Fisheries management: integrating societal preference, decision analysis, and ecological risk assessment

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Fisheries Management: Integrating Societal Preference, Decision Analysis, and Ecological Risk Assessment

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Abstract

Fisheries management is the practice of analyzing and selecting options to maintain or alter the structure, dynamics, and interaction of habitat, aquatic biota, and man to achieve human goals and objectives. The theory of fisheries management is: managers or decision makers attempt to maximize renewable "output" from an aquatic resource by choosing from among a set of decision options and applying a set of actions that generate an array of outputs. Outputs may be defined as a tangible catch, a fishing experience, an existence value, or anything else produced or supported by renewable aquatic resources. Overall output is always a mix of tangible and intangible elements. However defined, management goals and objectives are essential components of fisheries management or any other field of renewable natural resource management. Reaching consensus on management goals and objectives has never been a simple task. Beyond the broad and often conflicting goals of an agency, managers must decide who should set specific management objectives -- agency personnel, the public, or a combination of the two. Historically, rhetoric aside, fisheries managers in North America nearly always have consulted with professionals in governmental roles to set management objectives. In a strongly pluralistic society, this often resulted in protracted political and legal conflict. Increasingly, there are calls for use of risk assessment to help solve such ecological policy and management problems commonly encountered in fisheries management. The basic concepts of ecological risk assessment may be simple, but the jargon and details are not. Risk assessment (and similar analytical tools) is a concept that has evoked strong reactions whenever it has been used. In spite of the difficulties of defining problems and setting management objectives for complex ecological policy questions, use of risk assessment to help solve ecological problems is widely supported. Ecological risk assessment will be most useful (and objective) in political deliberations when the policy debate revolves around largely technical concerns. To the extent that risk assessment forces policy debate and disagreement toward fundamental differences rather than superficial ones, it will be useful in decision making.

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Fisheries Management

Fisheries are complex systems: there is the puzzle of interaction among fish populations, other biota, and the geochemical environment, as well as the often pervasive human component. Fishermen may be sportsmen, capital-intensive high-seas operators, or those fishing for subsistence. Other "users" may not even fish, but realize real "benefit" from the outdoor experience; merely knowing aquatic resources abound is more important to a segment of society than fish in the creel or crabs in the kettle.

On the marine side, fisheries management in such vast, complex environments is muddled by the interstate and/or international nature of the human component. Fleets may pursue many species over broad geographic regions. More importantly, commercial fishing may serve larger national objectives (e.g., creation of hard currency or providing employment) far beyond the size or value of the catch.

Most management problems now faced in fisheries management are not new (Pinchot, 1947; Callicott, 1990), nor are they dramatically different from the challenges facing other disciplines dealing with public policy (Castle, 1993). In short, current fisheries management problems are tangled and challenging, but our professional predecessors also faced difficult problems -- different for sure, perhaps even elementary in light of current knowledge or management options, but they were equally challenging.

Fisheries management has been defined as "the practice of analyzing and selecting options to maintain or alter the structure, dynamics, and interaction of habitat, aquatic biota, and man to achieve human goals and objectives" (Lackey, 1979). When we consider the number and diversity of the components that form fisheries (i.e., a plethora of flora and fauna, chemical and physical water characteristics, geologic and edaphic conditions in the watershed, various types of fishermen, and the related commercial and recreational activities), the breadth of fisheries management becomes apparent.

Freshwater fisheries managers, at least in North America, have nearly always been more concerned with aquatic habitats and the whole array of aquatic animal populations than their marine counterparts. The reason is understandable; marine fisheries managers can rarely exert much influence on habitats or nonexploited biota. Freshwater habitats and ecosystems, in contrast, may often be manipulated as part of a management strategy. Freshwater habitats also are routinely altered for many reasons: farming, housing construction, mining, and road construction, to name a few. Both groups of fisheries managers historically have been focused on target fish populations, but have been less interested (except for controlling harvest) in the human component. It is easier and less stressful for the manager to manipulate habitat, monitor biota, and control harvest than to work with the diversity of societal preferences.

Management Theory

If we make the assumption in fisheries management that all "benefits" (loosely defined as things that have value) derived from renewable aquatic resources are accruable to man, then we have a philosophic basis for management theory. This initial assumption is not as difficult to accept as it may appear if we can avoid the quicksand of semantics. For example, even though most people never see a gray whale, the *existence* of gray whales still has value to them. The important point is that we may choose to protect some or all species, maintain biological diversity at certain levels, or protect areas that no one visits because these decisions produce benefits to people -- not tangible benefits but benefits nonetheless. *Consumptive* use of resources (i.e., harvesting fish) is only one of the benefits derivable from fisheries. Other, nontangible benefits (e.g., the fishing "experience") may be of equal or greater importance in terms of societal benefits (Roedel, 1975).

A formal statement of the basic theory of fisheries management is:

$$Q_{max} = f\,(X_1, X_2, \ldots, X_m \mid Y_1, Y_2, \ldots, Y_n)$$

where

Q = some measure of societal benefit
X = a management decision variable (the vertical line reads "given")
Y = a management or ecological constraint variable

The theory might look imposing, but it is not conceptually complicated. It reads "the greatest (maximum) societal benefit (*Q*) from a fishery can be realized by manipulating a series of decision variables (*X's*), *given* a set of constraints (*Y'*s)." Controlled or partially controlled decision variables (*X'*s) are those regarded as management techniques (regulations, habitat improvement, environmental protection or manipulation, pollution control, etc.). Noncontrolled decision variables (*Y'*s) are random or dependent on other factors (weather, economic changes, recreation attitudes, oil spills, etc.). Variables, however, may overlap both categories. Within constraint variables the manager tries to select a series of decision variables and to maximize *Q*. Everything in management, whether it is biologic, economic, or social, fits into this theory (Lackey, 1979).

Fisheries management tries to maximize (within constraints) some measure of "output" from a fishery. Controversy over sustainability, protecting biological diversity, and protecting certain species is largely an issue of how society weights various constraint and decision variables. Q is the nebulous societal endpoint for which we only have an array of surrogate measures, whether they are pounds of fish, number of angler days provided, species preserved, ecosystems maintained in a desired state, or any of a number of economic indices. Further complicating achieving consensus on Q is the time dimension: short term time frames lead to very different management strategies than do longer term ones. In fact, identifying *Q* is a pivotal challenge in fisheries management or any field of natural resource management.

Societal Preferences

Setting management objectives is not a simple task in practice (Sylvia, 1992). Because of the divisiveness of setting goals and objectives in natural resources systems, establishment of management objectives may tend to be ignored. It is easy to scoff at this intentional oversight, but it does not occur without reason. Managers may be, in reality, unwilling to formulate goals and objectives for fear that some of the *real* objectives may be disapproved under public scrutiny and will not be approved by all interested parties (Fitzsimmons, 1996). Managers may be unable to formulate objectives because of a number of other difficulties: incomplete awareness of problems; incomplete knowledge of the intricacies of the problem; and inability because of time, money, or manpower constraints to devote sufficient thought to the effort. Furthermore and in spite of a vast literature on the subject, objective-setting methodology is not sufficiently defined and succinct to be of use to most fisheries managers. Although virtually everyone stresses the importance of management goals and objectives, the few sound techniques available are complex and laborious (Lackey, 1998).

Who should set objectives -- agency personnel, the general public, or a combination of the two? Historically, fisheries managers have used consultation between professionals in institutional (usually governmental) roles to set objectives. After all, they are the experts. Don't they know what is best for the resource? Critics term this an "elitist" planning process, but it does have the advantage of allowing those who are "best qualified" and most knowledgeable to determine objectives and make decisions to achieve those objectives. However, in these days of a pluralistic society, most professionals now advocate, at least publicly, use of systematic public input in setting goals and objectives. One of the most urgent social needs in natural resource management is determining public needs and preferences (Smith and Steel, 1996), but providing the public with understandable and credible assessments of the consequences of various choices is equally important. Many of the failures of management are attributable to the inability of planners and managers to consider the needs and desires of certain key segments of the public, or the failure to clearly state that some goals and objectives are not achievable. People may at one time have deferred to the experts, but deference is now often not the case.

An informed and concerned public is essential for natural resource decision making in the current political climate. Theoretically, a planning or management process involving the public is more nearly democratic, and as such probably should have a higher probability of success because it provides representation for those affected. Management personnel cannot rely solely on public opinion in formulating decisions. Public opinion is valuable input because light may be shed on the public response to potential management actions. Interactions between managers and the public may bring greater appreciation for both sides' viewpoints and problems. Greater understanding should ultimately improve natural resource management. Therefore, providing clear, accurate assessments of the ecological consequences of various management options is an essential role of fisheries professionals.

Although this sounds fine in theory, in practice it may lead to a rather traumatic way of doing business for professionals. There are also practical problems, not the least of which is figuring out how to do it. Societal preference is important, but how is it translated into something a manager can use?

Decision Analysis

Whatever it is we are trying to manage for, Q, usually involves more than a measure of pounds of fish or numbers of fish harvested. In the parlance of management by objectives, Q is a statement of the desired result of a decision or set of decisions. The *X'*s (decision variables) previously outlined could be viewed as "operational" objectives. Such statements as "to produce 200 pounds of fish per acre per year" or "to produce 2,000 angler visitor-days per year" are management objectives, at least as the words are typically applied in fisheries management.

We can sink into a swamp of semantics, but I am not equating an *objective* with a *goal.* A goal is as an end toward which a management strategy is directed. It is an ideal state, which is usually expressed in general or abstract terms. The few goals we commonly use in fisheries management usually deal with "best" or "wise" use of resources (Sylvia, 1992). "Conservation," "protection," and "enhancement" of resources are terms commonly associated with goals. Although a goal is extremely useful for a number of reasons, it does not supplant the role of objectives in management (Barber and Taylor, 1990).

Objectives have important properties that affect their use in renewable natural resource management. Objectives should be: (1) clearly stated; (2) specific, or as specific as possible, and not filled with broad, sweeping generalizations; (3) quantifiable by some means; if not empirically, then at least subjectively; (4) have a performance measure so that management progress can be evaluated; and (5) dynamic and reflect changing societal preferences and evolving ecological conditions or constraints.

Virtually all natural resource managers have recognized the inherent difficulties of operating without functional objectives, and this is certainly true in fisheries management. Many managers have tried to substitute more measurable objectives, but with less than exemplary success. Historically, the most common objective has been to maximize pounds or numbers of fish on a sustained basis. This is usually referred to as MSY (maximum sustained yield) or, possibly, equilibrium sustained yield. In the last few decades, this approach has come under increasing criticism primarily from those who do not agree with the basic concept that protein or biomass output from a fishery is the prime societal benefit from that resource (Roedel, 1975; Bottom, 1996; Malvestuto and Hudgins, 1996). There are many variants of the MSY approach; these usually revolve around maximizing yield of certain species or maximizing catches of individuals of a certain size.

Desirable properties of MSY are that it is conceptually simple and that it is an objective-oriented approach to management. However, MSY has some inherent disadvantages, the main one being that many recreational fisheries managers, and some commercial fisheries managers as well, regard catch as only one of several measures of output from a fishery. Catch is important, but *fishing* is also important. Numerous surveys have shown that many recreational anglers enjoy the fishing experience even though "fishing success" is less than what may be considered ideal (Hudgins, 1984). Other important aspects of angling "benefit" are the perceived quality of the outdoor experience, the environment, and the sporting challenge. Additional interrelated elements are species caught, fish size, and the angling method.

Even in commercial fisheries management, it is important to recognize that economic output, accruable to fishermen or society, is more important than the pounds of fish individual fisherman catch (Larkin, 1977). Among many, perhaps most, groups of commercial fishermen, psychological benefits (lifestyle preferences and personal satisfaction) are major factors in job satisfaction. Many may regard commercial fishing as a rough, dangerous, demanding, undesirable vocation, but such types of work nourish strong, enduring bonds among the participants.

There is no question in recreational fisheries management that the participants receive benefits of a psychological nature that may total more than the tangible benefits received from harvesting fish. However, there is no functional pricing system to value various recreational factors (and commercial factors), nor can benefits be easily determined by market survey (Repetto and Dower, 1992). Aesthetics probably can never be accurately measured, but by identifying the variables associated with the angling experience and angler's perceptions of them, a reasonable assessment of aesthetics can be obtained.

Another approach to management is maximizing aesthetics or environmental quality. Whereas this sounds laudable and desirable, it is extremely difficult to apply in practice. Often referred to as optimum sustained yield (OSY), it has some of the characteristics of MSY but the concept OSY means many different things to different people and has tended to be regarded as a philosophical rather than a pragmatic position (Roedel, 1975). More recently, some procedures have been developed to incorporate biological, economic, and social values into goal setting for fisheries management (Malvestuto and Hudgins, 1996).

A management goal intermediate between MSY and OSY is to focus on maximizing some measure of angler use or the quality of the angling experience. Of course, fishing quality is a vague and variable parameter, but certain factors that contribute to the fishing experience can be delineated and sometimes measured. The number of potential variables is great, but if the key ones could be identified, the analytical challenge would be much reduced. Maximizing the diversity of angling opportunity, commonly used in agency management programs, is a permutation of this approach.

One practical feature of fisheries management is that decision analysis and active management generally do not start until a management problem is apparent. The problem may be a decline in catch, the scarcity of preferred species, or a decline in biotic diversity. Most aquatic ecosystems are already significantly altered (and not producing the desired level of societal benefits) by the time fisheries managers become involved and a manager usually ends up adopting a strategy to allocate a scarce resource.

This discussion about management objectives does not solve any problems, but it points out some of the practical problems we face, especially: what are we attempting to achieve and how do we measure success? Faced with such tough decisions, perhaps there are other approaches or tools that would be suitable for fisheries management: ecological risk assessment is often suggested as a candidate.

Ecological Risk Assessment

Risk assessment has been applied in fisheries management to some relatively straightforward policy and management questions (Francis, 1992; Fogarty, Rosenberg, and Sissenwine, 1992; Peterson and Smith, 1982), but increasingly, there are calls for its use to help solve complex ecological problems (examples are declines in Pacific salmon, and the purported drastic decrease in biological diversity). Ecological risk assessment is usually defined as "the process that evaluates the likelihood that adverse ecological effects are occurring, or may occur, as a result of exposure to one or more stressors." (Patton, 1995). The general concept underlying risk assessment is relatively straightforward: an "adverse" event can be defined clearly; the probability of that event occurring ("risk") can be estimated; the estimate of that probability can be used to "manage" the risk (National Research Council, 1983; 1993).

The basic common-sense view of risk assessment may be intuitive, but the jargon and details are not. Risk assessment (as with similar analytical tools) is a concept that has evoked strong reactions (Regens, 1995). At one extreme, some have concluded that use of risk assessment in human health decision-making is "premeditated murder" (Merrell and Van Strum, 1990; Merrell, 1995). A number of philosophical and moral reasons for such strong negative reactions exist but they are usually based on either: (1) concerns that the analysis (risk assessment) and decisions (risk management) accept the premise that people will die prematurely to achieve the desired net benefits; or (2) a belief that the process of risk assessment places too much power with technocrats.

The other extreme position would mandate ecological risk assessment as the tool of choice for all ecological policy questions. Do you split the difference to determine which position is accepted? What happens if some scientific experts contend that the measures of ecological risk are often so imprecise that we might make irrevocable decisions based on primitive information, while other experts have much more confidence in current knowledge?

Reaction to ecological risk assessment may be less skeptical than reaction to risk assessment applied to human health problems, but even with ecological issues, both strong positive and negative responses occur (Pagel, 1995). Several bills have been introduced in the United States Congress that would command federal agencies to use risk assessment to set priorities and budgets. Several panels of scientists have made similar recommendations (National Research Council, 1983; 1993). Articles in popular and influential publications advocate use of a risk assessment approach. On the other hand, some conclude that risk assessment is a disastrous approach, one that is "scientifically indefensible, ethically repugnant, and practically inefficient" (O'Brien, 1995; Pagel and O'Brien, 1996).

Critics aside, risk assessment has been used extensively to link environmental stressors and their ecological consequences (Suter, 1993; National Research Council, 1993). The risks associated with chemical exposure are the typical concern. Quantifying the risk of various chemicals to human health is a logical outgrowth of risk assessment as applied in the insurance industry and other fields. Over the past 20 years, a body of procedures and tools has been used for environmental risk assessment for human health. Risk assessment applied to ecological problems is more recent, but has also focused primarily on chemicals, with animals used as surrogates for "ecological health" (Friant, *et al.* 1995). There have been relatively few applications in fisheries management except to help assess the ecological consequences of various chemicals on fish.

However, use of risk assessment for ecological problems has a outspoken group of critics (O'Brien, 1995) who argue that risk assessment (and risk management) is essentially triage -- deciding which ecological components will be "saved" and which will be "destroyed." The theme of "biospheric egalitarianism" is a perspective that makes risk assessment a real anathema. Many risk assessment critics appear to have a strong sense of technophobia, and often view mainstream environmental organizations as co-opted by industrial or technocratic interests (Lackey, 1994).

Risk assessment is also challenged from a different, more utilitarian perspective (Merrell, 1995; Pagel, 1995). The assertion is that, while the concept of risk assessment is sound, the *process* of risk assessment is often controlled by scientists and others who have political agendas that differ from the majority. Critics contend that "risk assessors" use science to support their position under the guise of formal, value-free risk analysis. Risk assessment as thus viewed has the trappings of impartiality, but is really nothing more than thinly disguised environmentalism (or utilitarianism). The apparent lack of credibility and impartiality of the science (and risk assessment) underlying the policy debates over acid rain, stratospheric ozone depletion, global climate change, and loss of biological diversity are often offered as examples of how science has allegedly been misused by scientists and others to advocate political positions. Reliance on scientific peer review and a "weight of evidence" approach are usually not convincing arguments to skeptics.

Risk *assessment* is usually separated from risk *management* in an attempt to reduce the likelihood that the personal values of scientists or analysts will corrupt the process. Such separation requires that scientists play clearly defined roles as technical experts, not policy advocates; these distinctions are blurred when scientists advocate political positions. Further, some critics charge that scientists who use their positions to advocate personal views are abusing their public trust. The counter-argument is that scientists, and all individuals for that matter, have a right to argue for their views and, as technical experts, should not be excluded simply because of their expertise. Some would further argue that scientists have not only a *right*, but a moral *responsibility* to participate in ecological policy debates. Others conclude that the execution of a scientific enterprise is value-laden and therefore already partially a political activity; that rather than attempting to be solely "scientifically objective," a scientist should also be an advocate. Either way, the role of the analyst must be clear to everyone using the results.

Like all analytical techniques used to expedite decision making, ecological risk assessment has strengths and weaknesses. It does appear that ecological risk assessment will be useful for a certain set of policy questions: those dealing with chemical effects, especially where there is a legislative or policy basis for defining what is "adverse" ecologically. However, the vast majority of fisheries management "decision" problems are simply too complicated to be addressed by risk assessment methods.

Conclusion

Biological and social science must be better linked if public decision making is going to effectively use what fisheries scientists and others have to offer. Certainly this is not a new refrain, but one that grows increasingly clear as society becomes more pluralistic. Too often, fisheries, forestry, and wildlife management problems are viewed solely in a biological or technical context. It is society that should define problems and set priorities; however, the public speaks with not one, but many voices. And let's accept the obvious fact that many of the stated public demands are mutually exclusive -- there will be winners and losers.

At least in an idealized world, scientists would maintain a real and perceived position of providing credible ecological information -- information that is not slanted by personal value judgements. Those involved in risk assessment cannot become advocates for any political position or choice, lest their credibility suffer. Such a position may be painful at times because no one can completely separate personal views from professional opinions. Risk assessors must be clear to the public (and political officials) on what scientific and technical information can and cannot do in resolving public choice issues. Let me be clear here: I am arguing that the work should be highly policy-relevant, but should not be colored with the policy preferences of scientists or analysts. The threat to the renewable natural resource professions is too great. An example of the currently perceived credibility of some types of scientists was captured in a headline in my local newspaper: "Ecologists Convinced that Climate is Warming; Scientists Not Sure."

Nor should we assume that complex ecological problems, such as the decline of the Pacific salmon or the collapse of important marine stocks, have only technological solutions. Tools such as risk assessment might help at the margins of the political process to answer certain narrowly defined questions, but they are not going to resolve the important elements of most fisheries management debates.

To the extent that risk assessment forces policy debate and disagreement toward fundamental differences rather than superficial ones, it will be useful in decision making. Otherwise, it is just the latest in a long procession of analytical tools, each of which has a role, albeit limited, in fisheries management.

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Dr. Robert T. Lackey, senior fisheries biologist at the U.S. Environmental Protection Agency's research laboratory in Corvallis, Oregon, is also courtesy professor of fisheries science and adjunct professor of political science at Oregon State University. Since his first fisheries job more than four decades ago mucking out raceways in a trout hatchery, he has dealt with a range of natural resource issues from positions in government and academia. His professional work has involved many areas of natural resource management and he has written 100 scientific and technical journal articles. His current professional focus is providing policy-relevant science to help inform ongoing salmon policy discussions. Dr. Lackey also has long been active in natural resources education, having taught at five North American universities. He continues to regularly teach a graduate course in ecological policy at Oregon State University and was a 1999-2000 Fulbright Scholar at the University of Northern British Columbia. A Canadian by birth, Dr. Lackey holds a Doctor of Philosophy degree in Fisheries and Wildlife Science from Colorado State University, where he was selected as the 2001 Honored Alumnus from the College of Natural Resources. He is a Certified Fisheries Scientist and a Fellow in the American Institute of Fishery Research Biologists.

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