Independent Science Panel
Technical Memorandum 2002-2
July 15, 2002

Responses of Salmon and Trout to Habitat Changes

Independent Science Panel
PO Box 43135
Olympia, WA 98504-3135
(360) 902-2216 FAX (360) 902-2215

Kenneth P. Currens, PhD
Hiram W. Li, PhD
John D. McIntyre, PhD
Walter F. Megahan, PhD
Dudley W. Reiser, PhD

STATE OF WASHINGTON
INDEPENDENT SCIENCE PANEL

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TO: Interested Parties

FROM: Kenneth Currens, Chair

SUBJECT: Technical Memorandum 2002-2: Responses of Salmon and Trout to Habitat Changes

The Independent Science Panel was established by the legislature in 1998 to provide independent review and oversight of Washington's salmonid recovery efforts. As part of our continuing work, we respond to tasks as assigned, and may comment on specific issues we think are particularly timely and relevant.

We believe understanding the extent to which empirical evidence exists for expectations associated with the responses of salmon and trout to changes in their habitat is such an issue for salmonid recovery. To help address this issue we asked Dr. Peter Bayley of Oregon State University, to review the scientific literature on the subject, with special attention on experimental design and related quantitative aspects, and prepare a report of his findings and recommendations. The attached Technical Memorandum summarizes our interpretation of Dr. Bayley's work, including its implications for monitoring.

This Technical Memorandum, Dr. Bayley's report, and his extended list of references are available from the web at: http://www.governor.wa.gov/esa/science/documents.htm, or from the Governor's Salmon Recovery Office by email to salmon@esa.wa.gov.

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RESPONSES OF SALMON AND TROUT TO HABITAT CHANGES

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Independent Science Panel[1]

Throughout Washington State, private citizens, local governments, and state and federal agencies are devoting money and time to protect and recover habitat for salmon. Everyone wants to know that his or her actions helped in the best possible way. The Salmon Recovery Funding Board (SRFB), which was formed by the legislature to help distribute moneys for salmon habitat projects and activities to watersheds, for example, views their primary role as helping "ensure the best possible investment of state and federal funds."

An important question is "How will we know if these investments are working?" To help answer that question, the 2001 Washington State Legislature required development of a comprehensive monitoring strategy and action plan to measure success in recovering salmon and watershed health. Monitoring is the fulcrum for salmon recovery[2] and watershed health. The balance of science, effective use of resources, and policy decisions that will recover salmon and ensure watershed health depends on scientifically valid monitoring. They assigned the Independent Science Panel (ISP) a review and advisory role in the development of this strategy.

Assessing What We Know

The ISP is aware that publications describing useful, quantitative relationships between habitat changes and fish responses are few. This makes choosing the best possible projects challenging. To help review what is known about these relationships, the ISP asked Dr. Peter Bayley, an internationally known quantitative ecologist at Oregon State University, to review available scientific literature and assess potentially useful relationships between fish responses and habitat changes. Dr. Bayley evaluated 441 publications from the 2,350 identified using database search criteria of five electronic databases of technical literature. He reviewed the design, analysis, and conclusions of the 30 most relevant publications in detail. This memorandum summarizes our view of Dr. Bayley's findings,[3] our thoughts about the weight of evidence regarding fish response to habitat change, and implications for monitoring.

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[1] Members of the Independent Science Panel (ISP) include Drs. Ken Currens (Chair), Dudley Reiser (Vice-Chair), Hiram Li, John McIntyre, and Walt Megahan. The ISP was formed in 1998 by the Salmon Recovery Act (77.85.040 RCW).

[2] Independent Science Panel (ISP). 2000a. Preliminary review of issues regarding development of a statewide salmonid recovery monitoring program. ISP Technical Memorandum 2000-1.

[3] A copy of Dr. Bayley's report is available online at (http://www.governor.wa.gov/esa/science/documents.htm) or by request from the Governor's Salmon Recovery Office (salmon@esa.wa.gov). Reference to and citation of specific data and sections of Dr.

Habitat Restoration and Fish

Dr. Bayley found that habitat restoration programs can produce significant gains in population density of juvenile salmonids. Most studies were insufficient, however, to determine whether or not habitat restoration increased numbers of juveniles migrating to the ocean or adults returning or to identify the specific actions causing increase if an increase was detected. This might at first appear that based on the weight of evidence in the literature, the benefits of habitat restoration may well be limited. Scientifically, this conclusion would be valid only if the studies were appropriately designed to detect these kinds of results. Dr. Bayley's analysis suggests that studies to evaluate effects of restoration may have shown no beneficial effects of restoration due to limitations in experimental design or procedure[4]. Concluding that restoration had no beneficial effect in these cases potentially leads to Type II statistical errors wherein a null hypothesis (e.g., restoration treatment has no effect on fish) is falsely accepted because of study limitations. This has important implications for monitoring efforts.

Implications for Monitoring

Dr. Bayley's review points to serious shortcomings in the statistical design, implementation, and analysis of monitoring projects that explains these failures. First, long-term, multiple year studies have decreased and been replaced by short-term monitoring over larger spatial scales (Figure 1).

Without long-term monitoring, it is difficult to detect trends in populations and the link between juvenile and adult abundances. Short-term, multiple watershed studies that trade space for time may help us understand factors controlling fish abundance that are related to spatial scale but they cannot substitute for long-term studies to determine cause and effect relationships. There are several limitations with short-term comparative approaches: (1) variations associated with patterns of climate change and their influences are not captured by the study (e.g., Pacific Decadal Oscillation); (2) replication is difficult and idiosyncratic conditions (differences in land-use, geology, topography, aspect) can confound the results; and (3) the approach assumes that population changes can be calculated from a cross sectional view of age class structure rather than by following reproduction and survival of cohorts (what epidemiologists call the ecological fallacy).

Spatial and temporal variation are important design elements in any monitoring effort (ISP Report 2000-2[5]). The best monitoring designs will characterize variation while monitoring demographic changes. The length of monitoring will be in units of generation

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Bayley's report in this Technical Memorandum does not necessarily represent ISP endorsement or agreement with all report conclusions and recommendations.

[4] See also: Reid, L.M. 2001. The epidemiology of monitoring. Journal of the American Water Resources Association. 37(4): 815-820.

[5] Independent Science Panel (ISP). 2000b. Recommendations for monitoring salmon recovery in Washington State. ISP Report 2000-2.

time. The number of generations needed will depend upon the statistical power of the test to detect change (ISP Report 2000-2).

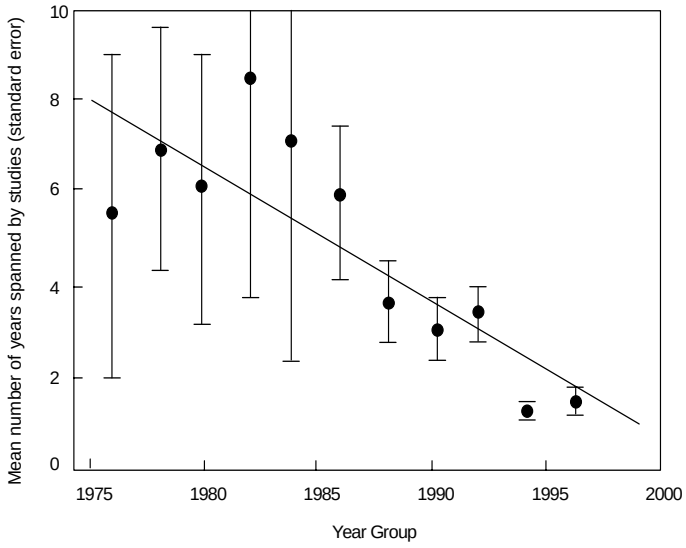

Figure 1. Salmon and trout studies are lasting significantly shorter amounts of time (P = 0.02). Figure is from Dr. Bayley's analysis of 128 studies from the scientific literature.

Second, information from many studies was not as useful as it could have been because of weaknesses in the design, analysis, or reporting of the results[3]. These weaknesses included:

- Lack of appropriate statistical power to detect changes,
- Failure to reduce or analyze the explanatory variables (e.g. habitat actions and changes) so that the most robust responses of the fish can be detected,
- Failure to test or explain how outliers (very unusual observations) were treated in the analysis,
- Failure to incorporate interaction between variables in the analysis,
- Failure to summarize how well the statistical model developed from the monitoring data actually performed in predicting fish responses, and
- Failure to address statistical bias in sampling, such as from different sampling methods, which can prevent valid comparisons of fish responses across time or watersheds.

In addition, Dr. Bayley notes that most studies ignored risk-based statistical analyses, which can be very useful for making management decisions. Instead, they relied only on traditional hypothesis tests based on arbitrary significance values to draw conclusions from the data. As the discussion of Type II error illustrates, with only this kind of analysis when a study fails to demonstrate a difference, the appropriate conclusion is that the study was inconclusive. Although this is scientifically rigorous, management

decisions often depend more on understanding the risk of a wrong conclusion from such data rather than whether a hypothesis was proved right or wrong. Incorporating statistical techniques that focus on estimating risk and that allow analysts to incorporate results from other studies (e.g., Carlin and Louis 2000[6], Bedford and Cooke 2001[7]) and traditional hypothesis testing into a single, eclectic approach can make monitoring results more useful.

ISP Conclusions

Restoration actions expected to withstand legal and scientific scrutiny need to show, with acknowledged error potentials, benefits to fisheries, population recovery and escapement, and effectiveness. Dr. Bayley's analysis showed that habitat can be manipulated to increase density of juvenile salmonids, but it is unclear whether these results reliably translate to greater juvenile or adult abundance or increased understanding that associates gains for fish with specific improvements in habitat. In the absence of these data, habitat "improvements" consist of actions "thought" by project proponents to be appropriate, rather than actions with strong empirical support.

Recommendations

Dr. Bayley's report raises important questions about the effectiveness of habitat projects and other habitat altering activities to improve existing fish habitat and/or the validity of the studies used to evaluate their effectiveness. However, activities are available for restoration programs that minimize or avoid these questions and generally can be expected to benefit fish populations by expanding fish habitat or preventing diversion of migrating fish. We recommend that restoration efforts be directed at these types of projects including acquisitions (e.g., water rights, riparian areas), barrier removal opportunities that will not result in expansion of exotic populations, screening opportunities, and other obvious impediments to fish production, especially for populations that are likely to be important to the viability of Evolutionarily Significant Units and Distinct Population Segments. Many other activities may also be beneficial.

The uncertainty associated with habitat restoration projects and other activities however, necessitates a systematic and scientific approach to determine what works. The ISP recommends that adaptive management strategies be developed and implemented as soon as possible to gain this information to help ensure the credibility of Washington's salmonid habitat recovery efforts. This information is also necessary for scrutinizing fish habitat projects and other habitat altering activities and their unintended effects on fish habitat and fish. It is conceivable, for example, that in some situations increasing the density of juveniles at one life stage could ultimately be harmful to the quantity and quality of fish at another life stage.

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[6] Carlin, B. P. and T. A . Louis. 2000. Bayes and Empirical Bayes Methods for Data Analysis, 2nd Edition. Chapman & Hall/CRC, New York.

[7] T. Bedford and R. Cooke. 2001. Probabilistic Risk Analysis: Foundations and Methods. Cambridge University Press, Cambridge.

We reiterate here for emphasis one of our recommendations from ISP Report 2002-2. Because sound bases do not seem to be readily available in the literature, we recommend that habitat restoration projects and other habitat altering activities be used to help define formal cause and effect relationships between habitat parameters and population change. Cause and effect can only be approached experimentally. Innovative and robust hypotheses must be developed, tested, and validated through rigorous monitoring. Efficiencies in habitat recovery are gained with this approach, because we learn what procedures do or do not produce the desired result (e.g., more fish), and results can be applied to the broadest extent possible.