Uncertainty and Instream Flow Standards: Perspectives Based on Hydropower Research and Assessment

By Webster Van Winkle, Charles C. Coutant, Henriette I. Jager, Jack S. Mattice, Donald J. Orth, Robert G. Otto, Steven F. Railsback, and Michael J. Sale

In a thought-provoking essay, "Uncertainty and Instream Flow Standards," Castleberry et al. (1996) argue that currently no scientifically defensible method exists [including the Physical Habitat Simulation System component (PHABSIM) of the Instream Flow Incremental Methodology (IFIM)] for defining instream flows needed to protect fish or aquatic ecosystems. They suggest (1) that an adaptive management approach is preferable, involving protective interim standards, a monitoring program, and an effective [institutional] procedure for revising interim standards in light of new information; and (2) that scientists and managers need to understand and consider the uncertainties in instream flow methods, develop and implement monitoring methods that will realize the potential of adaptive management, and develop the basic (mechanistic) biological knowledge about how flows affect the survival and reproduction of individuals.

We want to add to these constructive ideas to promote further discussion on the important issue of instream flow management. The scientific defensibility of any predictive assessment methodology needs to be judged based on its scientific foundations and its proven track record of use in specific environmental assessments. The adaptive management approach, while having a sound scientific foundation, is still developing a proven track record. Many perceive this approach as trial-and-error manipulations that provide an excuse for maintaining the status quo. Stated more strongly, adaptive management can be primarily a political process of adapting to changing political pressures, rather than a scientific process of adapting to increased scientific understanding. In reality, adaptive management requires dramatic experiments, including predictive models. We identify three additional needs to obtain the benefits of more flexible approaches such as adaptive management.

Webster Van Winkle and Charles C. Coutant are senior research staff members in the Environmental Sciences Division at Oak Ridge National Laboratory, Building 1505, P.O. Box 2008, Oak Ridge, TN 37831-6038; www@ornl.gov. Henriette I. Jager is a research associate in the Environmental Sciences Division at Oak Ridge National Laboratory. Jack S. Mattice is a project manager at the Electric Power Research Institute in Palo Alto, California. Donald J. Orth is a professor in the Department of Fisheries and Wildlife Sciences at Virginia Polytechnic Institute and State University in Blacksburg, Virginia. Robert G. Otto is a consultant in Cambridge, Maryland. Steven F. Railsback is with Lang, Railsback, & Associates in Arcata, California. Michael J. Sale is a group leader in the Environmental Sciences Division at Oak Ridge National Laboratory.

Decision-making Framework

Adaptive management requires a high level of institutional, legal, and political flexibility—more than now typically occurs (Castleberry et al. 1996). Many fisheries agencies have insufficient resources for the current backlog of hydropower instream flow studies (Railsback et al. 1990), much less for long-term monitoring and adaptive management at each site. In addition, deregulation of electricity generation in the United States is creating a competitive climate such that hydropower operators will be less able to afford adaptive management experiments.

However, the benefits of flexible requirements are being recognized and gradually implemented. In addition to the "Hodge Decision" (Castleberry et al. 1996), examples include the settlement agreements for the Skagit River Project in Washington and the New Don Pedro Project in California, both of which allow flows to be varied according to agreed rules as more information and better models are obtained from monitoring studies. Additional opportunities for adaptive management lie with federal water projects [e.g., the Glen Canyon Project (U.S. Bureau of Reclamation 1995)]. Federal projects are not bound by the procedures of the Federal Energy Regulatory Commission, and study and mitigation costs (including funding of resource agency participation) are heavily subsidized.

> adaptive management can be primarily a political process of adapting to changing political pressures, rather than a scientific process of adapting to increased scientific understanding

Management Objectives

A challenge to any approach based on population- or community-level effects is achieving agreement on management objectives that are acceptable to the public, simple to understand, ecologically meaningful, and measurable before designing a monitoring program or a model. The objective could range from target values for adult population density or production of a key fish species to maintainance of a balanced and indigenous fish community. Many of these objectives are difficult to measure. For example, providing a specified long-term average number of outmigrating salmon smolts per spawner may seem like a simple, well-defined management objective. However, determining whether this objective is being met based on variable and uncertain data gathered throughout the years is not simple. Nonetheless, the need to define such management objectives can be viewed as a strength of population- and community-level approaches (Orth 1995); while difficult, it does force decision makers to focus on real project effects, management options, and uncertainty.

Flow Manipulations, Monitoring Programs, and Models

The adaptive management approach requires several key components. The flow manipulation must involve a major change in the base flow regime for regulators and scientists to expect a measurable change. Minor flow changes may not provide the contrast needed to test the knowledge base and models used to develop management regulations and, thus, would fail to serve the decision-making purpose. While necessary for the adaptive management approach, flow manipulations and monitoring programs alone are not sufficient. For the adaptive management approach to be successful, it must include a methodology that provides two critical functions. First, it must provide the qualitative framework for identification and consensus-building concerning management objectives, flow manipulations, and monitoring. Second, it must provide a quantitative predictive tool [always combined with common sense, critical thinking about stream ecology, and careful evaluation of the actual consequences of flow modification (Castleberry et al. 1996)] that synthesizes the results from the monitoring program and makes quantitative predictions (absolute or relative) of fish population responses to alternative instream flow regimes and mitigation measures. Adaptive management can treat these predictions as hypotheses and design experiments to test their validity and improve predictions.

Although it has its weaknesses because of its limited focus on physical habitat, PHABSIM is such a tool. The individual-based modeling approach is another such tool that does not have this limitation. It replaces PHABSIM's reliance on habitat suitability curves with a mechanistic representation of the processes underlying fish growth, survival, and reproduction (e.g., Van Winkle et al. 1993). This representation varies with the life history of the species of interest, and density dependence (i.e., compensation) is an emergent population property of what happens to the individual model fish.

One such individual-based instream flow model (Van Winkle et al. 1996) is being developed in conjunction with a field evaluation of PHABSIM (Studley et al. 1996). By monitoring fish populations and habitat at 9 hydropower sites throughout 11 years and experimentally changing minimum flows (Studley et al. 1996), this study indicates that population responses to flow can be complex yet predictable. For example, at sites within one 5-km reach of the Tule River, California, factors that limited trout populations included base flows, scouring of redds by floods, winter temperatures too high for incubation, high summer temperatures, scarce spawning habitat, and interspecies competition. Physical habitat assessments alone cannot be expected to do well in such situations, yet many of these population-limiting factors have been successfully captured in the individual-based model and could be represented in a more comprehensive suite of models in IFIM. Preliminary results also indicate that relatively simple improvements to typical PHABSIM methods can produce instream flow assessments that are reasonably accurate and far less expensive than an adaptive management approach. At the very least, they can provide the initial predictions on which adaptive management can build.

Castleberry et al. (1996) correctly point out the uncertainties in simplistic instream flow assessments. We agree that the adaptive management approach has potential benefits and, in fact, we see a gradual trend toward more flexible assessment and management of water projects. However, before the adaptive management approach can be fully successful, it is clear that (1) decision-making frameworks; (2) management objectives; and (3) flow manipulations, monitoring programs, and models all need improvement. We emphasize that mechanistic models that depict the factors affecting the target aquatic resources (and not just physical habitat) must be key components of the adaptive management process. Without such models, the uncertainties may be greater than those currently encountered with habitat models, and as a consequence, eventual costs may be much higher than necessary.

Acknowledgments

The authors appreciate the constructive comments and perspectives of C. B. Stalnaker and two other reviewers. Preparation of this essay was supported by the Electric Power Research Institute under contract RP2932-2 (DOE ERD-87-672) with the U. S. Department of Energy, under contract DE-AC05-96OR22464 with Lockheed Martin Energy Research Corporation. This is Publication No. 4649 of the Environmental Sciences Division, Oak Ridge National Laboratory.

References

Castleberry, D. T., J. J. Cech Jr., D. C. Erman, D. Hankin, M. Healey, G. M. Kondolf, M. Mangel, M. Mohr, P. B. Moyle, J. Nielsen, T. P. Speed, and **J. G. Williams**. 1996. Uncertainty and instream flow standards. Fisheries 21(8):20–21.

Orth, D. J. 1995. Food web influences on fish population responses to instream flow. Bulletin Francais de la Peche et de la Pisciculture 337/338/339:317–328.

Railsback, S. F., C. C. Coutant, and **M. J. Sale.** 1990. Improving the effectiveness of fisheries agencies in developing hydropower mitigation. Fisheries 15(3):3–8.

Stalnaker, C. B. 1993. Fish habitat evaluation models in environmental assessments. Pages 140–162 *in* S. G. Hildebrand and J. B. Cannon, eds. Environmental Analysis. Lewis Publishers, Ann Arbor, MI.

Studley, T. K., S. F. Railsback, and **J. E. Baldrige.** 1996. Predicting fish population response to instream flows. Hydro Review 15(6):48–57.

U.S. Bureau of Reclamation. 1995. Operation of Glen Canyon Dam. Final Environmental Impact Statement, March 1995. U.S. Bureau of Reclamation, Colorado River Studies Office, Salt Lake City, UT.

Van Winkle, W., K. A. Rose, and **R. C. Chambers.** 1993. Individual-based approach to fish population dynamics: an overview. Trans. Am. Fish. Soc. 122:397–403.

Van Winkle, W., H. I. Jager, and **B. D. Holcomb.** 1996. An individual-based instream flow model for co-existing populations of brown and rainbow trout. EPRI Report TR 106258. Electric Power Research Institute, Palo Alto, CA.