Use of Modeling to Assess Impacts on Fish and Wildlife Resources

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ABSTRACT: Management of fisheries or wildlife systems is the practice of analyzing, making, and implementing decisions to maintain or alter the structure, dynamics, and interactions of habitat, biota, and man to achieve specific human goals and objectives through these renewable natural resource systems. The purpose of this paper is to place modeling into a context of renewable natural resource management. Managers, researchers, and administrators typically predict the consequences of proposed decisions with general rules, past experience, population and habitat models, experimentation, and trial and error. A key problem in formulating accurate predictions of the consequences of proposed decisions is the complexity of most fisheries and wildlife systems. Most models of renewable natural resources are quite similar in approach and philosophy, but dissimilar in intended purpose. Models used in fisheries and wildlife may be classified as to habitat, biota, human characteristics, or combinations of these three categories. Fisheries and wildlife systems, when viewed holistically, include ecological and social aspects. The future role of modeling in fisheries and wildlife management may or may not be great and depends in large measure on the relationship between "modelers" and decision-makers.

INTRODUCTION

Before considering the role of models in assessing the impacts of mining operations on fisheries and wildlife resources, two basic questions must first be answered. What is the role of modeling in fisheries and wildlife management? And more generally, what is the general approach to management of fisheries and wildlife systems?

Over the last few years, fisheries and wildlife management has been afflicted by what can be called the "business school syndrome". Many of the methods which have developed in business schools are now being applied or at least considered in fisheries and wildlife management (Lackey 1978).

Foremost among the current issues in natural resource management relate to the goals and objectives of society concerning utilization of our natural resources (Bennett, Hampton, and Lackey 1978). The public has become much more vocal in demanding that it be involved in determining management goals, policies, and practices. With increased public involvement in management, agencies have been forced to question basic management goals and objectives. For example, the traditional concept of increasing biological yield is giving way to a broader concept of balanced production of consumptive and non-consumptive outputs. In short, management agencies must now determine what society does desire of fisheries and wildlife systems. The concept of managing by objectives affects the potential role of modeling in fisheries and wildlife management.

Attempts to apply modeling techniques to management problems are clearly constrained by measurement of the model's output. Subjective criteria, such as user attitudes, are very difficult to handle in modeling

(Powers and Lackey 1976). Perhaps at this time, we lack theories of general management in fisheries and wildlife, but modeling has been proposed as a vehicle by which useful and appropriate theories can be developed (Jester et al. 1977). Whether this is, or will be, the case remains to be seen.

Modeling as a management tool is still in its infancy. Models of biological systems have provided valuable information and furthered our understanding of the complex interactions in natural systems. However, examples of models used to determine management policies are almost nonexistent.

The purpose of this paper is to evaluate the potential role of modeling in assessing the impacts of mines on fisheries and wildlife resources. We have intentionally directed our comments to the general use of models rather than become involved in specific applications of particular models.

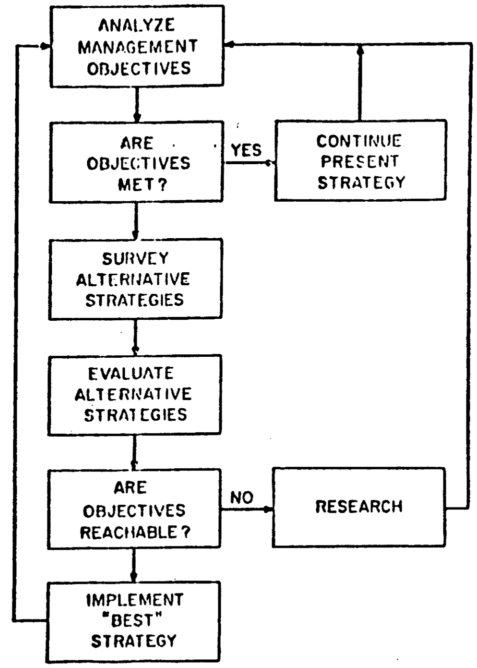

Figure 1. Simplified decision making model used to trace representative decisions in fisheries and wildlife management (from Powers, Lackey, and Zuboy 1975).

THE DECISION MAKING PROCESS

Decision making in fisheries and wildlife management operates according to the general scheme outlined in Figure 1. Observations are basically how we see the world, i.e., there might be the interactions between a mining activity and its ultimate effects on aquatic or terrestial ecosystems. Seldom, if ever, are our observations completely objective. Past experiences, attitudes, and values affect our perceptions. Whether a situation warrants a change in operation is highly dependent on an individual's perception.

Theory is based on perception. If we place a certain pollutant in a stream we anticipate certain impacts based on our understanding of the interrelationship between the components of the system. Prediction then becomes the essence of management.

The whole decision making process, as outlined in Figure 1, is interconnected and continuous. Theory, prediction, observation, and decision are very difficult to separate. Observations and decisions are usually defined in the context of our current theories and predictive abilities.

Prediction is the core of most management activities. An examination of the papers published in technical journals reveal that they usually relate to either observation or prediction.

Clearly there is no best way to predict impacts in fisheries and wildlife management, be they the results of mining operations or of fishing or hunting regulations. Management agencies have utilized many different approaches in the past without the benefit of models. However, in this paper we are primarily concerned with models as predictors.

MODELS

A model is essentially nothing more than an abstraction of a system. It represents a simplification of reality. In developing a model the modeler must decide what are the most important components of the system and how they interact. In this respect the model may be viewed as a formulation of a theory, the conceptualization of how the modeler perceives operation of the system.

Models can take many forms. There are four commonly used types: verbal; graphical; physical; and mathematical. Mathematical models are typically either analytical or computer implemented. Detailed descriptions of specific models and the justification for using models have been presented in numerous books and articles and will not be considered in this paper except to emphasize that models can be a powerful tool, but only a tool which must be integrated into overall resource management programs (Lackey 1975). There is no best model. Each model is appropriate in some situations and inappropriate in others. A model can only be evaluated in a context of its intended use. Whether a model is developed as a research or management tool, it can only be evaluated in relation to the objectives and goals of the total program. The objectives and its expected utility must be clearly defined before the model is developed.

A model often provides useful information and insight but lacks the required predictive ability. If the ultimate goal of the modeling effort was to produce a predictive tool, then the model did not fulfill the objectives of the study, no matter how much insight it provided.

Fisheries and Wildlife Models

One convenient way to categorize models used in fisheries and wildlife is by the boundaries of concern. Three categories are appropriate: habitat; biota; and the human dimension.

Habitat models may be broken down into either micro or macro. Micro describes models of individual habitat characteristics; macro describes models that tend to be broad brush environmental assessment types. Micro models might deal with dissolved oxygen curves in streams, whereas macro models might be concerned with very large scale habitat changes brought about by massive strip mining. Their main purpose is to provide information on the potential changes in the biota component of the system. Only recently has any real emphasis been placed on modeling the habitat component of natural systems. Most modeling in fisheries and wildlife management has been concerned with the biotic component. However, there have been many models developed in forestry that deal with maximizing timber production.

Models which deal with the biotic component of fisheries or wildlife systems may be of two types. The compartment (or mechanistic) models are concerned with such things as energy or biomass flows within a community or population. In contrast, population-structured models typically follow the numbers of animals or plants. Although distinction between the two is somewhat artificial, generally it sufficies for purposes of categorization.

Much attention has been directed toward single species population models, usually a recreationally or commercially valuable species which is being managed for some specific purpose. These models usually consider the population as an isolated entity and try to predict changes in population density or biomass with changes in management practices. Models which deal with multiple species or with habitat-biota systems are necessarily much more complex and less easily utilized in a management capacity.

The third type of model in fisheries and wildlife management are those dealing with the human dimension. There are two types: economic and socio-psychological. Economic models are best exemplified by benefit-cost studies. This is a very common approach to modeling human values and activities and in many respects is analogous to the population models of the previous section. In contrast to population models, socio-psychological models are very difficult to develop because they tend to deal with human behavior. Fairly well developed models on motivation and attitudes are presently being used to predict worker suitability and potential output in industrial situations. Sociologists have also used models in their research, but only recently has the human component of the natural resource system received attention.

When all three components of habitat, biotic, and human dimension are combined, the result is either a fisheries or wildlife system model. Models of these total systems are clearly going to be complex and this poses some of the major problems with modeling, management, or decision making. To adequately describe and model a complex system usually requires a model that is so complex that the manager-decision maker usually does not have the expertise to evaluate the strengths and weaknesses of the model. A real danger in using a model for management purposes is that the manager, if he is not involved in development of the model, may not be aware of the ingrained assumptions in the model. It is imperative that the potential user be either involved in development of the model via a team approach or that he is throughly knowledgeable about the model's assumptions and potential predictive capabilities. The latter can sometimes be accomplished by user workshops, short courses, or by integrating the modeler into the management phase of the program.

It is our feeling that the future of modeling in improving management should be more concerned with the development of simpler models of more complex systems rather than more complex models of complex systems.

MANAGEMENT

Management and modeling are very closely intertwined. Modeling activities must be integrated with management activities to be effective. We are not simply dealing with problems of human use and perception, but a complex system of ecological and sociological interactions.

A basic assumption of management is that all benefits from management are solely accruable to man. We are not so naive as to define benefits solely in economic terms but rather in terms of the total consumptive, nonconsumptive, economic, and intangible benefits to society.

How do we define these benefits? There are a variety of ways, all of which have a place in management.

Output from fisheries or wildlife systems may readily be measured in pounds of biomass of fish or wildlife produced. This is very commonly used but has been often criticized as a poor measure of system performance.

Outputs as numbers of either fish or wildlife has also been proposed. Some would argue that this moves our management towards a dimension of "quality." Others would perceive such output as merely a ramification of maximizing output of biomass.

Some measure of participation may be used for fisheries or wildlife systems. If people use the resource, the resource must have some social benefit. However, there is a serious issue whether measuring participation will result in optimal use of resources because most fisheries and wildlife systems are common property resources. Maximizing participation may result in excessive use.

Another potential output of a system deals with diversity of opportunity. This measure of output tends to add a dimension of quality in practice.

For those individuals who have an economic bend, maximizing "net income" is a measurable, social output which can be easily integrated with other public uses of resources. However, how do you relate and define intangible output from a system in terms of net income?

User satisfaction is a measure of output from a system. It is commonly advanced by those with a sociological orientation, but how do you handle this measure? It is intuitively appealing, particularly in concept, but very difficult to apply in practice.

What then can be used as measures of management output (and modeling output)? Maximum sustainable yield and its permutations are the easiest to define, but are perhaps very unrealistic. Maximum economic yield is advocated by many people, but it is very difficult to apply in practice. It tends to mean different things to different people. Related to the issue of measuring output from fisheries and wildlife systems is the idea of how do we measure these things? Who will set these goals and objectives? These are not easy questions to answer for modelers, managers, or administrators.

The primary role of modeling, as we see it at this point, is to force the modeler and manager to formalize their objectives and determine the important components of the system. The information and understanding gained in developing the model may out weigh the potential use of the model as a predictive management tool. Models are already fairly ingrained in research efforts in ecology and natural resources. The biological models, either habitat or population models have been and are currently being developed. More specifically, models that relate to the impacts of mining activities are currently available (LeFranc 1977; Saunders 1977). Sociological models are being used in a diversity of fields and are increasingly being used for natural resource systems.

The important thing to realize is that to integrate these models into the management decision making process will require major philosophical changes by both the managers and the modelers. A much closer interaction between these two groups must evolve. The distinction between these groups is purely artificial but tends to develop at the division of labor level for structuring an agency.

The potential for using models in managing natural resources is too great to ignore. However, models must be accepted only as tools to aid in the management process and, therefore, must be integrated into the overall system and not viewed as offering ultimate solutions.

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