The Merging of Empirical and Modeling Research:
Columbia River Models and Beyond

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Abstract

Empirical studies alone provide insufficient guidance to managers charged with making the difficult public policy decisions demanded by “goals-based" environmental legislation. Mathematical models are needed to integrate independent empirical studies into tools to help evaluate complex management alternatives. Specifically, they could be used to determine a suite of actions that will not jeopardize the recovery of Snake River salmon stocks listed under the Endangered Species Act. For example, what should the river flow schedule be? How much spill should there be? Should smolts be barged around dams? How much should we harvest? How much hatcheries produce? How much predator control should there be? Soule (1987) has noted that mathematical models should be “tools for thinkers, not crutches for the thoughtless." Current modeling practices, in which model development and utilization is restricted to small independent teams of scientists representing competing stakeholders, encourages more crutches than tools. Decision-makers and the public see model results, but rarely have an opportunity to become engaged in the modeling process. The Columbia River Salmon Passage (CRiSP) Project at the University of Washington School of Fisheries is helping to create more tools and fewer crutches by opening up the modeling process. CRiSP models merge empirical data from many studies into user-friendly programs that are available to other researchers and the public through Mosaic on the Internet. All models are fully documented with on-line help and have tutorials to demonstrate model functions. Parameters can be changed easily with mouse tools and model results can be viewed in graphical format immediately after completing a run. The benefit of an open modeling process is not in disseminating results that support a political agenda, but in engaging the public in the modeling process, thereby exposing model assumptions, behavior, and limitations. As Carl Walters has stated: “When you... recognize modeling as a very human way of groping for understanding, it should be obvious who will benefit most from it: *those who engage in it directly.*" There are other benefits as well. In his key-note address last April, Dr. Alverson concluded: “The use of facts and statistics in the public influence game has become an art to which science seemingly takes a back seat." The “many-to-many" communication format now available on the Internet offers new opportunities to bring science back into the open and combat the “one-to-many" communication format dominating the public relations game. With “ecosystem management" on the horizon, large scale mathematical models will become increasingly popular. If these models are to become tools instead of crutches, the scientific community must devote more resources to open modeling processes.

Preface

Thank you, Steve. It's a pleasure to be here today. I'm quite flattered to be a part of this panel. I'm also very proud to be a graduate of the School of Fisheries and now to be a member of the professional staff. This is a remarkable institution. The breadth and quality of the faculty, staff, and students is unmatched. It is a stimulating environment to work and learn in, and when given half a chance to show our stuff without a lot of political meddling, the science actually works. I would also like to say a few kind words about fishery science in general. I think it was Ray Hilborn who said that the phrase “It doesn't take a rocket scientist to do such and such" should be changed to “It doesn't take a fishery scientist to .... " The public, and often other scientists, don't appreciate how difficult it is to manage our last hunted resources on a commercial scale within a free market economy and an environment subjected to an increasing human population. I think we can all take great pride in the fact that ours is for the most part an applied science and that we accept the difficult challenges that go with it.

Before starting, I’d like to tell a little story about Steve. I first met Steve out at Neah Bay in about 1980. My crew and I had just driven out in a U-Haul van to change crews on our longliner and send a load of blackcod and rockfish back to Seattle. We were getting a nice price for thornyheads at the time and we had them iced right at the top of the totes to prevent crushing. I should mention that thornyheads are also called “idiot” rockfish by the fishermen. Steve had just finished a troll trip and was looking for a ride back to Seattle. We didn’t have room in the cab so Steve and his deckhand got into the back with the fish. As we watched the van pull away one of my crewmembers asked who that was in the back, and I said it was Steve Mathews from the UW School of Fisheries. And he said, boy that really is a truck load of idiots!

Text

Shortly after being asked to participate on this panel, I was discussing the issue of allocating funds between empirical and modeling research with a colleague on the CRiSP project. His comment was that deciding between the two was a bit like going into a shoe store and trying to decide whether to buy a right ... or a left. It took a moment for his analogy to sink in, but when it did, I realized it was a good one. If you want to make progress, you really need both. And the style of each may not be too important, as long as the two fit together comfortably.

The scientific process is often described as an iterative dance between empirical observation, hypothesis formation and model building, followed by more observations, and so on. Thus, creating separate institutions, such as the Fisheries Research Institute (FRI) and the Center for Quantitative Science (CQS), each emphasizing a different aspect of the scientific process perhaps more accurately represents a divergence, rather than merging, of empirical and modeling research. Why separate the two in the first place? The answer is that scientific models, whether described in common language or mathematics, serve two functions: (1) to explain observations, and (2) to make predictions. Those models described in common language are best suited for explanation while those described in the more precise language of mathematics are better at prediction. CQS was formed largely because fisheries is an applied science, and as such, demanded predictive models.

Scientists can be quite optimistic about the ability of their models to make predictions (especially when writing grant applications). No one has been more confident than the famous French mathematician Laplace, who about 200 years ago boasted that if he knew all the initial conditions he could specify the future states of nature. Modern scientists are more skeptical. In this month's issue of Scientific American, noted paleontologist Steven Jay Gould states: “The history of life is not necessarily progressive; it is certainly not predictable."

While I think most scientists today would side more with Gould's view than Laplace's, our political leaders seem more inclined to side with Laplace. Over the past 30 years our country has enacted an impressive body of environmental legislation aimed at protecting and managing natural resources to make the earth more (to use a popular buzzword) “sustainable" for our use. This legislation is largely “goals based" in that only the objectives are specified, usually in very nebulous terms (e.g., provide the “greatest benefit to the nation" and “prevent overfishing" in the case of the Magnuson Fishery Conservation and Management Act or as in requiring that government actions, such as conducting a commercial fishery or operating a hydropower system, do not “jeopardize" the recovery of species listed under the Endangered Species Act). Such laws tacitly assume that modern science can translate these legislative goals into suitable mathematical objective functions and has the necessary modeling tools to determine how best to achieve them.

A former attorney for the Natural Resources Defense Council describes his experiences with goals based legislation as follows:

> “... the 1970 Clean Air Act was a mistake because it is based upon an important misconception about how statutes can work to achieve their goals....The Act ordains that its environmental goals must be achieved. It purports to realize those goals not by stating rules of conduct ... but by mandating a process under which entities other than Congress must promulgate controls to achieve the goals....The problem with goals statutes that broadly delegate decision-making authority is that they leave key value choices to low visibility decision-makers fearful of making controversial choices." Schoenbrod (1984).

I suspect that many in this audience have at some point in their career been one of these low visibility decision-makers. There certainly is no shortage of controversial issues in fishery management. And while these issues seem to be getting more controversial all the time, by stepping up to those challenges fishery science has an opportunity to play a pivotal role in shaping the future of the environmental movement. I am thinking specifically of the problem of saving Pacific salmon.

I applied for my current position working on Columbia River salmon problems because I had a sense that a bit of important history was being made here. Saving Pacific salmon stocks will become the “Acid Test" for society's willingness to address the problems of continued population growth and resource consumption. Four factors distinguish this issue from other endangered species cases. First, this is the first time a species listed under the ESA has value to every member of society--salmon define the spirit and culture of the Pacific Northwest. Second, the threats to the species come from every member of society--miners, tug boat operators, hydropower operators and consumers, recreational and commercial harvesters and processors, loggers, farmers and ranchers, and tourists. Third, saving salmon stocks will require significant habitat rehabilitation, not simply habitat protection, as was the case for two other famous ESA cases--the snail darter (threatened by Tellico Dam) and the spotted owl (threatened by logging of old growth forests). And finally, the costs of habitat rehabilitation will be enormous. The draft recovery plan for the three Snake River salmon stocks calls for a financial commitment of $300 million per year for 10 years. More recent estimates are about twice that amount. To put these figure in perspective, the annual budget for the entire National Marine Fisheries Service is about $270 million per year.

In short, for the first time we have met the enemy, and the enemy is us. How we solve this dilemma will indicate the real strength of the environmental movement and society's willingness to make individual sacrifices for the common good. The problem extends far beyond biological considerations--it will challenge the principles on which our country was founded: individual freedom and the pursuit of happiness in a free market economy.

For the case of Snake River salmon, the public policy decisions required by the ESA are numerous and difficult. What river flow schedule? How much spill? How much harvest? How much hatchery production? How much predator control? There is considerable scientific uncertainty surrounding all of these questions. Empirical studies alone cannot provide sufficient guidance to managers charged with making these difficult public policy decisions. Yet the law mandates that these decisions be made now. Mathematical models are needed to integrate the independent empirical studies into tools to help evaluate the complex management alternatives and to identify research needs.

For the remainder of my time, I would like to focus on how we use models now, my vision of how we might use models in the future, and why this vision holds promise for improving the iterative dance between empirical observation and modeling that we call the scientific process. I begin by stating my two favorite quotations about modeling. The first is from Carl Walters book on adaptive management. He states: “When you... recognize modeling as a very human way of groping for understanding, it should be obvious who will benefit most from it: *those who engage in it directly.*" The second quotation is from a paper by Soule, who stated that models should be “tools for thinkers" not “crutches for the thoughtless." With these thoughts as a background let's take a look at how the typical modeling process works today. It usually works something like this.

- A complex management problem is identified by decision makers;
- A team of scientists is formed to analyze the problem;
- The team uses previous empirical studies to develop a mathematical model of the system;
- The most experienced programmer on the team is selected to code the model;
- Managers request analysis of competing management strategies;
- Team members gather data necessary for the analysis;
- Only one or two team members actually run the model;
- Team chairman reports model results to decision makers;
- Decision-makers pick out a new set of scenarios for analysis, and so on.

This type of process has a certain “black box" quality about it. Few people outside the modeling team get a chance to really fiddle with the model. There is no instant feedback and limited learning. And despite lots of graphs and charts to illustrate the uncertainties of the predicted results, the decision makers never really “feel" those uncertainties. There is simply no substitute for sitting down at the computer, making a few minor parameter changes, and watching the results take on chaotic behavior. Worse, if separate models are developed by competing stakeholders, the models become pawns of the political process and learning can actually be inhibited. In short, the current process does not provide an optimal environment for learning and tends to build more crutches than tools.

The Columbia River Salmon Passage Project (CRiSP) at the School of Fisheries is experimenting with a new modeling process that we hope will improve the prospects for learning and will create more tools than crutches. We have constructed two models. The first is a mechanistic model of downstream passage from smolt release to the river mouth; the second is a more empirical harvesting model based on the Pacific Salmon Commission's Chinook Model. The most distinguishing feature of these models is not their mathematical characteristics, but their development process and utilization methods. We have given far more emphasis than usual to the process of designing the computer code and user interfaces, both of which allow the user to easily change not only the model parameters, but also the functional relationships. The models are well documented, including manuals, tutorials, and on-line help. On the surface, they are more like computer graphics programs or games than scientific models.

Perhaps the most interesting utilization concept is that our models will soon be available to other scientists and the public via a user-friendly interface, such as Mosaic, on Internet. To give you a feel for the communication power of this medium, during the past eight weeks on the Internet, we had over 9,000 visits to our Mosaic home page, over 2,000 coming in just one week. This “many-to-many" communication format of the Internet represents a quantum leap in progress toward creating modeling tools instead of modeling crutches. My vision of the next 25 years is that most mathematical models used to help manage large complex fishery systems, such as Pacific salmon fisheries or the Bering Sea groundfish and crab fisheries, will be available to the public for simulating any management scenario. Most management models are recalibrated on an annual basis based on data collected from the fishery and research cruises. Once calibrated, the model user should be able to invoke any management regime desired and observe the predicted model outputs--all from the comfort of their own home or office (provided it is equipped with a computer and modem). One or more newsgroups will be formed around each model to allow users to compare results and more importantly, to critique model assumptions, parameter values, and functional relationships, and to make suggestions for improvement. In short, our vision is to get more people intimately involved in the modeling process, including people who spend most of their time collecting field data. The real value of this approach is not in touting the predictions of a particular model, but to expose the model's assumptions and weaknesses. In the beginning it will be absolute chaos! But, we will have progressed (or some may say regressed) from black box to “Pandora's box."

Previous attempts to increase modeling exposure have focused on small workshops that bring together modelers, fishermen, managers, etc. to study model behavior. But these forums still have the black box quality. A few models have been caste in the form of computer games, but they have lacked the truly global communication network of the Internet and Mosaic.

In his keynote address last April Dr. Alverson noted: “The use of facts and statistics in the public influence game has become an art to which science seemingly takes a back seat." The black box modeling approach only exacerbates this public relations problem. Howard Rheingold, author of “Virtual Reality" and “Virtual Communities," proposes that the many to many communication format made available through services like the Internet has the potential to revive the old “Town Meeting" concept, in which everyone participates in debates over controversial public policy decisions. This format offers exciting opportunities to enhance the merging of empirical and modeling research. I look forward to the 100th Anniversary Celebration to see how it all works out.