made using the observed flow and water temperature indices in Table 1 (Survival with), and by using flow (m^3/s) and water temperature (^oC) exposure indices recalculated to approximate conditions that would have occurred if flow had not been augmented (Survival without).

Cohort	Survival with	Recalculated		Survival without	Difference in survival
		Flow	Temperature		
			1998		
1	77.2±6.5	2,066	18.3	64.8±5.8	12.4
2	60.7±6.6	1,689	19.3	47.7±7.0	13.0
3	55.3±6.8	1,468	20.1	36.1±9.3	19.2
4	33.8±8.0	988	21.3	14.8±13.1	19.0
			1999		
1	87.3±7.5	2,128	17.1	75.0±5.2	12.3
2	70.6±4.7	1,667	18.4	53.5±4.3	17.1
3	77.5±5.8	1,837	18.0	60.9±4.0	16.6
4	45.9±4.6	943	20.1	22.2±9.4	23.7
			2000		
1	61.5±6.7	1,314	17.0	54.2±6.8	7.3
2	49.4±5.5	1,078	17.9	41.5±6.5	7.9
3	47.4±5.3	978	18.6	33.8±6.7	13.6
4	31.4±7.5	587	20.1	12.8±10.6	18.6

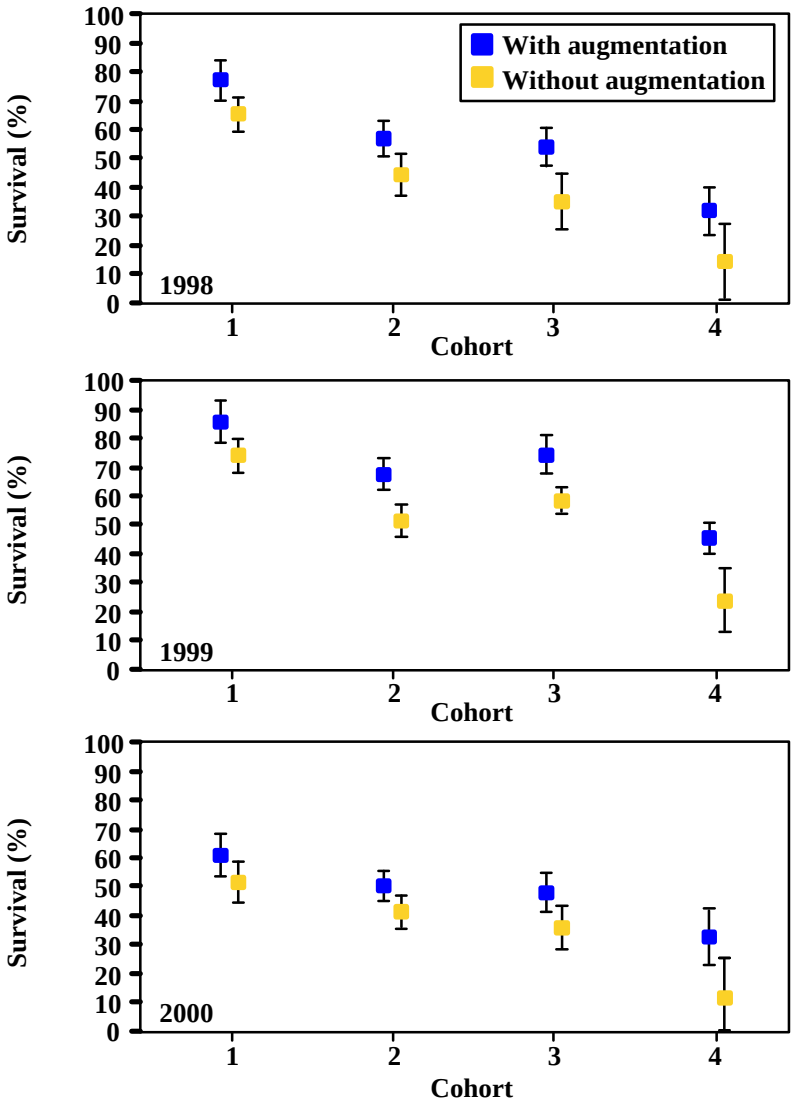

Figure 20. Survival (±95% C.I.) to the tailrace of Lower Granite Dam for PIT-tagged wild subyearling fall chinook salmon (1998 top; 1999 middle; 2000 bottom) predicted from observed mean flow and water temperatures (from Table 1), and from mean flows and water temperatures recalculated to represent those that would have occurred if flow were not augmented (from Table 3). The equation Cohort survival = 140.82753 + 0.02648 Flow -7.14437 Temperature was used to make both sets of predictions.

Fall Chinook Survival and Passage Discussion and Conclusions

Survival of wild subyearling fall chinook salmon from release in the Snake River to the tailrace of Lower Granite Dam generally increased as flow increased and decreased as temperature increased. Based on the regression model developed by Connor et al. (In press b) and reported herein, survival is predicted to change by approximately 3% with each change of 100 m^3/s in flow when temperature is held constant. The change in survival is approximately 7% for each 1^oC increase or decrease in temperature when flow is held constant. Kjelson et al. (1982), Kjelson and Brandes (1989), and Connor et al. (1998) also reported that survival of subyearling chinook salmon during seaward migration is directly proportional to flow and inversely proportional to temperature.

Flow and temperature were closely correlated in the above three studies (e.g., r = -0.999; Connor et al. 1998), thus the researchers could not determine if the high correlation between survival and one variable was caused by the other variable. Flows and temperatures were atypically uncorrelated (r = -0.45) fin the 1998-2000 Connor et al. (In press b) study, therefore the researchers were able to enter both of these predictor variables in the same multiple regression equation without detectably biasing the regression coefficients. Both regression coefficients differed significantly from zero (flow $P \leq 0.0001$; temperature $P = 0.003$). Connor et al. (In press b) conclude that flow and temperature act together to influence fall chinook salmon survival.

After a candid discussion on the shortcomings of their study, Connor et al. (In press b) concluded that summer flow augmentation increased the survival of young fall chinook salmon passing downstream in Lower Granite Reservoir especially when flow releases were timed to the passage of smolts in July and August.

Spill

Employing the use of spill for juvenile migrants has long been used as an effective management tool for improving passage survival of migrating juvenile salmon at mainstem hydroelectric projects. Routing smolts through spillways at hydroelectric projects in the Columbia and Snake rivers is generally considered to be the safest passage strategy, when compared to the passage survival through bypass systems and turbine routes. Recently, analyses conducted by Muir et al. (2001) reconfirmed the findings of numerous earlier studies by demonstrating that spillway survival of smolts exceeds that incurred through both turbines and collector/bypass systems at dams on the Snake River.

Spill is also an effective tool in decreasing the amount of delay experienced by fish in forebays and tailraces of dams where predator populations and predation rates are highest. Spill can greatly reduce delay of smolts as demonstrated at the forebay of The Dalles Dam by Snelling and Schreck (1994). Spill establishes a large flow net with increased velocity that disperses predators from the forebay and tailrace areas thus reducing the potential for predator/prey interactions (Faler et al., 1988).

Spilling water can cause high dissolved gas to concentrate by entrainment of air in the form of bubbles as it passes over the spillway and plunges to the tailrace. The air is forced into solution, causing the water to become "supersaturated" at ambient atmospheric pressure with respect to dissolved gas. Water that is supersaturated with respect to dissolved gases may cause gas bubbles to form in the bodies of fish and other aquatic animals under certain conditions that impair their ability to function, or in extreme situations may lead to death. Consequently, spill management must recognize the tradeoff between survival benefits and the detrimental effects of high total dissolved gas levels.

The "Spill and 1995 Risk Management" report was developed by the region's fishery agencies and tribes document and provided part of the biological justification for the implementation of the 1995 Biological Opinion spill program. The document reviewed all available studies and quantified the trade-off between the increase in salmon survival associated with an increase in spill passage, against the potential fish mortality that might be incurred from increased levels of total dissolved gas (TDG). The assessment concluded that the benefits of spill passage outweighed the risk up to TDG levels between 120 to 125%. The annual voluntary spill program has been implemented within these constraints since that time.

In 2000 the NMFS included Appendix E in their Biological Opinion. This appendix was meant to serve as the justification and risk assessment for the spill program included in the 2000 Biological Opinion. The appendix addresses the 120% dissolved gas ceiling and builds on the findings of the 1995 document with information collected subsequently. The NMFS also uses the SIMPAS model as a means of quantifying an amount of system survival attributable to the 120% TDG spill program. The NMFS concludes, "the risk associated with a managed spill program to the 120% total dissolved gas (TDG) level is warranted by the projected 4% to 6% increase in system survival of juvenile salmonids. Recent research and biological monitoring results support the findings of the 1995 report, which predicted that the TDG in the 120% to 125% range, coupled with vertical distribution fish passage information indicating that most fish migrate at depths providing some gas compensation, would not cause juvenile or adult salmon mortalities exceeding the expected benefits of spillway passage. NMFS finds little evidence that this expected survival improvement would be reduced by the mortality related to gas bubble trauma (GBT). NMFS also concludes that physical and biological monitoring of GBT signs can continue to be used to indicate dissolved gas exposure in adult and juvenile salmon migrants."

Evidence for Spill Survival Benefits

The multiple regression analyses conducted for survival of steelhead and chinook from Lower Granite Dam to McNary Dam all include a spill related variable in the models. This suggests the importance of spill in the determination of juvenile survival.

An analysis of smolt survival in the lower Columbia River index reach was possible based on the implementation of a limited spill program during the drought year, 2001. The McNary Dam passage distribution of PIT tagged yearling chinook was split into nine multi-day blocks with at least 10,000 PIT tagged smolts per block. The plot (Figure 21) of the estimated survival from McNary Dam tailrace to Bonneville Dam tailrace shows evidence of shifts in estimated survival for yearling chinook smolts passing McNary Dam in the May 1-10, May 11-21, and May 22 to

June 9 periods. Spill at The Dalles and Bonneville dams only began on May 16 and at John Day Dam on May 25. It is likely that the survival data is grouped due to the impacts of spill, with higher survivals estimated during periods of higher spill. Further evidence implicating spill as a causal factor in increasing survival is based on the significant change in collection efficiency at John Day Dam, dropping nearly 45% for yearling chinook post initiation of spill, suggesting a far greater proportion of fish passing over the spillway at John Day Dam.

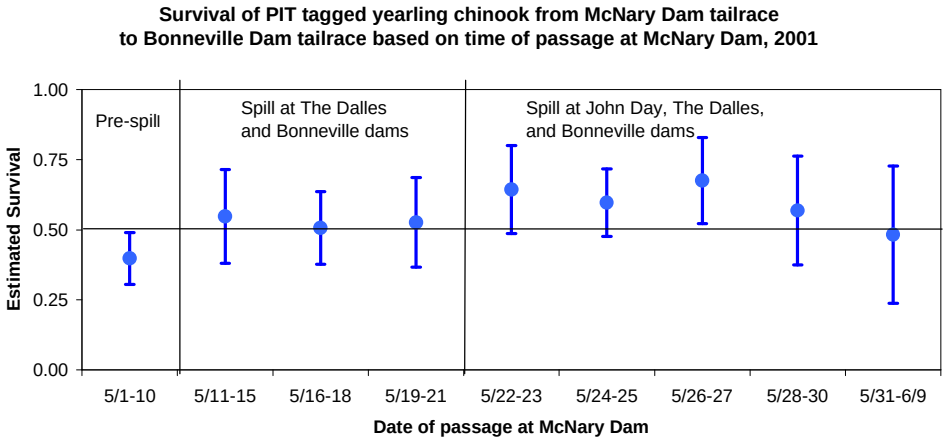

Figure 21. Survival of PIT tagged yearling chinook from McNary Dam tailrace to Bonneville Dam tailrace based on time of passage at McNary Dam, 2001.

Evidence for the Appropriateness of the Current Total Dissolved Gas Standards

The effects of elevated dissolved gas on migrating juvenile and adult salmon due to voluntary spill have been monitored each year of spill program implementation. Based on seven years of data from the biological monitoring program, the average incidence of gas bubble disease signs has been low, although the state-allowed maximum TDG due to spill was 120 percent in the tailrace and 115 percent in forebays during periods of voluntary spill. A high percentage of the spill that did occur in some years was involuntary, and often resulted in dissolved has levels above the 120% waiver. The following graphs (Figures 22 and 23) depict the incidence and severity of signs of GBT in fish collected for observation over the seven years, grouped in 5 percent TDG levels. Increases in the incidence of signs were observed with increases in the levels of TDG. The severity of signs also increased, but not until dissolved gas levels were above the 120 to 125% level.

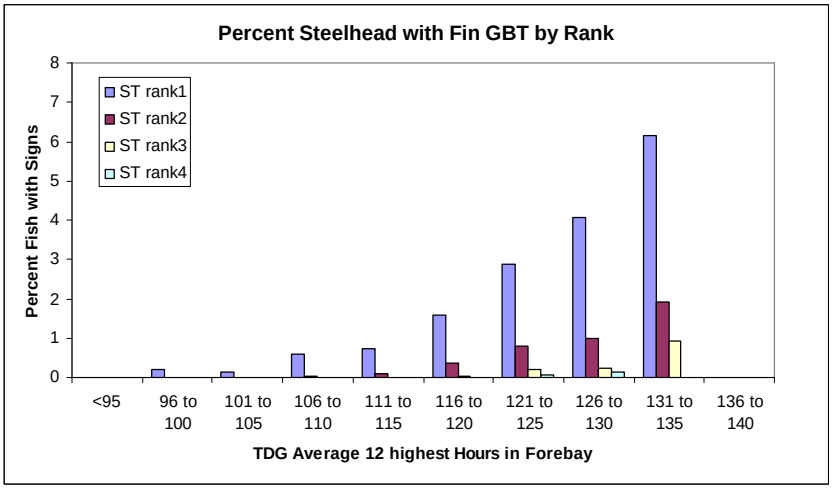

Figure 22. Percent Steelhead with Fin GBT by Rank.

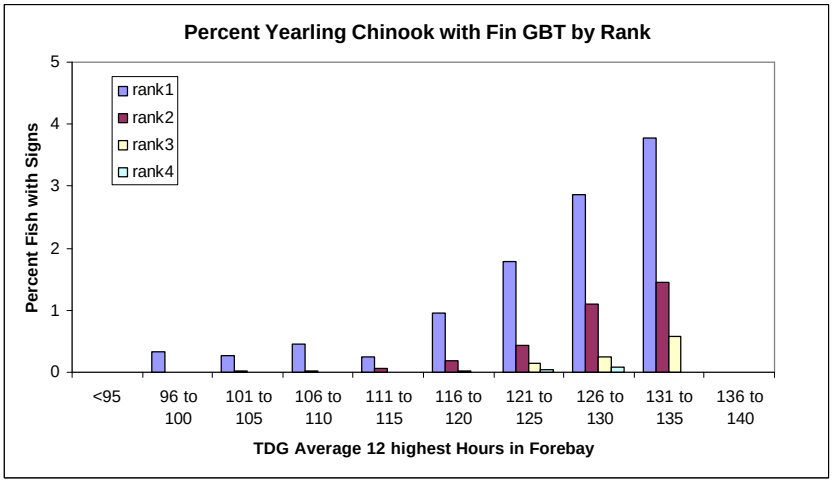

Figure 23. Percent Yearling Chinook with Fin GBT by Rank.

Additional information regarding the effects of total dissolved gas on the survival of juvenile salmonids can be ascertained from the relation between juvenile survival and total dissolved gas concentrations. The following graphs (Figures 24 and 25) depict the relation between smolt survival between the tailrace of Lower Granite to the tailrace of McNary Dam plotted as a function of the average total dissolved gas concentration at Ice Harbor indexed as described in the multiple regression analyses performed previously in this document.

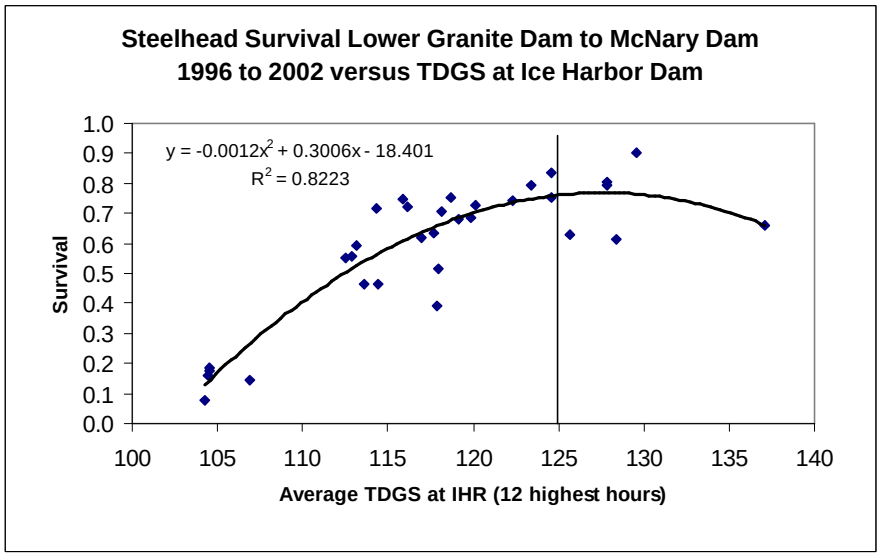

Figure 24. Steelhead Survival Lower Granite Dam to McNary Dam 1996 to 2002 versus TDGS at Ice Harbor Dam.

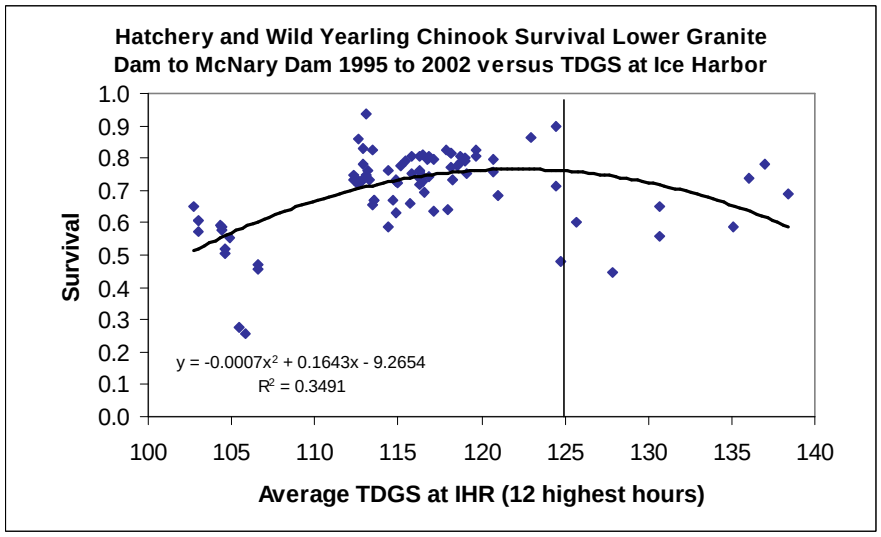

Figure 25. Hatchery and Wild Yearling Chinook Survival Lower Granite Dam to McNary Dam 1995 to 2002 versus TDGS at Ice Harbor.

These data suggest that total dissolved gas concentrations above 125% may have had a negative impact on survival. These high total dissolved gas measurements are a function of uncontrolled spill that occurred in the hydrosystem because of flow in excess of the hydraulic capacity of the project, or due to spill in excess of generation needs. They are not caused by the implementation of the Biological Opinion Spill Program.

All of the information collected to-date of survival and the benefits associated with spill indicate that spill provides a significant benefit to juvenile survival at levels up to 125% in the tailrace of the dam. The data suggest that the spill program has a built-in margin of error for total dissolved

gas. This allows the implementation of the Biological Opinion Spill Program with little or no impact due to small excursions from the 115% forebay and 120% tailrace total dissolved gas criteria.

Adult Return Analysis

We evaluated the impacts of flow and spill on the survival of smolts-to-adults and spawner-to-spawner to investigate the total impact of these factors on overall survival. The data set used in the adult analyses is presented in Table 1 (Appendix A). Because the ocean has a very large influence on these survival rates we included a measure of climate and ocean conditions in this analyses. We used the parameter delta derived in the Plan for Analyzing and Testing Hypotheses (PATH), which is a measure of climate/ocean mortality influences that are common to both spring/summer chinook stocks originating lower in the Columbia (e.g. John Day River) and in the Snake River (Deriso et al. 2001). Because these stocks are genetically very similar, have similar migration, ocean entry and adult return timing, we expect both to respond to ocean changes in a similar manner (Schaller et al. 1999, 2000). This is evidenced by the large returns occurring for all stocks during recent good ocean conditions (see Figure 26). The Yakima SARs averaged (geometric mean) nearly 4 times higher than Snake River SARs, but were similar in pattern over time to the Snake River SARs (Figure 1; Joint Technical Memorandum to NWPPC, March 19, 2002).

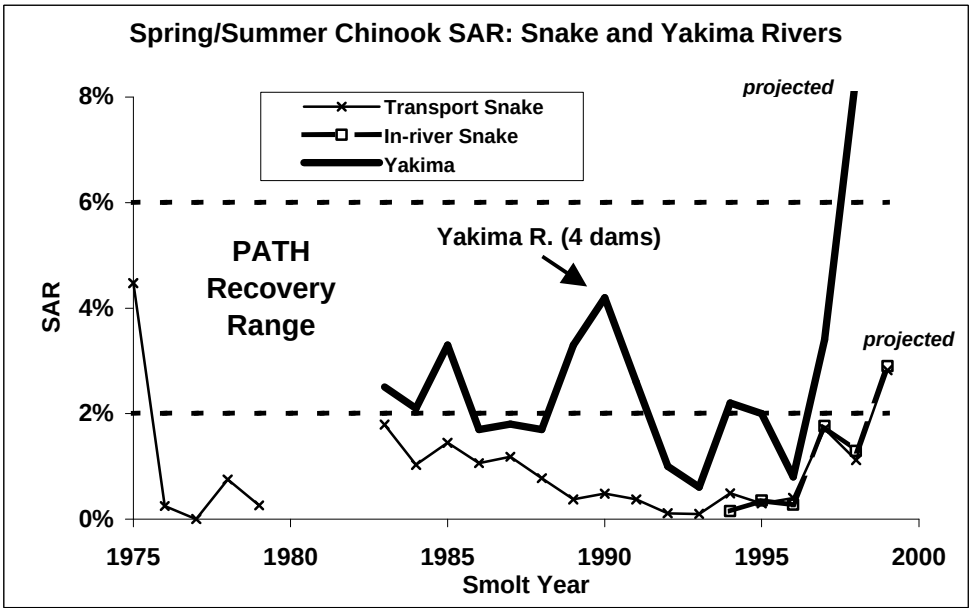

Figure 26. Smolt to adult return rates (SAR) Snake River spring/summer chinook, (transported 1975-1999; inriver migrants 1994-1999), and Yakima spring chinook, 1983-1998.

Dependent variables were wild Snake River chinook and steelhead SARs; spawner to spawner ratios from index stocks of Snake River spring/summer chinook used in PATH and NMFS Biological Opinion; and the direct and delayed hydrosystem survival of Snake River spring/summer chinook relative to downriver spring/summer chinook, estimated in PATH by the parameter mu (Deriso et al. 2001). Snake River wild chinook SARs for 1975-1994 were from

PATH and reported in NMFS (2000) white papers; SARs for 1995-1999 from the CSS annual report (Bouwes et al. 2002). Snake River steelhead SARs for 1975-1994 were from PATH and reported in NMFS (2000) white papers. The chinook spawner to spawner ratios (S:S) used in the analysis were from updated run reconstructions, as of March 2002. The S:S ratio used in this analysis was the median of the seven index stocks. Independent variables included water travel time, two measures of spill , updated estimates of climate effects (delta), and the proportion of smolts that were transported in barges and trucks. Annual water travel times (WTT) were the average times for water to move through the hydrosystem, LGR reservoir to BON dam, between April 16-May 31 and estimated as function of reservoir volume and flow. The proportion of water spilled each migration year (PropSpill) was represented as the daily spill/flow averaged over the migration season and across the 8 projects. Average volume spilled was calculated as daily spill averaged over the migration season and across all projects. The transport proportion was calculated as the number of smolts arriving at LGR dam divided by the number of smolts transported at LGR, LGS, and LMN over the whole season. The number of smolts arriving at LGR dam was estimated by methods described in Petrosky et al. (2001). The data source for the number of smolts transported came from Park (1985) for migration years 1975-1980, FTOT reports for migration years 1981-1984 and from the Fish Passage Center database from 1985-1996. Calvin Peters (ESSA Technologies, personal communication, March 2002) provided updated estimates of the climate effect (delta) and relative hydrosystem survival of Snake River versus downriver stocks (mu) (Deriso et al. 2001), through the 1995 migration year.

We transformed the dependent (SAR and S:S) variables by natural logarithms. We regressed Snake River spring/summer chinook ln(SARs) between 1975 (the year the last dam went in on the Snake River) and 1996 (SARs were not available between migration years 1985-1991) to all possible combinations of the above water travel time ,spill, climate, and transportation proportion variables. In addition, we conducted a stepwise regression between these response and explanatory variables to avoid using explanatory variables that were highly correlated with each other.

Both BIC scores and the stepwise regression suggested that the most parsimonious model (the model with the fewest number of explanatory variables explaining the greatest amount of variability in survival) that best explained spring/summer chinook SARs was the transportation proportion (Appendix A, Tables 2 and 3). We found a moderate to strong relationship between chinook SARs and transportation proportion (r^2=0.64, $p<0.001$); however this relationship was negative suggesting years in which the proportion transported increased the SARs decreased (Figure 27).

After demonstrating the large negative influence of transportation proportion on spring/summer chinook SARs (the best 10 models all included this variable), we evaluated the influence of other variables on survival of transported and non-transported fish over these life-stages by removing this variable from the model. BIC scores and the stepwise regression suggested that spring/summer chinook SARs were best explained by WTT and climate effects (Appendix A, Tables 4 and 5). A moderate relationship was observed between SARs explained by WTT and climate effects (r^2=0.48, $p<0.03$).

We also did a similar regression analyses for spring/summer chinook spawner-to-spawner ratios ln(S:S) because we had a more complete time series and data were collected in a similar fashion over the time series. The spawner/spawner ratio for chinook was best explained by WTT and climate effects (r^2=0.63, p<0.001; Appendix A, Tables 6 and 7).
Regression analyses were also performed on the relative hydrosystem mortality (mu) using the explanatory variables. The best model explaining relative hydrosystem mortality was WTT (r^2=0.42, p<0.002, Appendix A Tables 8 and 9). As WTT increased the relative hydrosystem mortality also increased (Figure28).

Finally, using the same regression analyses we evaluated the variables that influenced steelhead SARs. The best model selected suggested a moderate relationship between steelhead SARs and water travel time, the interaction between spill and water travel time, and climate (r^2=0.52, p<0.007).

Although these relationships are not driven by water travel time in itself, given the numerous environmental factors that influence survival of salmonids over this large portion of their life cycle as well as the large variability in the data, this factor remained as an important contributor to salmon survival.

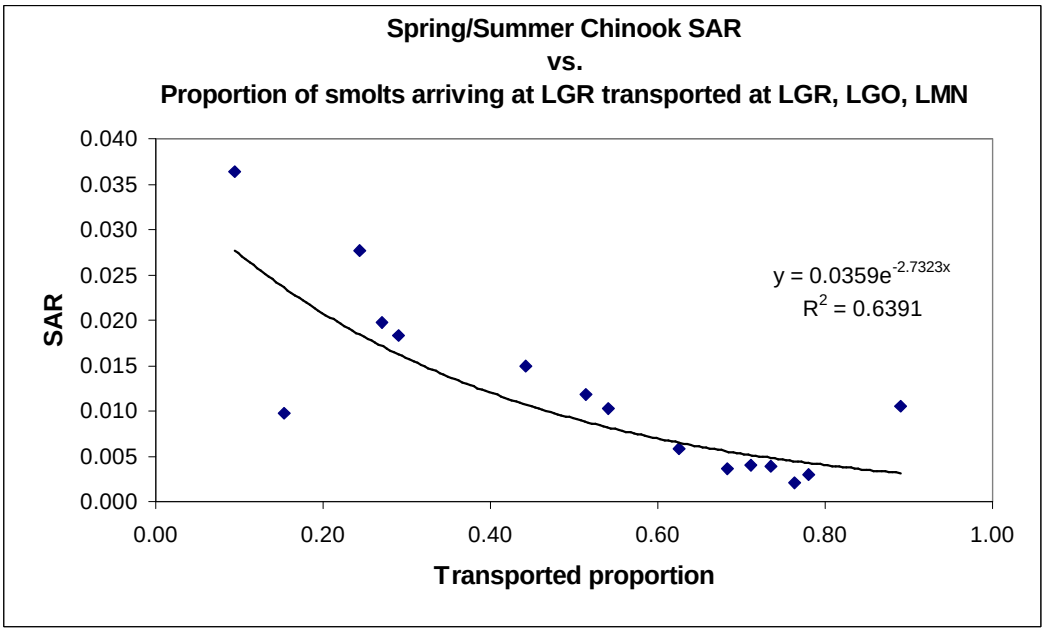

Figure 27. Relationship between Snake River spring/summer chinook smolt-to-adult survival (SAR) and the proportion of smolts arriving LGR that were transported at LGR, LGO, LMN.

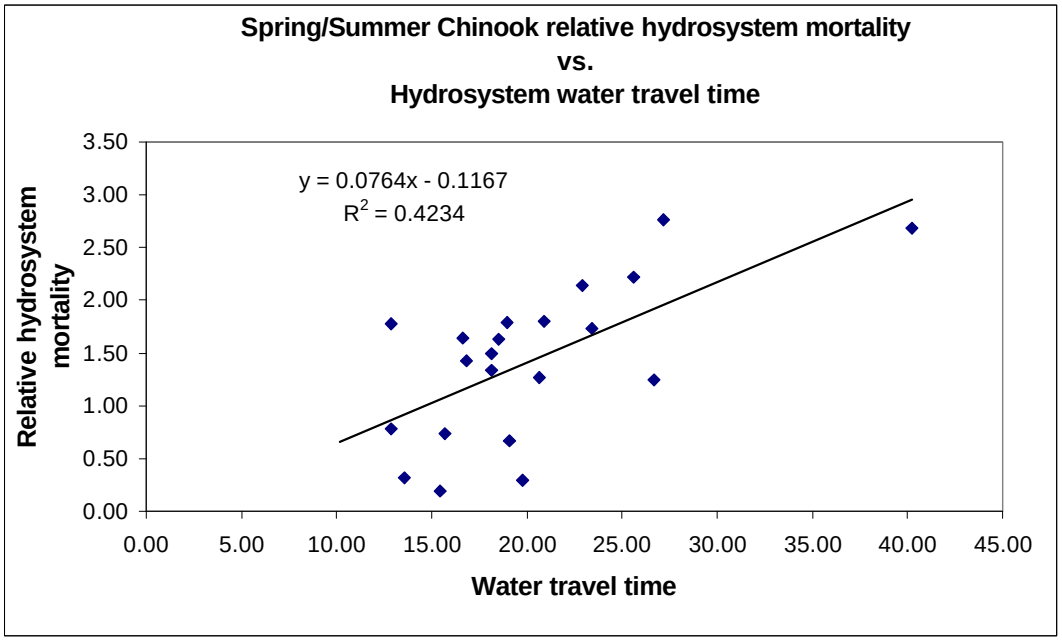

Figure 28. The relationship between water travel time through the hydrosystem and the hydrosystem mortality for Snake River spring/summer chinook relative to Lower-Columbia River spring/summer chinook (mu). Relationships of Spawner:Spawner Ratios to Water Travel Time and Climate/Ocean Conditions.

Juvenile migration conditions and climate/ocean conditions were both influential in explaining patterns of adult recruitment of wild Snake River spring/summer chinook. The relationship of predicted spawner-to-spawner ratios to water travel time and the climate/ocean influence (delta) is shown in Table 22 and Figure 29. The water travel times from Biological Opinion spring flow targets range from approximately 16.5 to 20 days, and are shaded in Table 22 and Figure 29. Observed water travel times ranged from 14 to 46 days in the fitted data (11 days was observed in 1997); and delta ranged from –1.9 (poor ocean) to 1.0 (favorable ocean). Salmon managers have no control of climatic/ocean conditions, thus we focus this discussion on predicted life-cycle survival (S:S ratio) at different water travel times, for average (delta = 0), good (delta = 1.0) and poor (delta = -1.0) climate/ocean conditions. A delta value of 1.0 indicates climate/ocean influence resulted in nearly a three-fold higher than average survival (exp(1.0)); a delta value of –1.0 indicates ocean survival was only about 1/3 as high as average. The time frame in designating “average”, “poor” or “good” climate/ocean conditions was 1959-1995 smolt migration years (Deriso et al. 2001).

Table 22. Predicted spawner:spawner ratios from observed ln(S:S), water travel time (WTT) and climate/ocean influence (delta), Snake River spring/summer chinook, smolt migration years 1975-1995. Combinations of WTT and delta that predict population declines (S:S < 1.0) are in red, those that predict population increases (S:S > 1.0) are bolded. BiOp flow targets produce WTT in the range of 16.5 to 20 days (shaded cells). Good, average, and poor climate/ocean conditions are represented by delta = 1.0, 0, and –1.0 respectively.

	DELTA								
WTT	**-1**	**-0.75**	**-0.5**	**-0.25**	**0**	**0.25**	**0.5**	**0.75**	**1**
10	0.57	0.73	0.93	**1.18**	**1.50**	**1.90**	**2.42**	**3.07**	**3.90**
15	0.40	0.51	0.65	0.82	**1.05**	**1.33**	**1.69**	**2.15**	**2.73**
20	0.28	0.36	0.45	0.58	0.73	0.93	**1.18**	**1.50**	**1.91**
25	0.20	0.25	0.32	0.40	0.51	0.65	0.83	**1.05**	**1.34**
30	0.14	0.17	0.22	0.28	0.36	0.46	0.58	0.74	0.93
35	0.10	0.12	0.16	0.20	0.25	0.32	0.40	0.51	0.65
40	0.07	0.09	0.11	0.14	0.18	0.22	0.28	0.36	0.46
45	0.05	0.06	0.08	0.10	0.12	0.16	0.20	0.25	0.32

Under average climatic/ocean conditions (delta = 0), the predicted spawner-to-spawner ratio exceeded 1.0 (indicating population growth) only when water travel times were faster than 16 days (Table 22; Fig. 29). Predicted spawner to spawner ratios for water travel times associated with the Biological Opinion flow targets would approach or meet replacement of the populations for average climatic/ocean conditions. At 30 days WTT, the predicted recruits to the spawning ground were only 36% of the parent generation. At 20 days WTT, 73% of the parent generation was predicted to return to the spawning grounds, over a doubling of life cycle survival for a 10 day reduction in WTT, but insufficient for the population to increase.

Under good climatic/ocean conditions (delta = 1.0), the predicted spawner-to-spawner ratio exceeded 1.0 (indicating population growth) when water travel times were faster than 29 days (Table 22; Fig. 29). Predicted spawner to spawner ratios for water travel times associated with the Biological Opinion flow targets would exceed replacement of the populations for good climatic/ocean conditions. At 30 days WTT, the predicted recruits to the spawning ground were 93% of the parent generation. At 20 days WTT, 191% of the parent generation was predicted, again over a doubling of life cycle survival for a 10-day reduction in WTT.

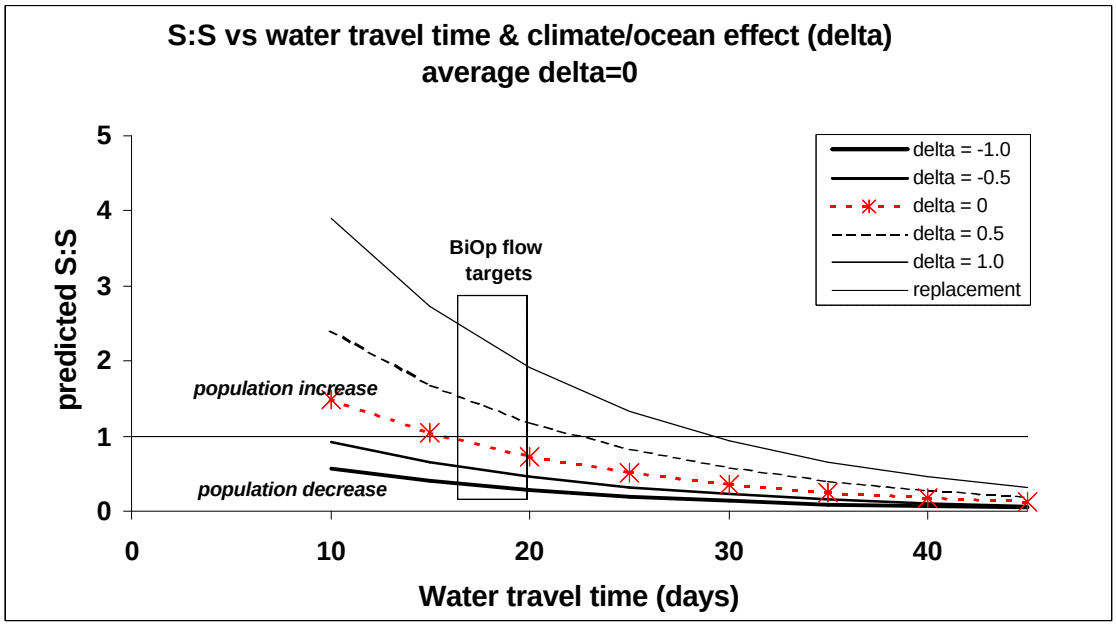

Figure 29. Predicted spawner:spawner ratios from observed ln(S:S), water travel time (WTT) and climate/ocean influence (delta), Snake River spring/summer chinook, smolt migration years 1975-1995. Population increases when S:S exceeds 1.0; and decreases when S:S < 1.0. BiOp flow targets produce WTT in the range of 16.5 to 20 days.

Under poor climatic/ocean conditions (delta = -1.0), the predicted spawner-to-spawner ratio was always less than 1.0 (indicating population decline) at all water travel times (Table 22; Fig. 29). Predicted spawner-to-spawner ratios for water travel times associated with the Biological Opinion flow targets would provide protection for the populations for poor climatic/ocean conditions, but be insufficient to prevent declines. At 30 days WTT, the predicted recruits to the spawning ground were only 14% of the parent generation. At 20 days WTT, 28% of the parent generation was predicted to return to the spawning grounds.

It is important to recognize that the relationships described above are inherently optimistic because we fit a density independent model. In reality, as the population increased toward carrying capacity, egg-to-smolt survival would decrease, and higher SARs would be needed for population growth to occur. For a given ocean condition, faster water travel times would be needed to maintain or rebuild the populations at higher spawner levels, particularly if regional harvest goals were to be achieved.

The Biological Opinion flow targets appear to represent a minimum needed to maintain the Snake River spring/summer chinook populations for average to good ocean conditions, and provide inadequate protection for poor ocean conditions. The Council's proposed relaxation of spring flow targets would increase water travel times and reduce protection against population declines and the likelihood of rebuilding Snake River spring/summer chinook.

Relationships of Chinook and Steelhead SARs to Water Travel Time and Climate/Ocean Conditions

Juvenile migration conditions and climate/ocean condition were both influential in explaining patterns of smolt-to-adult survival rates (SARs) of wild Snake River spring/summer chinook and steelhead. The relationships of predicted chinook and steelhead SARs to water travel time and the climate/ocean influence (delta) are shown in Figures 30 and 31. The water travel times from Biological Opinion spring flow targets range from 16.5 to 20 days, and are shaded in the figures. Observed water travel times ranged from 14 to 46 days in the fitted data; and delta ranged from –1.9 (poor ocean) to 1.0 (favorable ocean). We again focus this discussion on predicted smolt-to-adult survival at different water travel times, for average (delta = 0), good (delta = 1.0) and poor (delta = -1.0) climate/ocean conditions.

PATH estimated a median 4% SAR was needed for spring/summer chinook recovery, and 2% SAR to meet survival criteria. PATH did not establish a steelhead SAR range associated with survival and recovery criteria.

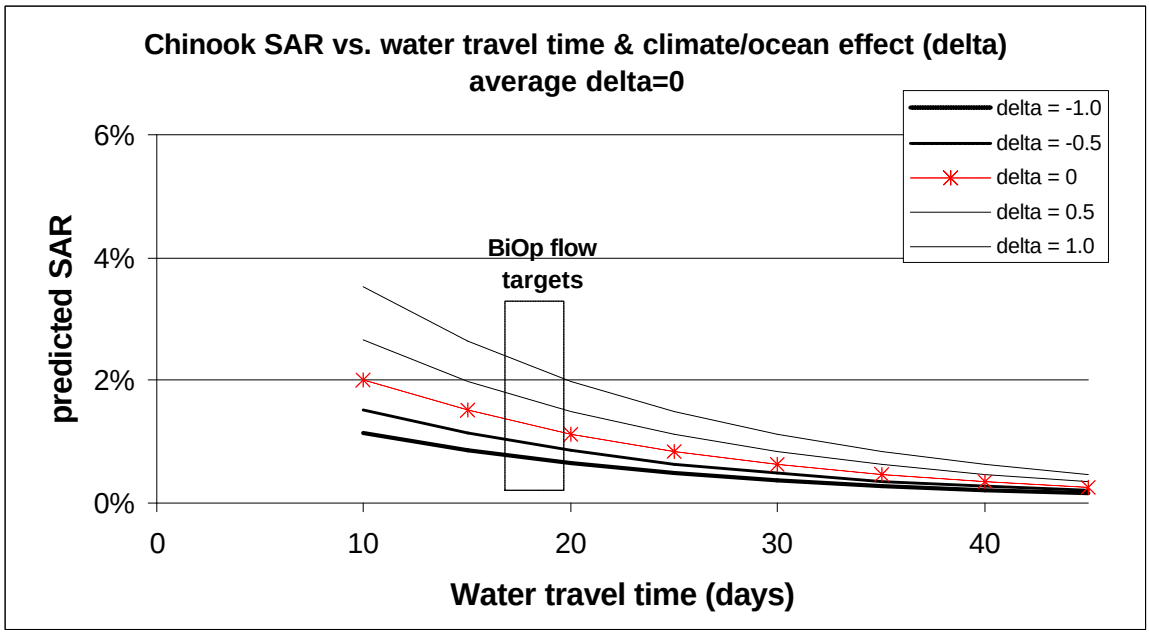

Figure 30. Predicted SAR from observed ln(SAR), water travel time (WTT) and climate/ocean influence (delta), Snake River wild spring/summer chinook, smolt migration years 1975-1995. Estimated SAR range needed for recovery is 2%-6%. BiOp flow targets produce WTT in the range of 16.5 to 20days.

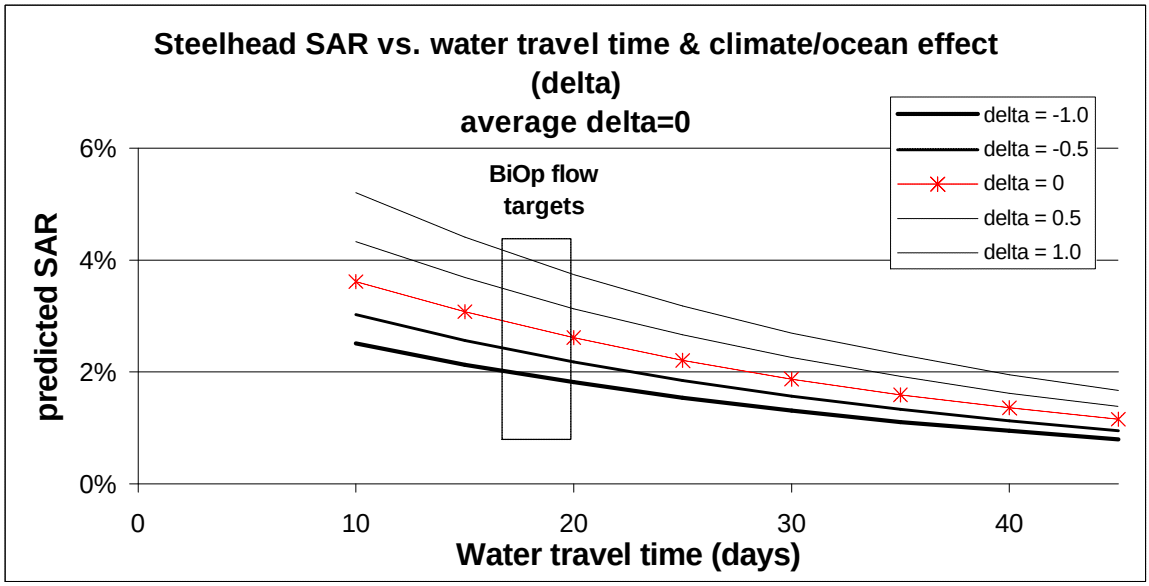

Figure 31. Predicted SAR from observed ln(SAR), water travel time (WTT) and climate/ocean influence (delta), Snake River wild steelhead, smolt migration years 1975-1995. SAR range needed for recovery has not been established. BiOp flow targets produce WTT in the range of 16.5 to 20days.

Under average climate/ocean conditions (delta = 0), the predicted SARs for spring/summer chinook exceeded 2% only at the high flows and water velocities (WTT = 10 days; Fig. 30). Predicted SARs for water travel times associated with the Biological Opinion flow targets ranged from 1.1% to 1.4% for average climatic/ocean conditions. At 30 days WTT, the predicted SARs were only 0.6%. At 20 days WTT, predicted SARs were 1.1%, a 78% improvement in life stage survival for a 10-day reduction in WTT, but less than the SAR range identified in PATH as needed for survival and recovery.

Under average climate/ocean conditions, the predicted steelhead SARs for water travel times associated with the Biological Opinion flow targets ranged from 2.6% to 2.9% (Fig. 31). At 30 days WTT, the predicted SARs were 1.9%. At 20 days WTT, predicted SARs were 2.6%, a 39% improvement in life stage survival for a 10-day reduction in WTT.

Under favorable climate/ocean conditions (delta = 1.0), the predicted SARs for spring/summer chinook exceeded 2% at average and above flows and faster water velocities (WTT = 20 days; Fig. 30). Predicted SARs for water travel times associated with the Biological Opinion flow targets ranged from 2.0% to 2.4% for good climatic/ocean conditions. At 30 days WTT, the predicted SARs were only 1.1%. At 20 days WTT, predicted SARs were 2.0%, a 78% improvement in life stage survival for a 10-day reduction in WTT, and within the SAR range identified by PATH as needed for survival and recovery.

Under good climate/ocean conditions, the predicted steelhead SARs for water travel times associated with the Biological Opinion flow targets ranged from 3.75% to 4.2% (Fig. 31). At 30

days WTT, the predicted SARs were 2.7%. At 20 days WTT, predicted SARs were 3.75%, a 39% improvement in life stage survival for a 10-day reduction in WTT.

Under poor climate/ocean conditions (delta = -1.0), the predicted SARs for spring/summer chinook never approached 2% at any flows and water velocities (Fig. 30). Predicted SARs for water travel times associated with the Biological Opinion flow targets ranged from 0.65% to 0.8% for poor climatic/ocean conditions. At 30 days WTT, the predicted SARs were only 0.36%. At 20 days WTT, predicted SARs were 0.65%, a 78% improvement in life stage survival for a 10 day reduction in WTT, but much lower than the SAR range identified by PATH as needed for survival and recovery.

Under poor climate/ocean conditions, the predicted steelhead SARs for water travel times associated with the Biological Opinion flow targets ranged from 1.8% to 2.0% (Fig. 31). At 30 days WTT, the predicted SARs were 1.3%. At 20 days WTT, predicted SARs were 1.8%, a 39% improvement in life stage survival for a 10-day reduction in WTT.

Results from this study suggest that relaxation of spring flow objectives from those specified in the Biological Opinion would likely decrease the SARs of wild Snake River spring/summer chinook and steelhead.

TRANSPORTATION

Several studies summarized in Giorgi et al. (2002) provide mechanisms and empirical information that suggests that increasing flow decreases the amount of time a smolt spends in the hydrosystem and subsequently mortality. Giorgi et al. (2002) also summarizes results reported by NMFS, which have not been able to reject hypotheses that increases in flows have no benefit to salmon survival. Based on this study, the Council has suggested relying mainly on transportation as mitigation for the impacts of the hydropower system rather than meeting flow targets. However, the benefits to transportation also remain equivocal. The Giorgi et al. (2002) report reviewed Bouwes et al. (2001) and Sandford and Smith (2002) as recent studies evaluating the benefit of transportation relative to migrating through the hydrosystem. Giorgi et al. (2002) concluded that transported fish generally exhibited higher SARs than fish that migrate in-river. Giorgi et al. (2002) failed to emphasize the important conclusions to these studies relevant to actual hydrosystem operations. Emphasis should have been placed on the comparison between wild smolts transported at all sites to the control, wild smolts that experienced a migration through the hydrosystem as if the transportation/collection system were not in place. Bouwes et al. (2001) found in 4 out of the 6 years analyzed, transported wild fish actually exhibited slightly lower SARs (point estimates) than wild fish that migrated through the hydrosystem undetected. Sandford and Smith (2002) also demonstrated equivocal differences between transported (they did not evaluated total transport SAR from all projects) and control in-river migrants as only 4 out 20 data sets demonstrated significant benefits to an optimistic representation of transportation. See Joint Technical Memorandum to NWPPC, March 19, 2002.

Our analysis also does not support the hypothesis that transportation provides a benefit to the overall survival of wild spring/summer chinook and steelhead. The spring/summer chinook S:S and steelhead SARs were not significantly influenced by the transportation proportion, and the spring/summer chinook SARs actually decreased as the proportion of smolts transported

increased. Because transportation has failed to demonstrate statistically significant increases over fish that migrate in-river, by applying similar logic used to reject flow target as a management tool, we would expect the Council to adopt a management action that ceased transportation as well. The Council's draft mainstem amendments to the Fish and Wildlife program appear to apply a double standard to what are acceptable and unacceptable management strategies.

Because the benefits of flow and transportation are not clear the region has adopted a spread the risk approach whereby both flow augmentation and transportation strategies be used as partial mitigation to the hydrosystem. The Council has proposed a spread the risk approach only for transportation, however; based on our results removing flow targets will increase the risk to populations evaluated in this analysis.

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APPENDIX A

Table 1: Information used in analysis. See text for details on data compilation of SARch (Snake River spring/summer chinook smolt-to-adult survival), lnSSch (Snake River spring/summer chinook ln Spawner to Spawner), mu (direct and delayed hydrosystem survival of Snake River spring/summer chinook relative to Mid-Columbia spring/summer chinook survival), SARst (Snake River steelhead smolt-to-adult survival), wtt (water particle travel time through Lower Granite Reservoir to Bonneville Dam), spill (average proportion of the flow spilled over dams), avgspill (average volume-kcfs-spilled over dams), climate (climate affect), ptranss (proportion of Snake River spring/summer chinook smolts arriving at LGR, LGO, LMN that were transported in barges and trucks), ptranst(proportion of Snake River steelhead smolts arriving at LGR, LGO, LMN that were transported in barges and trucks)

Obs	year	SARch	lnSSch	mu	SARst	wtt	spill	avgspill	climate	ptranss	ptranst
1	1975	0.036	-0.347	0.74	0.021	15.71	0.406	69.74	0.22	0.09	0.17
2	1976	0.010	-0.905	1.78	0.020	12.89	0.481	112.36	-0.18	0.15	0.14
3	1977	0.004	-2.031	2.68	0.010	40.23	0.004	0.82	-0.41	0.68	0.64
4	1978	0.010	-0.641	1.33	0.033	18.16	0.145	29.28	-0.50	0.54	0.65
5	1979	0.012	-0.410	0.29	0.034	19.75	0.073	16.46	-1.26	0.51	0.66
6	1980	0.006	-1.405	1.49	0.027	18.11	0.081	19.34	-0.45	0.63	0.79
7	1981	0.015	-0.153	1.27	0.012	20.65	0.089	20.72	-0.33	0.44	0.74
8	1982	0.018	1.281	0.32	0.040	13.55	0.355	85.41	0.15	0.29	0.53
9	1983	0.020	0.504	0.19	0.034	15.45	0.326	74.31	-0.33	0.27	0.67
10	1984	0.028	0.489	0.78	0.046	12.84	0.300	74.92	0.22	0.24	0.65
11	1985	.	1.556	0.67	0.040	19.06	0.109	22.36	0.87	0.69	1.00
12	1986	.	-0.240	1.64	0.041	16.64	0.210	48.27	0.33	0.64	0.92
13	1987	.	-0.786	2.22	0.052	25.58	0.053	11.73	0.42	0.64	0.96
14	1988	.	-0.425	1.25	0.027	26.67	0.031	5.17	-0.03	0.58	0.87
15	1989	.	-1.116	1.79	0.012	18.93	0.117	22.71	-0.49	0.60	0.80
16	1990	.	-0.444	2.14	0.030	22.92	0.108	19.45	0.58	0.64	0.85
17	1991	.	-0.570	1.81	0.019	20.91	0.161	38.75	-0.35	0.81	0.93
18	1992	0.002	-2.318	2.77	0.013	27.18	0.150	22.28	-1.09	0.76	0.93
19	1993	0.004	-2.199	1.43	0.013	16.80	0.231	56.65	-1.94	0.74	0.85
20	1994	0.010	-0.269	1.73	0.015	23.40	0.199	28.98	0.34	0.89	0.92
21	1995	0.003	-0.379	1.63	.	18.49	0.258	51.96	0.07	0.78	0.86
22	1996	0.004	-0.608	.	.	13.38	0.395	107.41	.	0.71	0.82

Table 2: Model comparisons with parameter estimates for ln (spring/summer chinook SARs) as function of wtt, spill, inter (interaction of wtt and spill estimated as wtt*spill), climate, and ptranss (see definitions to variables in Table 1). Shaded row is the best-fit model based on BIC score (lower scores are better fit models). Only the best 10 models with 3 or less explanatory variables are displayed.

Adjusted r^2	r^2	AIC	BIC	Parameter Estimates					
				Intercept	wtt	spill	inter	climate	ptranss
0.6363	0.6923	-15.7283	-12.7173	-3.36120	.	.	.	0.33405	-2.36221
0.6262	0.7124	-14.6778	-10.7195	-2.89070	.	-1.18510	.	0.38215	-2.74048
0.6210	0.7085	-14.4861	-10.6477	-3.14694	-0.01862	.	.	0.34198	-2.05827
0.6126	0.7020	-14.1795	-10.5319	-3.09728	.	.	-0.05143	0.37047	-2.48514
0.6064	0.6367	-15.4047	-13.4093	-3.34185	.	.	.	.	-2.66249
0.5868	0.6504	-13.9412	-11.7168	-3.14497	-0.01707	.	.	.	-2.39034
0.5842	0.6802	-13.1887	-10.1480	-2.29878	-0.03303	-1.65791	.	.	-2.72556
0.5789	0.6437	-13.6753	-11.5658	-3.07160	.	-0.67668	.	.	-2.90316
0.5722	0.6380	-13.4555	-11.4406	-3.24728	.	.	-0.01828	.	-2.71782
0.5643	0.6649	-12.5347	-9.8858	-2.83270	.	-4.47013	0.24669	.	-3.50571

Table 3: Relationship between SAR and WTT, PropSpill, and ptrans stepwise regression for sp/su chinook SARs

Dependent Variable: lnSARch

Stepwise Selection: Step 1

Variable ptranss Entered: R-Square = 0.6367 and C(p) = 4.0159

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	6.13535	6.13535	21.03	0.0006
Error	12	3.50086	0.29174		
Corrected Total	13	9.63620			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	-3.34185	0.32457	30.92697	106.01	<.0001
ptranss	-2.66249	0.58058	6.13535	21.03	0.0006

Bounds on condition number: 1, 1

All variables left in the model are significant at the 0.1500 level.

No other variable met the 0.1500 significance level for entry into the model.

Summary of Stepwise Selection								
Step	Variable Entered	Variable Removed	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	ptranss		1	0.6367	0.6367	4.0159	21.03	0.0006

Table 4: Model comparisons with parameter estimates for ln (spring/summer chinook SARs) as function of wtt, spill, inter (interaction of wtt and spill estimated as wtt*spill), climate (see definitions to variables in Table 1). Ptrans was not included in this analysis. Shaded row is the best-fit model based on BIC score (lower scores are better fit models). Only the best 10 models with 3 or less explanatory variables are displayed.

Adjusted r^2	r^2	AIC	BIC	Parameter Estimates				
				Intercept	wtt	spill	inter	climate
0.3842	0.4789	-8.3548	-4.5910	-3.33244	-0.05754	.	.	0.55993
0.3710	0.5161	-7.3927	-2.3054	-2.53110	-0.07474	.	-0.11762	0.65058
0.3298	0.4844	-6.5046	-1.9849	-2.98382	-0.06657	-0.70309	.	0.60322
0.2816	0.4474	-5.5327	-1.6264	-4.52431	.	7.07556	-0.41603	0.49688
0.2474	0.3053	-6.3283	-4.3370	-3.38346	-0.06618	.	.	.
0.2160	0.3969	-4.3100	-1.1582	-3.73312	-0.04500	5.68111	-0.36117	.
0.2130	0.3340	-4.9207	-2.6783	-4.89273	.	1.88233	.	0.50695
0.2068	0.3288	-4.8120	-2.6167	-4.91379	.	8.10073	-0.42484	.
0.1927	0.2548	-5.3475	-3.6359	-4.41290	.	.	.	0.66837
0.1901	0.3147	-4.5199	-2.4507	-3.79631	-0.05458	0.84218	.	.

Table 5: Stepwise regression for sp/su chinook SARs w/o ptrans

Dependent Variable: lnSARch

Stepwise Selection: Step 2

Variable climate Entered: R-Square = 0.4789 and C(p) = 2.5236

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	4.61479	2.30740	5.05	0.0277
Error	11	5.02141	0.45649		
Corrected Total	13	9.63620			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	-3.33244	0.54054	17.34979	38.01	<.0001
wtt	-0.05754	0.02646	2.15917	4.73	0.0523
climate	0.55993	0.29245	1.67332	3.67	0.0819

Bounds on condition number: 1.0299, 4.1198

All variables left in the model are significant at the 0.1500 level.

No other variable met the 0.1500 significance level for entry into the model.

Summary of Stepwise Selection								
Step	Variable Entered	Variable Removed	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	wtt		1	0.3053	0.3053	4.0304	5.27	0.0405
2	climate		2	0.1736	0.4789	2.5236	3.67	0.0819

Table 6: Model comparisons with parameter estimates for ln (spring/summer chinook spawner:spawner survival) as function of wtt, spill, inter (interaction of wtt and spill estimated as wtt*spill), climate, and ptranss (see definitions to variables in Table 1). Shaded row is the best-fit model based on BIC score (lower scores are better fit models). Only the best 10 models with 3 or less explanatory variables are displayed.

Adjusted r^2	r^2	AIC	BIC	Parameter Estimates					
				Intercept	wtt	spill	inter	climate	ptranss
0.6026	0.6622	-16.1548	-11.5179	1.95728	-0.09331	.	-0.12420	0.96941	.
0.5928	0.6335	-16.4417	-13.0381	1.11800	-0.07148	.	.	0.95809	.
0.5926	0.6537	-15.6327	-11.2172	1.87762	-0.09459	-1.56578	.	0.97455	.
0.5725	0.6366	-14.6194	-10.6302	1.16529	-0.06596	.	.	0.94862	-0.29051
0.4598	0.5139	-10.5078	-8.8338	0.36724	.	.	.	0.94382	-1.25700
0.4309	0.5163	-8.6127	-7.0065	0.17478	.	0.49460	.	0.94239	-1.07498
0.4292	0.5148	-8.5496	-6.9668	0.26871	.	.	0.01959	0.94290	-1.19218
0.4249	0.5111	-8.3906	-6.8666	-0.39686	.	5.40226	-0.29117	0.95190	.
0.4241	0.4817	-9.1622	-7.8601	-0.63634	.	1.69162	.	0.96638	.
0.4039	0.4337	-9.3035	-8.1231	-0.31694	.	.	.	0.99816	.

Table 7: Stepwise regression for ln(spawner/spawner) sp/su chinook

Dependent Variable: lnSSch

Stepwise Selection: Step 2

Variable wtt Entered: R-Square = 0.6335 and C(p) = 1.7233

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	12.46888	6.23444	15.56	0.0001
Error	18	7.21289	0.40072		
Corrected Total	20	19.68177			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	1.11800	0.48035	2.17074	5.42	0.0318
wtt	-0.07148	0.02282	3.93244	9.81	0.0058
climate	0.95809	0.21664	7.83736	19.56	0.0003

Bounds on condition number: 1.0035, 4.014

All variables left in the model are significant at the 0.1500 level.

No other variable met the 0.1500 significance level for entry into the model.

Summary of Stepwise Selection								
Step	Variable Entered	Variable Removed	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	climate		1	0.4337	0.4337	8.8409	14.55	0.0012
2	wtt		2	0.1998	0.6335	1.7233	9.81	0.0058

Table 8: Model comparisons with parameter estimates for mu (relative hydrosystem mortality of spring/summer chinook) as function of wtt, spill, inter (interaction of wtt and spill estimated as wtt*spill), climate, and ptranss (see definitions to variables in Table 1). Shaded row is the best-fit model based on BIC score (lower scores are better fit models). Only the best 10 models with 3 or less explanatory variables are displayed.

Adjusted r^2	r^2	AIC	BIC	Parameter Estimates					
				Intercept	wtt	spill	inter	climate	ptranss
0.4828	0.5604	-23.4717	-18.6082	-1.55562	0.08454	2.46368	.	.	1.48165
0.4690	0.5487	-22.9186	-18.2906	-1.21933	0.07934	.	0.13625	.	1.10161
0.4291	0.4862	-22.1964	-19.0993	-0.27614	0.05803	.	.	.	0.96012
0.4084	0.4675	-21.4466	-18.5718	-0.88393	0.09649	.	0.11352	.	.
0.3965	0.4870	-20.2298	-16.7277	-0.67953	0.08538	-2.65864	0.27399	.	.
0.3955	0.4862	-20.1964	-16.7081	-0.27613	0.05803	.	.	0.00074325	0.96040
0.3929	0.4232	-21.7680	-19.5162	-0.11758	0.07647	.	.	.	.
0.3783	0.4405	-20.4048	-17.8369	-0.63183	0.09221	1.06168	.	.	.
0.3751	0.4689	-19.4995	-16.2959	-0.89277	0.09639	.	0.11439	-0.04097	.
0.3600	0.4240	-19.7952	-17.4054	-0.11979	0.07628	.	.	-0.03055	.

Table 9: Stepwise regression for relative mortality sp/su chinook

Dependent Variable: mu

Stepwise Selection: Step 1

Variable wtt Entered: R-Square = 0.4232 and C(p) = 2.7175

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	4.51739	4.51739	13.94	0.0014
Error	19	6.15630	0.32402		
Corrected Total	20	10.67370			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	-0.11758	0.43170	0.02403	0.07	0.7883
wtt	0.07647	0.02048	4.51739	13.94	0.0014

Bounds on condition number: 1, 1

All variables left in the model are significant at the 0.1500 level.

No other variable met the 0.1500 significance level for entry into the model.

Summary of Stepwise Selection								
Step	Variable Entered	Variable Removed	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	wtt		1	0.4232	0.4232	2.7175	13.94	0.0014

Table 10: Model comparisons with parameter estimates for ln (steelhead SARs) as function of wtt, spill, inter (interaction of wtt and spill estimated as wtt*spill), climate, and ptranss (see definitions to variables in Table 1). Shaded row is the best-fit model based on BIC score (lower scores are better fit models). Only the best 10 models with 3 or less explanatory variables are displayed.

Adjusted r^2	r^2	AIC	BIC	Parameter Estimates					
				Intercept	wtt	spill	inter	climate	ptranst
0.4323	0.5220	-34.2612	-29.7278	-2.12802	-0.05528	.	-0.13030	0.36968	.
0.3897	0.4861	-32.8129	-28.9194	-2.22112	-0.05625	-1.60427	.	0.37760	.
0.3403	0.4444	-31.2554	-28.0354	-3.20726	-0.03910	.	.	0.35574	0.46735
0.3346	0.4046	-31.8704	-29.3959	-2.99219	-0.03272	.	.	0.36305	.
0.2101	0.2933	-28.4414	-26.9918	-2.19424	-0.05657	.	-0.12575	.	.
0.2049	0.3304	-27.5221	-25.8331	-3.50977	.	3.53358	-0.25331	0.35650	.
0.2000	0.2421	-29.0449	-27.6923	-3.65203	.	.	.	0.37972	.
0.1750	0.3053	-26.7843	-25.3817	-2.29969	-0.05065	1.46060	-0.21558	.	.
0.1694	0.3006	-26.6498	-25.2988	-2.40124	-0.05684	.	-0.10992	.	0.22259
0.1614	0.2497	-27.2451	-26.1373	-3.71540	.	0.34267	.	0.37405	.

Table 11: Stepwise regression for steelhead SARs

Dependent Variable: lnSARst

Stepwise Selection: Step 3

Variable inter Entered: R-Square = 0.5220 and C(p) = 2.8508

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	2.63954	0.87985	5.82	0.0069
Error	16	2.41735	0.15108		
Corrected Total	19	5.05690			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	-2.12802	0.52776	2.45640	16.26	0.0010
wtt	-0.05528	0.01807	1.41428	9.36	0.0075

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
inter	-0.13030	0.06575	0.59347	3.93	0.0649
climate	0.36968	0.13361	1.15656	7.66	0.0138

Bounds on condition number: 1.6624, 12.985

All variables left in the model are significant at the 0.1500 level.

No other variable met the 0.1500 significance level for entry into the model.

Summary of Stepwise Selection								
Step	Variable Entered	Variable Removed	Number Vars In	Partial R-Square	Model R-Square	C(p)	F Value	Pr > F
1	climate		1	0.2421	0.2421	7.5439	5.75	0.0275
2	wtt		2	0.1625	0.4046	4.4967	4.64	0.0459
3	inter		3	0.1174	0.5220	2.8508	3.93	0.0649

Appendix B
Survival Estimates for Survival Analysis

Survival Estimates For Survival Analysis For Reach McNary to Bonneville ST 1999 to 2002; CH1 1999 to 2002

Species	Migr_yr	Release	Reach	Survival	Species	Migr_yr	Release	Reach	Survival
ST	1999	5/11 to 6/8	MCN to BON	0.717	CH1	1999	4/25-5/8	MCN to BON	0.672
ST	2000	5/11 to 6/8	MCN to BON	0.505	CH1	1999	5/9-5/22	MCN to BON	0.756
ST	2001	5/11 to 6/8	MCN to BON	0.217	CH1	1999	5/23-6/5	MCN to BON	0.660
ST	2002	5/11 to 6/8	MCN to BON	0.532	CH1	2000	4/25-5/8	MCN to BON	0.661
					CH1	2000	5/9-5/22	MCN to BON	0.669
					CH1	2001	4/25-5/8	MCN to BON	0.452
					CH1	2001	5/9-5/22	MCN to BON	0.516
					CH1	2001	5/23-6/5	MCN to BON	0.593
					CH1	2002	4/25-5/8	MCN to BON	0.694
					CH1	2002	5/9-5/22	MCN to BON	0.819
					CH1	2002	5/23-6/5	MCN to BON	0.671

Survival Estimates For Survival Analysis For Reach Rock Island to McNary ST 1998 to 2002; CH1 1998 to 2002

Species	Migr Yr	Release	Reach	Survival	Species	Migr Yr	Rel Dates	Reach	Survival
CH1	1998	4/21-5/4	RIS to MCN	0.589	ST	1998	4/21-5/4	RIS to MCN	0.586
CH1	1998	5/5-5/18	RIS to MCN	0.926	ST	1998	5/5-5/18	RIS to MCN	0.600
CH1	1999	4/21-5/04	RIS to MCN	0.741	ST	1998	5/19-6/1	RIS to MCN	0.455
CH1	1999	5/05-5/18	RIS to MCN	0.744	ST	1999	4/21-5/04	RIS to MCN	0.670
CH1	1999	5/19-6/01	RIS to MCN	0.794	ST	1999	5/05-5/18	RIS to MCN	0.607
CH1	2000	4/21-5/4	RIS to MCN	0.783	ST	1999	5/19-6/01	RIS to MCN	0.681
CH1	2000	5/5-5/18	RIS to MCN	0.790	ST	2000	4/21-5/4	RIS to MCN	0.913
CH1	2001	4/21-5/4	RIS to MCN	0.527	ST	2000	5/5-5/18	RIS to MCN	0.657
CH1	2001	5/5-5/18	RIS to MCN	0.677	ST	2000	5/19-6/01	RIS to MCN	0.405
CH1	2001	5/19-6/01	RIS to MCN	0.588	ST	2001	4/21-5/4	RIS to MCN	0.247
CH1	2002	4/21-5/4	RIS to MCN	0.649	ST	2001	5/5-5/18	RIS to MCN	0.230

Survival Estimates For Survival Analysis For Reach Lower Granite to McNary ST 1996 to 2002; CH1H 1995 to 2002; CH1W 1995,1996,1998 to 2002

Species	Dates	migr_yr	Reach	Survival	Species	Release	Migr_yr	Reach	Survival	Species	Release	Migr_yr	Reach	Survival
ST	4/17-4/23	1998	LGR to MCN	0.616	CH1H	4/1-4/7	1998	LGR to MCN	0.806	CH1W	4/1-4/7	1998	LGR to MCN	0.760
ST	4/24-4/30	1998	LGR to MCN	0.752	CH1H	4/8-4/14	1998	LGR to MCN	0.737	CH1W	4/8-4/14	1998	LGR to MCN	0.741
ST	5/1-5/7	1998	LGR to MCN	0.682	CH1H	4/15-4/21	1998	LGR to MCN	0.744	CH1W	4/15-4/21	1998	LGR to MCN	0.804
ST	5/8-5/14	1998	LGR to MCN	0.688	CH1H	4/22-4/28	1998	LGR to MCN	0.807	CH1W	4/22-4/28	1998	LGR to MCN	0.786
ST	5/15-5/21	1998	LGR to MCN	0.754	CH1H	4/29-5/5	1998	LGR to MCN	0.793	CH1W	4/29-5/5	1998	LGR to MCN	0.799
ST	5/22-5/28	1998	LGR to MCN	0.627	CH1H	5/6-5/12	1998	LGR to MCN	0.805	CH1W	5/6-5/12	1998	LGR to MCN	0.823
ST	4/17-4/23	1999	LGR to MCN	0.746	CH1H	5/13-5/19	1998	LGR to MCN	0.863	CH1W	5/20-5/26	1998	LGR to MCN	0.600
ST	4/24-4/30	1999	LGR to MCN	0.721	CH1H	4/1-4/7	1999	LGR to MCN	0.830	CH1W	4/1-4/7	1999	LGR to MCN	0.776
ST	5/1-5/7	1999	LGR to MCN	0.705	CH1H	4/8-4/14	1999	LGR to MCN	0.754	CH1W	4/8-4/14	1999	LGR to MCN	0.808
ST	5/8-5/14	1999	LGR to MCN	0.632	CH1H	4/15-4/21	1999	LGR to MCN	0.720	CH1W	4/15-4/21	1999	LGR to MCN	0.795
ST	5/15-5/21	1999	LGR to MCN	0.744	CH1H	4/22-4/28	1999	LGR to MCN	0.806	CH1W	4/22-4/28	1999	LGR to MCN	0.790
ST	5/22-5/28	1999	LGR to MCN	0.837	CH1H	4/29-5/5	1999	LGR to MCN	0.815	CH1W	4/29-5/5	1999	LGR to MCN	0.814
ST	4/17-4/23	2000	LGR to MCN	0.715	CH1H	5/6-5/12	1999	LGR to MCN	0.799	CH1W	5/6-5/12	1999	LGR to MCN	0.694
ST	4/24-4/30	2000	LGR to MCN	0.595	CH1H	5/13-5/19	1999	LGR to MCN	0.796	CH1W	5/13-5/19	1999	LGR to MCN	0.756
ST	5/1-5/7	2000	LGR to MCN	0.549	CH1H	5/20-5/26	1999	LGR to MCN	0.716	CH1W	5/20-5/26	1999	LGR to MCN	0.900
ST	5/8-5/14	2000	LGR to MCN	0.559	CH1H	4/15-4/21	2000	LGR to MCN	0.936	CH1W	4/8-4/14	2000	LGR to MCN	0.727
ST	4/24-4/30	2001	LGR to MCN	0.159	CH1H	4/22-4/28	2000	LGR to MCN	0.764	CH1W	4/15-4/21	2000	LGR to MCN	0.825
ST	5/1-5/7	2001	LGR to MCN	0.177	CH1H	4/29-5/5	2000	LGR to MCN	0.717	CH1W	4/22-4/28	2000	LGR to MCN	0.748
ST	5/8-5/14	2001	LGR to MCN	0.187	CH1H	5/6-5/12	2000	LGR to MCN	0.749	CH1W	4/29-5/5	2000	LGR to MCN	0.727
ST	5/15-5/21	2001	LGR to MCN	0.143	CH1H	5/20-5/26	2000	LGR to MCN	0.729	CH1W	5/6-5/12	2000	LGR to MCN	0.731
ST	5/22-5/28	2001	LGR to MCN	0.079	CH1H	4/8-4/14	2001	LGR to MCN	0.573	CH1W	5/13-5/19	2000	LGR to MCN	0.732
ST	4/24-4/30	2002	LGR to MCN	0.461	CH1H	4/15-4/21	2001	LGR to MCN	0.605	CH1W	5/20-5/26	2000	LGR to MCN	0.858
ST	5/1-5/7	2002	LGR to MCN	0.466	CH1H	4/22-4/28	2001	LGR to MCN	0.593	CH1W	4/8-4/14	2001	LGR to MCN	0.649
ST	5/8-5/14	2002	LGR to MCN	0.390	CH1H	4/29-5/5	2001	LGR to MCN	0.578	CH1W	4/15-4/21	2001	LGR to MCN	0.605
ST	5/15-5/21	2002	LGR to MCN	0.516	CH1H	5/6-5/12	2001	LGR to MCN	0.552	CH1W	4/22-4/28	2001	LGR to MCN	0.588
ST	5/22-5/28	2002	LGR to MCN	0.724	CH1H	5/13-5/19	2001	LGR to MCN	0.470	CH1W	4/29-5/5	2001	LGR to MCN	0.521
ST	4/24-4/30	1996	LGR to MCN	0.793	CH1H	5/20-5/26	2001	LGR to MCN	0.276	CH1W	5/6-5/12	2001	LGR to MCN	0.507
ST	5/1-5/7	1996	LGR to MCN	0.792	CH1H	4/22-4/28	2002	LGR to MCN	0.586	CH1W	5/13-5/19	2001	LGR to MCN	0.458
ST	5/15-5/21	1996	LGR to MCN	0.659	CH1H	4/29-5/5	2002	LGR to MCN	0.733	CH1W	5/20-5/26	2001	LGR to MCN	0.258
ST	4/17-4/23	1997	LGR to MCN	0.902	CH1H	5/6-5/12	2002	LGR to MCN	0.638	CH1W	4/22-4/28	2002	LGR to MCN	0.730
ST	4/24-4/30	1997	LGR to MCN	0.611	CH1H	5/13-5/19	2002	LGR to MCN	0.732	CH1W	4/29-5/5	2002	LGR to MCN	0.657
ST	5/1-5/7	1997	LGR to MCN	0.804	CH1H	5/20-5/26	2002	LGR to MCN	0.755	CH1W	5/6-5/12	2002	LGR to MCN	0.660
					CH1H	4/15-4/21	1995	LGR to MCN	0.725	CH1W	5/13-5/19	2002	LGR to MCN	0.640
					CH1H	4/22-4/28	1995	LGR to MCN	0.668	CH1W	5/20-5/26	2002	LGR to MCN	0.773
					CH1H	4/29-5/5	1995	LGR to MCN	0.779	CH1W	4/15-4/21	1995	LGR to MCN	0.825
					CH1H	4/15-4/21	1996	LGR to MCN	0.586	CH1W	4/22-4/28	1995	LGR to MCN	0.669
					CH1H	4/22-4/28	1996	LGR to MCN	0.683	CH1W	4/29-5/5	1995	LGR to MCN	0.795
					CH1H	4/29-5/5	1996	LGR to MCN	0.652	CH1W	5/6-5/12	1995	LGR to MCN	0.759
					CH1H	5/6-5/12	1996	LGR to MCN	0.689	CH1W	4/15-4/21	1996	LGR to MCN	0.736
					CH1H	5/13-5/19	1996	LGR to MCN	0.779	CH1W	4/22-4/28	1996	LGR to MCN	0.480
					CH1H	4/29-5/5	1997	LGR to MCN	0.444	CH1W	4/29-5/5	1996	LGR to MCN	0.556

Appendix C

FISH PASSAGE CENTER

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January 10, 2003

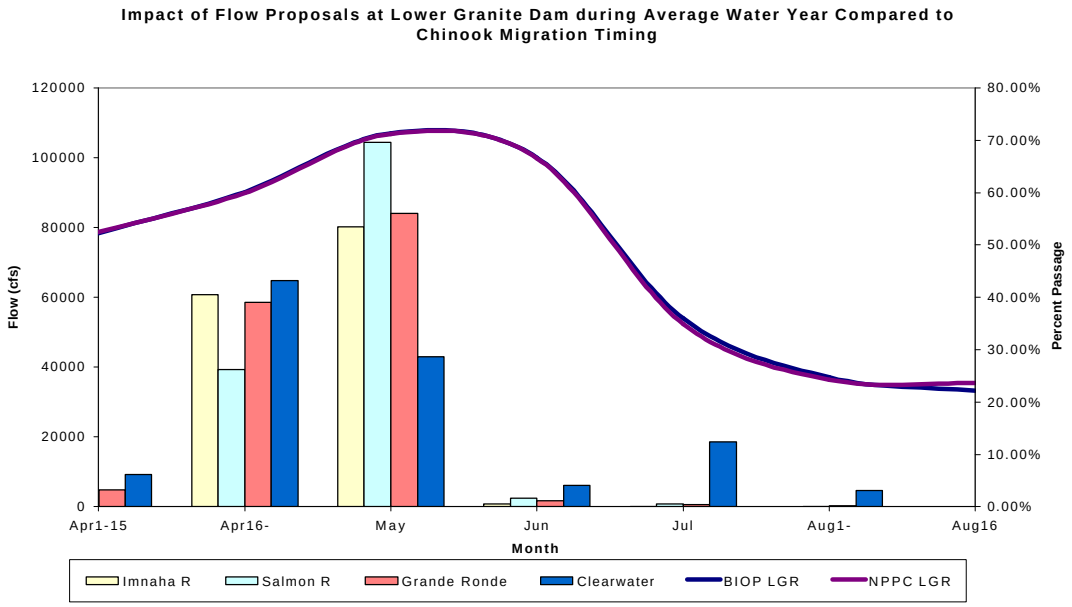
Independent Scientific Advisory Board
Northwest Power Planning Council
851 SW 6th Avenue, Suite 1100
Portland, OR 97204-1348

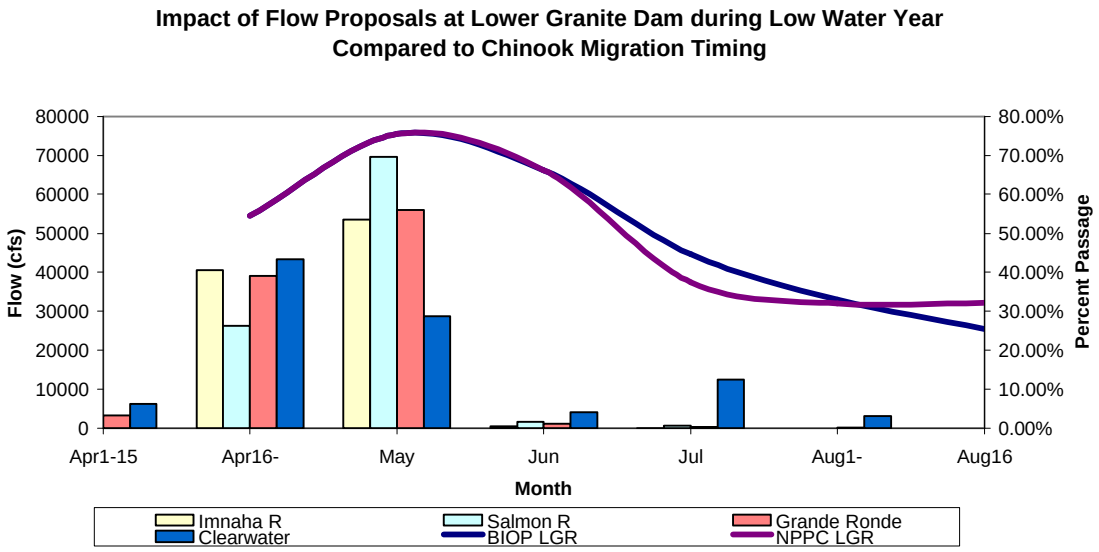
Dear ISAB Members,

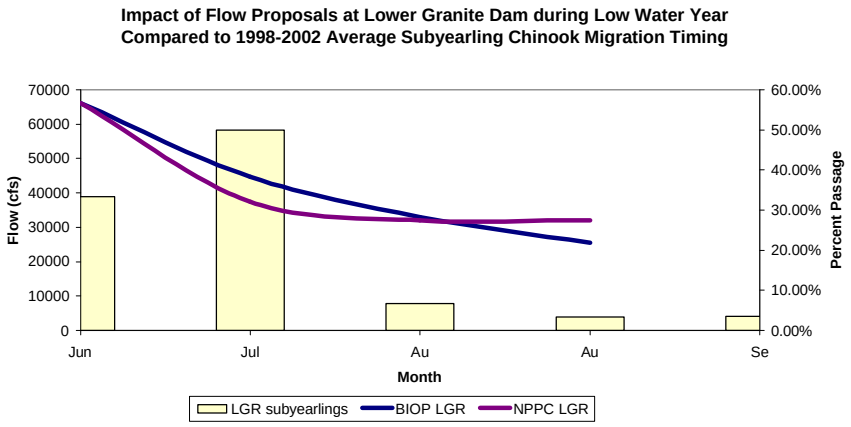
On December 17, 2002 a group of fishery agency and Fish Passage Center staff met with the Independent Scientific Advisory Board (ISAB) to discuss the comments developed by the State, Federal, and Tribal Anadromous Fish Managers on the Northwest Power Planning Council's (NWPPC) Draft Mainstem Amendments as they Relate to Flow/Survival Relationships for Salmon. A series of questions were developed by the ISAB prior to the meeting and the attendees responded to those questions during the meeting. As a follow up to the meeting we are providing a written response to the questions (Attachment A).

Additionally, at the meeting we expressed concern regarding the range of timing exhibited by the different stocks of salmon. We told the ISAB that we would provide them with that information for consideration during their present review. The following graphs depict the timing of specific stocks together with the flows that occur under low and average flow levels for the 50 year historic record, both under the implementation of the Biological Opinion and under the proposed NPPC amendments.

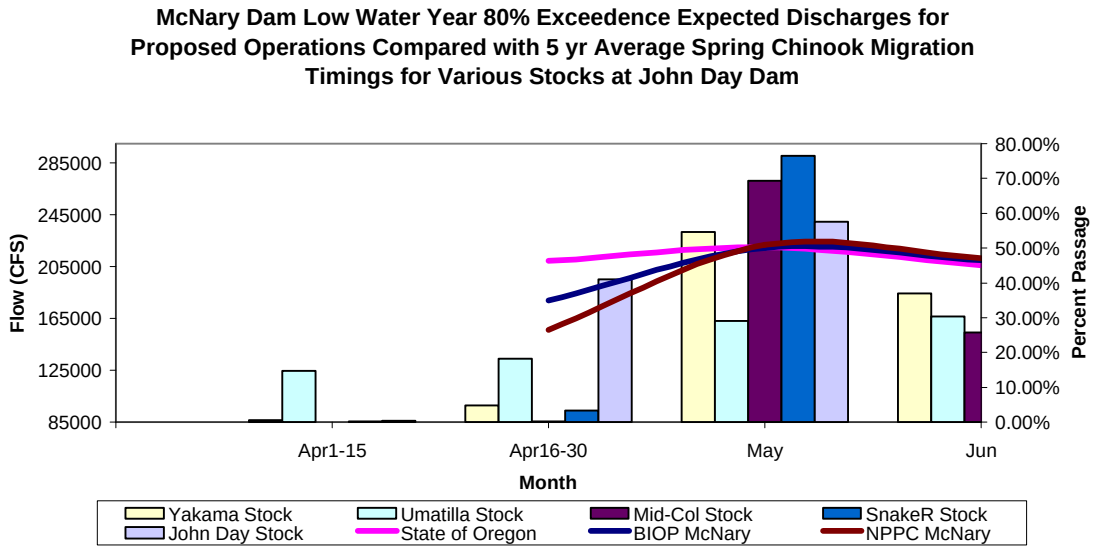
The first two graphs look at arrival time at Lower Granite Dam of yearling and subyearling chinook stocks migrating over the entire spring and summer periods for available PIT tag information. The third graph focuses on the summer period and the migration timing of subyearling chinook. As seen from the graphs, shifting water out of July could have serious impacts to a large proportion of the chinook migrants.

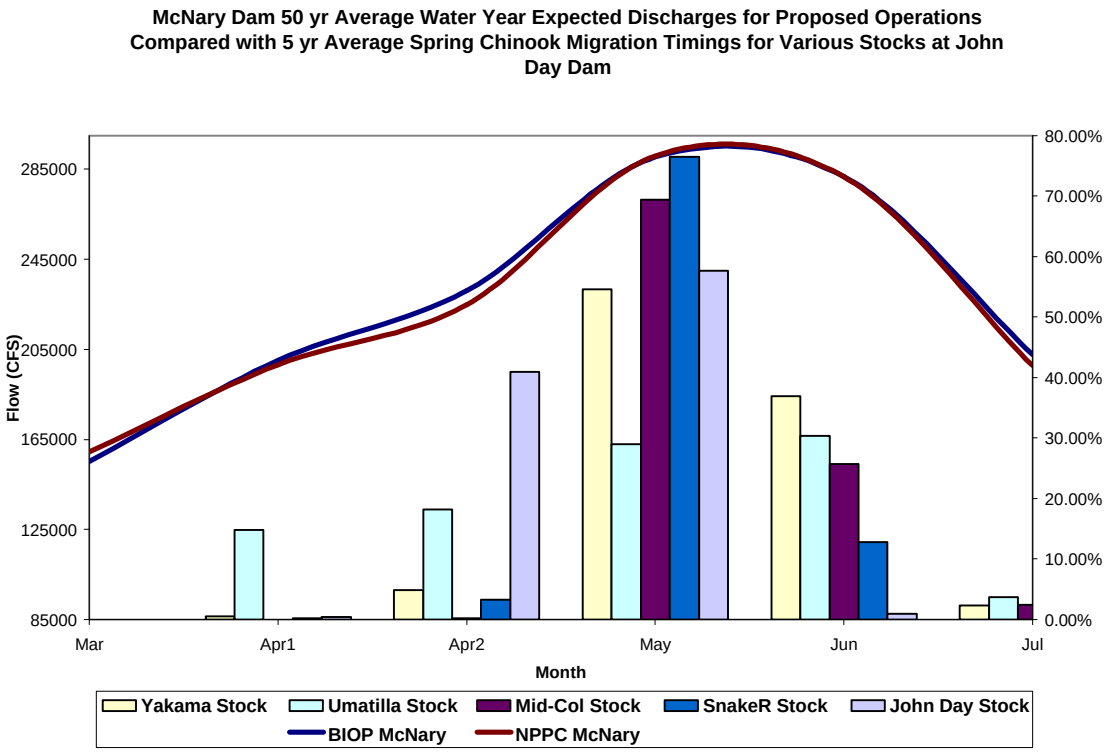

Impact of Flow Proposals at Lower Granite Dam during Average Water Year Compared to Chinook Migration Timing
Flow (cfs)
Percent Passage
Month
Apr1-15
Apr16-
May
Jun
Jul
Aug1-
Aug16
Imnaha R
Salmon R
Grande Ronde
Clearwater
BIOP LGR
NPPC LGR


Impact of Flow Proposals at Lower Granite Dam during Low Water Year Compared to Chinook Migration Timing
Flow (cfs)
Percent Passage
Month
Apr1-15
Apr16-
May
Jun
Jul
Aug1-
Aug16
Imnaha R
Salmon R
Grande Ronde
Clearwater
BIOP LGR
NPPC LGR



The next two graphs show the migration timing of chinook stocks in the Lower Columbia River. Here we can see that while the second half of April is not normally characterized as a significant passage period for spring migrating juveniles as a whole, it does represent a period of time when significant proportions of specific stocks are migrating. Stocks migrating from the John Day, Umatilla and Yakama river basins dominate the second half of April.





We hope this information is helpful to you in your present review. Please feel free to contact us if you need any additional information.

Sincerely,

Michele DeHart
Fish Passage Center Manager

ATTACHMENT A

Documentation of December 17th, 2002 responses to the ISAB questions on the Benefits of Flow Augmentation document.

I. What do you mean by "…the discrete relation between flow and water transit time (WTT) (also known as water particle travel time)" see (Figures 1 and 2 showing relation between WTT and average flow in the Snake River and McNary Dam reservoir). How is WTT computed for the rest of the analyses in your report?

The word "discrete" relation was poor wording – it should read "direct" relation (or possibly it would be better to say "inverse" relation). The reason flow and water transit time are related is that water transit time is computed as a function of flow. For a single reservoir and its respective dam, water transit time is computed as Volume/Flow where river discharge (flow) and volume at the associated reservoir elevations for the time period of interest is used. This approach allows a specific water transit time to be generated for each individual segment of the overall reach for which travel time and survival estimates are being generated. This is an improvement over the methods used in the past where flow was simply indexed over a calculated number of days at a particular dam such as Lower Monumental Dam or Ice Harbor Dam (e.g., dates of middle 50% passage at the dam and dates from release to median passage at the dam are two common methods of averaging flows).

II. Karl Dreher in his presentation to the Council on 12/11/02 seems to claim that there is no relationship between flow and water particle travel time, i.e., velocity. This seems to be in direct conflict with Figures 1 and 2. Please explain the difference interpretations. How were the figures developed? Formula? Assumptions? What is the evidence for a relationship?

We were not present at the Karl Dreher presentation and, therefore, cannot respond to what was said during his presentation. However, the relation between flow and water transit time is a physical relation. Water transit times through the reservoirs were calculated using the storage replacement method, of which flow is inversely related. This method was suggested as the preferred option by Hydrological Engineering Center at the COE. Furthermore, the COE Hydrological Engineering Center ran their HEC-2 model over the Lower Snake River over the same range of conditions as used in the FPC analysis (the data used to compute water transit times) and it is consistent with the results obtained using the storage replacement method. Marshall C. Richmond, Chief Engineer at the Pacific Northwest National Laboratory in Richland, Washington provided estimates of water transit times through the Hanford Reach at various discharges using their 1D unsteady flow model (MASS1) (Richmond, Perkins, Chien, 2002).

III. What is "Average Q", e.g. at McNary Dam.

Average Q at any project is the average over the period of interest of the COE's daily average discharge values for that project.

IV. What do you mean by "Whenever a component survival estimate was greater than 1, then the standard error divided by 1 was used as the threshold criteria."

When a component survival estimate (e.g., LMN to MCN) is estimated to be greater than 1, then we simply used the value of the standard error divided by 1 in the decision of whether the CV was greater than 0.25. This was to avoid shrinkage in the CV as the point estimate increased 100% survival. The goal was to not compute an overall reach survival estimate from the product of a the various segments of the overall reach if any individual segment's survival point estimate was so imprecise as to have a confidence interval of approximately +/- 50% of the point estimate.

V. In Figures 3, 4, and 5, e.g., "Wild yearling chinook travel time versus water transit time. Hatchery Yearling Chinook Median Travel Time versus Water Transit Time Lower Granite Dam to McNary Dam 1995 to 2002" why is the one year (upper center) so far from the others? High travel time but mid water transit time?

The data point with an estimated high travel time and mid-range water transit time is from the April 1-7 release block in 2002. Water temperature on April 1 was approx 8?C (46?F), the lowest of the years considered. Smolt travel time from LGR to LGS was 19 days (approx 60% of total reach travel time) for these early fish, while water transit time was only 4 days. Cold water and low smoltification apparently contributed to the long travel time estimate, which for the reach was about 50% longer than the next weekly block.

VI. In Figures3, 4, and 5, e.g., "Wild yearling chinook travel time versus water transit time. Hatchery Yearling Chinook Median Travel Time versus Water Transit Time Lower Granite Dam to McNary Dam 1995 to 2002" why is the one year (upper center) so far from the others? High travel time but mid water transit time?

The three data points with extremely long travel times are not from three years, but instead are simply the three temporal periods of 2001. The travel time/water transit time plots for the Mid-Columbia River reach include up to three temporal (two-week) periods per year.

VII. When is multicollinearity a problem? My rule was always to see if there were wild changes in the coefficients with minor changes in the data set. See the quote "The correlation between WTT and SPILLPROP for steelhead was r = -0.87, a level still low enough so that multicollinearity is not a problem."

Multicollinearity was considered to be a problem in the strictest interpretation of when it creates singularity in the inverse of the variance-covariance matrix. The rule of thumb from Myers' regression text was used. Since multicollinearity is less than the extreme case still has an unfavorable effect of inflating the variances of the parameters being estimated, we cannot rule out a particular parameter may not be important just because its slope parameter was not significant when in the presence of its moderately collinear pair in the model. But when both moderately collinear pairs of factors are able to remain in the model jointly, then it good evidence that each factor is important to the relation being modeled.

VIII. In regression modeling with highly correlated variables, I (McDonald) have used "ridge regression" to help stabilize the coefficients, i.e., usually one coefficient is large and negative and the other is large and positive, but residuals continue to look good, and they jump around if small changes are made in the data. Have you considered using ridge regression to include both temp and flow in the models when temp and flow are highly correlated? If no, why not?

We did not attempt to run ridge regression. The technique in Myers' regression textbook was reviewed. However, the dangers of arrive at an improper shrinkage factor *k*, which is key to properly adjusting the variance-covariance matrix before inverting it, lead us away from pursuing that approach further.

IX. Have you conducted any new analysis of Billy Connor's data? Starting on page 23 it seems like you are mostly quoting and repeating his results. Are there any differences in your interpretation of the data and Connor's?

The document was developed collectively by a group of State, Federal and Tribal staff and FPC staff. Billy Connor took part and was responsible for developing this section.

X. Do you have any concerns with the methods used by Connor to estimate "…mean flows and water temperatures recalculated to represent those that would have occurred if flow were not augmented (from Table 3)." What are the assumptions and methods?

This is the methods section from Connor et al. (in press b). The flow exposure index was recalculated after subtracting the daily volume of water released for summer flow augmentation (Appendix 1). The water temperature exposure index was recalculated using temperatures that were simulated for the tailrace of Lower Granite Dam under the flow conditions had the summer flow augmentation not been implemented (Appendix 2). Water temperatures were simulated using a one-dimensional heat budget model developed for the Snake River by the U.S. Environmental Protection Agency (Yearsley et al. 2001). Past model validation showed that daily mean water temperatures simulated for July and August were within an average of 1.1oC of those observed (Yearsley et al. 2001).

XI. This is the first time that we have seen three variables in the regression models to predict survival. What is different or what data have been added to previous analyses? See, e.g., "Table 7. Multiple regression models for predicting survival of combined hatchery and wild yearling chinook salmon in the Snake River from the tailrace of Lower Granite Dam to the tailrace of McNary Dam." Please review the criteria used for selection of the models. In particular was AIC used? Maybe I missed it.

Using more than simply a flow-related variable to determine a relation with smolt survival is not a new idea. NMFS in publish papers has utilized several predictor variables in the regression models. In studies of smolt travel time in the past we have utilized several predictor variables in regression models. In the present application to smolt reach survival, the predictor variables

were water transit time, proportion of spill, and water temperature. Because each of these predictor variables are linked to conditions at can influence survival, the model that contained the most predictor variables that each had slope parameter significantly different than zero was chosen as the best model with explanatory capability. Even when spill proportion did not remain in a model in the presence of water transit time, we acknowledged that its influence was still present because the spillway route is a dam's highest survival route based on past NMFS studies.

XII. Explain the interpretation of "Figure 21. Survival of PIT tagged yearling chinook from McNary Dam tailrace to Bonneville Dam tailrace based on time of passage at McNary Dam, 2001." What is this figure telling us?

Figure 21 simply shows the estimated survival of yearling chinook temporally blocked based on dates of passage at McNary Dam to the tailrace of Bonneville Dam. Superimposed on the resulting survival estimates over the season is the annotation as to whether or not spill was occurring at downstream dams in the reach of interest, and if so, at how many dams. The point of the plot is to show that there was a trend in increasing survival in the lower Columbia River in 2001 that was coincident with the increase in spill be provided at dams within the reach. Flows were only moderately changing in 2001 and water temperatures followed the normal course of increasing over time, which links well with increasing predation activity over time. Under these conditions, one would expect reach survival to decrease over the season had spill never been used in the lower Columbia River. The fact that this trend was not observed lends more support to the benefit of the limited spill periods over which the additional spillway route of passage was available at the dams to improving smolt survival over what would have otherwise occurred without any spill provided.

(Then answers to questions 13-15 were previously provided to the ISAB and are attached here.)

XIII. Are there confounding factors that would explain the negative relationship noted in the quote "We found a moderate to strong relationship between chinook SARs and transportation proportion (r 2 =0.64, p<0.001); however this relationship was negative suggesting years in which the proportion transported increased the SARs decreased (Figure 27)." Are the years with low SAR just the years with bad ocean conditions and high proportion of transported fish?

XIV. How do we interpret the information in Figure 28 dealing with mu, i.e., "…direct and delayed hydrosystem survival of Snake River spring/summer chinook relative to downriver spring/summer chinook, estimated in PATH by the parameter mu (Deriso et al. 2001)"?

XV. What is the parameter "delta" derived in the Plan for Analyzing and Testing Hypotheses (PATH), as a measure of climate/ocean mortality influences? How is it measured? See Table 22 and Figure 29. Help interpret Figure 29.

Additional Questions e-mailed on December 12th, 2002.

1. **A major criticism of flow augmentation coming from the upper basin folks is that the interannual patterns of flow, travel time, and survival that the FPC generally has used are not relevant to the within-year amounts of additional water that are provided by flow augmentation policies. Over the broad span of flows among years, there is a clear trend (amplified by recent extreme high and low flow years). On this most folks seem to agree. However, they say that a relatively small amount of added water volume within a year may not mean much for fish. In fact, they say it means most for fish depending on when and how (what temperatures, etc.) that water is added, not the volume. The ISAB said as much in its last report on the subject. That seems to be one reason they suggest shifting the timing of the water that is used for FA. Would the FPC provide their evidence that within-year flow augmentation is important for survival, and specifically when and under what conditions they believe it is most valuable (e.g., late summer flows of cold water from Dworshak for cooling the Lower Snake).**

The difficulty in determining the effect of "flow augmentation" is that flow augmentation implicitly means that flow is being added to a level of flow provided for other uses. The present hydrosystem operations as anticipated by the Biological Opinion are the result of consideration and melding of power, flood control, recreation, resident fish and fish passage needs. It is difficult therefore to quantify actual "flow " for fish passage. Flows provided for fish migration also generates power and other benefits. The separation of flows provided for fish benefits versus power or other benefits is an accounting issue that has never been clearly resolved. For example, the accounting of flow for fish or power was raised during the winter months of 2001, when power demand required higher flows during the winter months, which also benefited the natural spawning area below Bonneville Dam. Similar accounting issues have been raised regarding spill. The Biological Opinion identifies specific levels of spill for fish passage; often spill levels are higher because of flood control or flow in excess of power generation needs. The accounting for this excess spill separately from the BIOP spill levels is a prevailing question. We do not know how to accurately and separately account for the amount of flow that results from each of the purposes of system operations. Our analysis addresses the benefit of flow for fish passage regardless of whether the flow is the result of flood control releases or hydropower generation.

The effect of flow increases and decreases on fish travel time can be estimated using the flow/water transit time and travel time relationships developed for specific River reaches. These relationships have been developed over several decades over a wide variation of conditions. The recent data and the historical data have remained consistent over the years. This is because the mechanisms of travel time are less complicated and involve fewer variables. Flow is the direct and determining factor over fish travel time. On the other hand, juvenile survival estimates are an index describing the juvenile migration. Determination of incremental flow and survival is difficult because of the actual complex mechanisms that determine survival. A within year flow survival relationship does not emerge in the present data, not because flow is not important but, because of several factors including the limitations of data collection and analysis. First, juvenile survival is the result of many direct and indirect environmental and biotic variables. By necessity these variables such as flow are described as averages over a period of time. This dampens the effect of that variable. Second, within year flow survival relationships are not

apparent from available data because the individual survival release groups overlap and the environmental variables such as flow is averaged over many days and many overlapping release groups. Third, annual estimates of survival address the problem of overlap to some degree, however the annual flow average (even over large groups) had not changed substantially until 2001, when the Biological Opinion measures were not implemented. Our present data shows a significant flow survival relationship as a result of the large change that occurred in the flow variable when the Biological Opinion measures were not implemented.

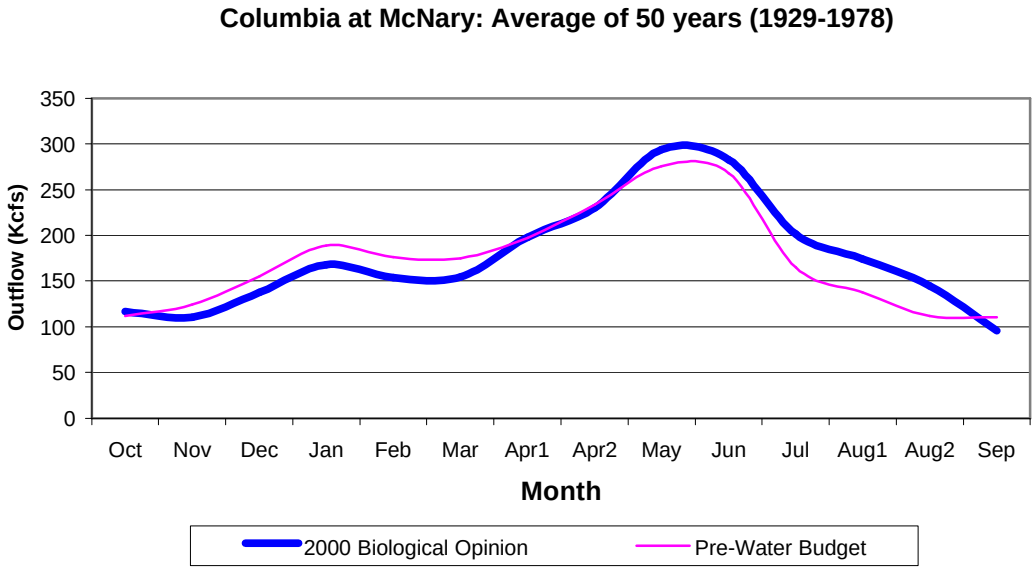
The FPC identified these issues in memorandums to the Fishery Managers in 1992 and again in 1995 that the problem of excessive overlapping of PIT tagged release groups as they migrate through the study reach will not allow discrete partitioning of the incremental effects of environmental or biotic variables that affect survival. NMFS recognized this phenomenon after implementing the methodology for several years. Smith and Muir (1996) state, "Identifying and quantifying relationships between environmental variables and survival and travel time of release groups of PIT tagged migrant juvenile salmonids have presented difficult challenges. Chief among these is that fish from a single release group do not migrate as a group but spread out over time. If conditions change over a short period of time relative to the time it takes for the bulk of the release group to migrate through a particular river section then different fish from the group experience different levels of various environmental factors. In this situation estimated survival probabilities (defined for the entire release group) are usually valid estimates of average survival for the group. However, it is difficult to accurately quantify the environmental conditions to which the entire release group was exposed and to relate that to the survival estimates. More over, if a series of releases is made and migrations are protracted the various release groups may have considerable overlap in passage distributions, further clouding the relationship between survival probabilities and environmental variables by decreasing the contrast in the levels of exposures among the various groups."

The above problems created by overlapping environmental and biotic conditions within a single year are reduced when comparisons are made across years. Nevertheless, the environmental and biotic conditions observed across years must span a fairly wide range of values to offset the natural variability inherent in them. Therefore the regression analyses demonstrate statistical significant differences in survival due to these environmental and biotic conditions. The year 2001 is so an important in these regression analyses because it defines the true range of conditions that are possible in the present hydrosystem. When 2001 survival data is considered, the FPC analyses demonstrate that statistically significant relations between reach survival of yearling chinook and steelhead smolts and the flow-related variable of water transit time are obtainable. But even these relations do not allow the determination of incremental effects of flow augmentation alone. In our answer to your Question 9, we discuss how spill also influences the smolt survival in the reach by providing the route of highest survival at each dam to the proportion of smolts that utilize that route. Therefore, in every reach survival estimate there are contributions of both spill passage at the dams and flow-related variables in the reservoirs to the overall smolt survival estimates. We have been successful in demonstrating that analyses of survival data must include a series of years in order to get a wide enough range of environmental and biotic conditions to show statistically significant relations between smolt survival and a joint set of predictor variables which include a flow-related variable.

The fact that among year flow, water transit time, fish transit time relations can be established provides significant reasons to achieve, at a minimum, Biological Opinion flow objectives in any given year. The proposed NWPPC Program measures would move water from the fish migration period, back to the winter period, affecting flow during the fish migration period. This would be contrary to the intent of the Biological Opinion. Seasonal flow targets were derived in order to meet minimal hydrosystem survival rates in conjunction with harvest, hatchery and habitat measures, which are required to achieve overall population survival and recovery. Flows should be met throughout the migration period because of differences in passage timing for individual populations. Within populations there are different out migration timing for various life-history strategies (e.g. differing overwintering locations within a tributary). The importance of providing protection measures across populations and life-history types has been thoroughly documented, such as ISG Return to the River(1996, 2000) and NMFS Viable Salmonid Populations (McElhany et al. 2000). In addition, in river survival estimates represent only one component of the life cycle, which flows can effect. Other effects of flow include the additional direct mortality that occurs down stream of reach studies and the indirect or delayed mortality that occurs as a result of fish condition, arrival timing and estuary and plume conditions.

2. **With the Canadian Treaty dams providing most of the reshaping of the annual hydrograph for the Columbia River from its historical pattern, how much influence on the lower Columbia discharge (and therefore changed fish survival) can we realistically expect from augmented flows from Hungry Horse, Libby, Dworshak, and the Hells Canyon project? Aren't the changed flows and survivals fairly trivial? (Unless carefully timed, as above).**

The operation of the Canadian Projects was factored into the development of the actions necessary to implement the Biological Opinion flow measures. The changes in flow that result from operating the US Reservoirs to the April 10th upper rule curve, and the augmentation volumes from these reservoirs are not trivial in achieving the Biological Opinion flows and affecting survival. A comparison could be made to the operation of the power system prior to the implementation of the Water Budget and the subsequent implementation of the Biological Opinion. Both scenarios occurred with the Canadian Treaty dams in place, yet significantly more water was moved into the fish migration period.



Answers to Questions 13-15 from the ISAB on Fish and Wildlife Managers-NWPPC Response Flow and Spill Update Summary of Data Analysis and Review Regarding Mainstem Fish Passage Relating to Flow

Answers Prepared by:

Charlie Petrosky
Idaho Fish and Game

and

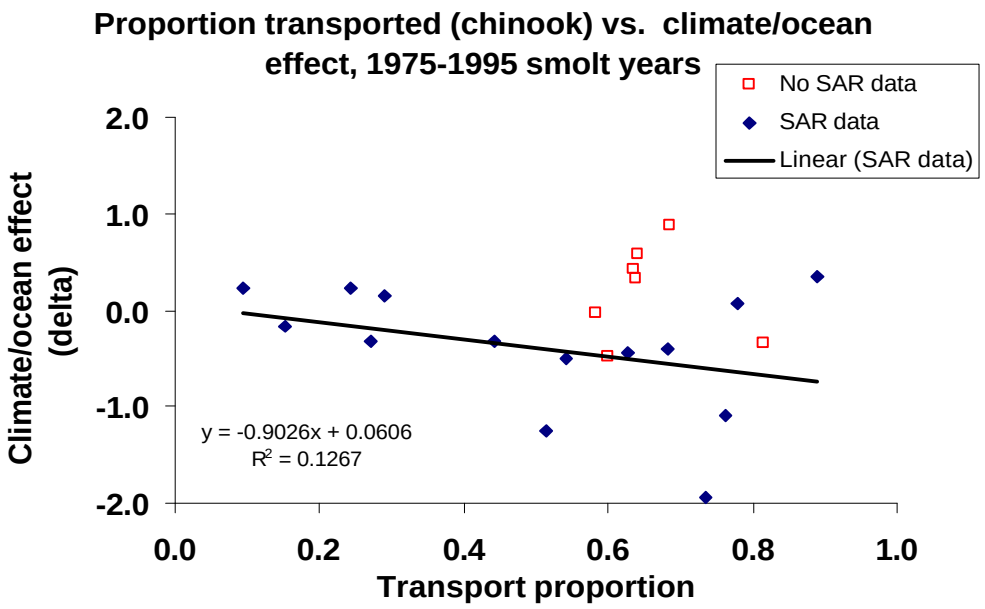
Howard Schaller
US Fish and Wildlife Service

December 17, 20002

ISAB Question XIII

Graphed the two variables in question relating to potentially confounding factors

Transport Proportion Vs Delta



Any relationship between proportion transported and delta appears to be weak

It is apparent from the data that the years with high transport proportions are not always the years with bad ocean conditions

ISAB Question XIV

In the Model from figure 28:
μ represents the relative difference in mortality between upriver and downriver stocks;

In Deriso et al. (2001) μ is subtracted from ln(R/S) in linear Ricker function

$$\ln(R/S) = (a + d_t - X_n - \mu_t) - b*S$$

where;

- **a** =intrinsic rate of population growth 'Ricker a'
- d_t = common year effect (climatic/ocean effect)
- X_n =direct hydrosystem mortality for lower river stocks
- μ_t =differential mortality (relative difference in mortality between upriver and downriver stocks)
- $_t$ =year

e.g., for μ = 1 (Snake River stocks had a relative mortality increase of 1.0); translates to a relative survival of 0.366; exp(-μ)

1975-1995 range of observed μ was 0.19 to 2.77;
Snake River stocks survived 6% to 83% as well as the downriver stocks

μ	relative survival
0.0	1.00
0.5	0.61
1.0	0.37
1.5	0.22
2.0	0.14
2.5	0.08
3.0	0.05

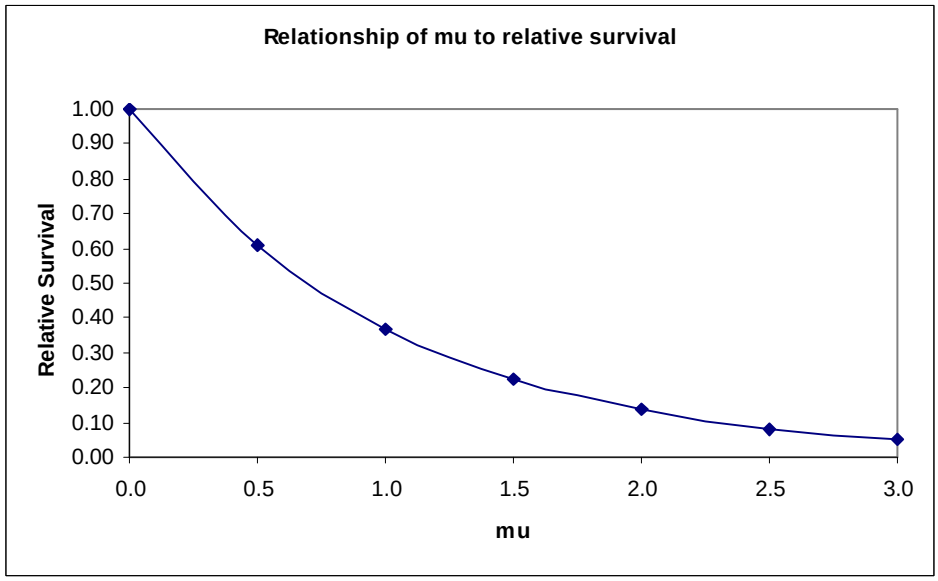


Figure 28 indicates that relative hydrosystem mortality increased with increased water travel times

ISAB Question XV part 1

In the Model from figures 29-31 where;
d is defined as common year effect (climatic/ocean effect)
from Deriso et al. (2001) see derivation from description of μ

ln(SAR) = WTT + delta or ln(S/S) = WTT + delta

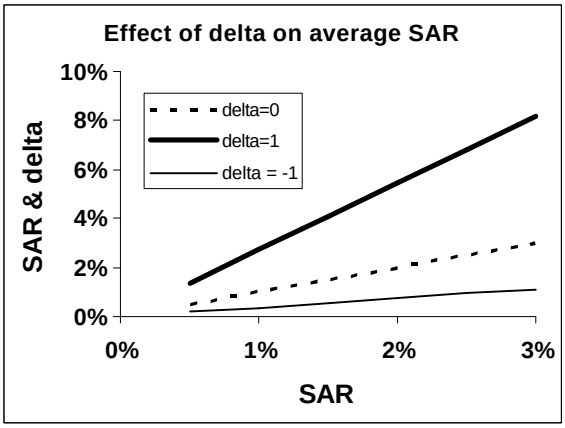
effect of delta is additive to ln(SAR) and productivity (ln(R/S) or ln(S/S))

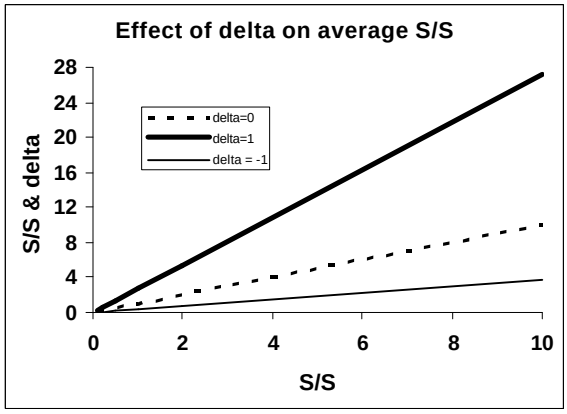
ln(SAR) delta=0	ln(SAR) delta=1	ln(SAR) delta = -1	ln(S/S) delta=0	ln(S/S) delta=1	ln(S/S) delta = -1
-5.30	-4.30	-6.30	-2.30	-1.30	-3.30
-4.61	-3.61	-5.61	-1.61	-0.61	-2.61
-4.20	-3.20	-5.20	-0.69	0.31	-1.69
-3.91	-2.91	-4.91	0.00	1.00	-1.00
-3.69	-2.69	-4.69	0.69	1.69	-0.31
-3.51	-2.51	-4.51	2.30	3.30	1.30

effect of exp(delta) is multiplicative to SAR and R/S or S/S

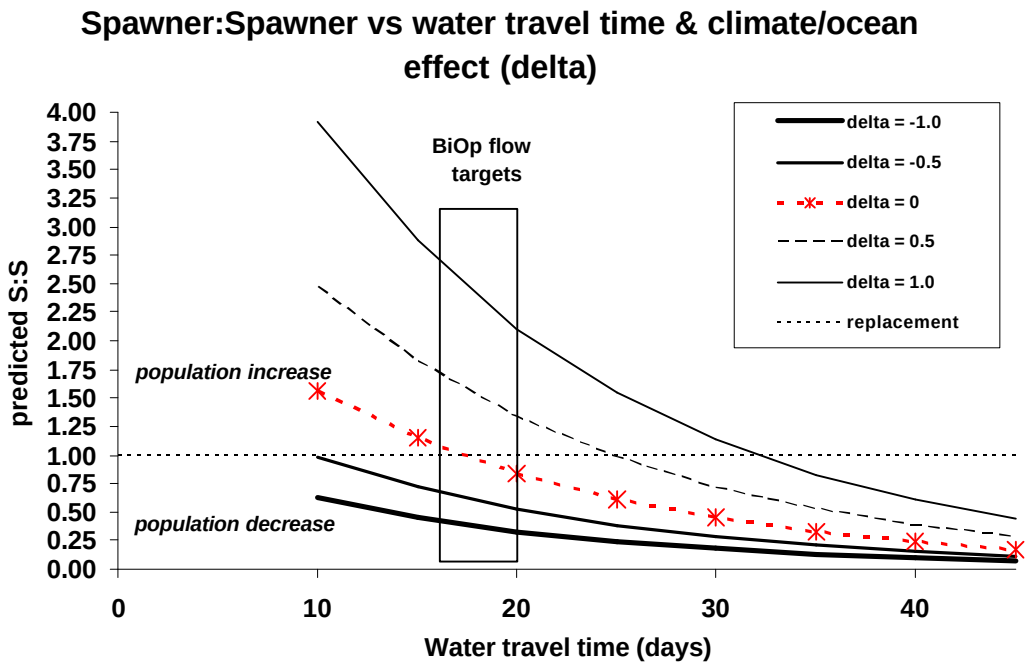
SAR delta=0	SAR delta=1	SAR delta = -1	S/S delta=0	S/S delta=1	S/S delta = -1
0.50%	1.36%	0.18%	0.10	0.27	0.04
1.00%	2.72%	0.37%	0.20	0.54	0.07
1.50%	4.08%	0.55%	0.50	1.36	0.18
2.00%	5.44%	0.74%	1.00	2.72	0.37
2.50%	6.80%	0.92%	2.00	5.44	0.74
3.00%	8.15%	1.10%	10.00	27.18	3.68

e.g., if SAR = 1%, effect of delta =1 is a 2.72 fold increase in SAR
e.g., if SAR = 1%, effect of delta =-1 is a 1/2.72 fold change in SAR





ISAB Question XV part 2



A water velocity and survival (population productivity) relationship is apparent when assessing adult spring/summer chinook information

Focusing on the yellow bar, which represents the water travel time (velocity) generated by BIOP flow targets (yellow bar), we can observe the population performance relative to replacement (the dashed horizontal line)

For the BIOP Flow target velocities the populations approach or exceed replacement under average to good climate/ocean conditions

However, below Biop Flow targets the populations approach or exceed replacement only under good climate/ocean conditions

Risk of further population decline is greater below the BIOP flow targets