Managing Trends in Angler Consumption in Freshwater Recreational Fisheries

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MANAGING TRENDS IN ANGLER CONSUMPTION IN FRESHWATER RECREATIONAL FISHERIES

by

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ABSTRACT

A basic activity of freshwater recreational fisheries management agencies is forecasting societal demand for fisheries resources and producing the necessary supply. Today, potential consumption often exceeds the supply of fisheries of the desired quality. A primary means for enhancing contemporary fisheries management may be to regulate angler consumption. Operations research techniques are well suited for handling the complexities involved with planning multiple action policies for regulating angler consumption.

PISCES is a computer simulator of the recreational fisheries management system of Tennessee, but is adaptable for use in any state. The purpose of PISCES is to aid in planning fisheries management decision policies at the macro level. PISCES generates predictions of how fisheries management agency activities will affect angler consumption for a fiscal year. Subjective probability distributions for random variables and Monte Carlo simulation techniques are employed in PISCES to produce an expected value and standard deviation for each prediction. Test runs under realistic hypothetical situations and discussions with personnel of the Tennessee Wildlife Resources Agency suggest that PISCES may help fisheries management agencies to improve budget allocation decisions, to formulate multiple action policies for regulating angler consumption, and to optimize fisheries development.

INTRODUCTION

Fisheries are systems consisting of aquatic biota, aquatic habitat, and man, interacting through time and space (Fig. 1). Fisheries management is the science of making and implementing decisions to maintain or alter the structure, dynamics, and interactions of fisheries components to achieve specific human objectives. Throughout the United States, agencies in state government have fisheries management as their legal mandate. Management agencies make decisions about such things as stocking fish, season length, license fees, and how to allocate millions of dollars in public funds.

Choosing among decision alternatives is a difficult task for fisheries agency personnel. A state fisheries management system contains many different fisheries types (i.e., lakes, ponds, streams, etc.), each complex in its own right and also interacting with other fisheries types. The impact of implementing different decision alternatives in the management system is rarely clear.

Methods for predicting the impact of alternative management decisions include rules of thumb, past experience, standard population models, experimentation, trial and error, and pure guess (Lackey 1974). Each method has a place in fisheries management, but the complexity of fisheries and fisheries problems may reduce the reliability of predictions to unacceptable levels. Therefore, fisheries agency personnel are often inconsistent in their ability to choose the best decision alternatives.

Recognition of the problem of effectively choosing among management decision alternatives prompted the Division of Federal Aid, Fish and Wildlife Service, United States Department of the Interior, to sponsor a research and development project at Virginia Polytechnic Institute and State University. The objective of the research described here was to develop a methodology for predicting the consequences of fisheries management agency activities and expenditures on resource consumption (angler-days). A computer-implemented simulator was developed in partial fulfillment of the research objective and to aid in planning fisheries management decision policies at the macro level in state agencies.

REGULATING ANGLER CONSUMPTION

Angler consumption of fisheries resources is one of the major interactions of man with aquatic biota and habitat (Fig. 1). Thus, consumption is a major concern of management agencies, but consumption trends in recreational fisheries are generally out of control (McFadden 1969). In practice, consumption trends are nearly always viewed as phenomena extrinsic to fisheries management, but in reality are only partially extrinsic. Virtually all management agency programs and activities have an effect on the location and intensity of angler consumption. Land acquisition, dam construction, pollution control, fish stocking, and access development are common examples.

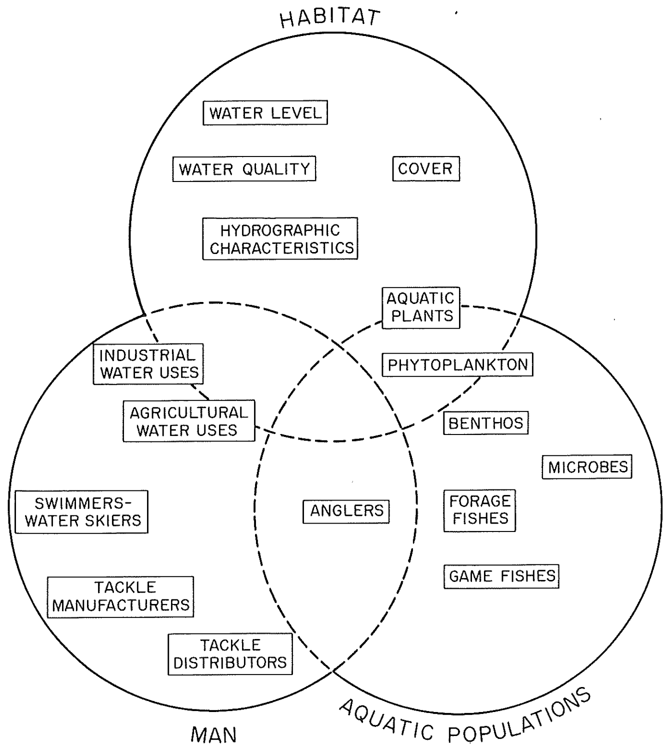

Figure 1. Graphical model of a generalized freshwater recreational fishery showing major system components.

Planning in recreational fisheries management is largely involved with forecasting the demand and providing an adequate supply of fisheries resources for the future. Producing or maintaining the necessary supply of fisheries may be difficult because all agencies have political, technical, and ecological constraints, and limited financial resources. In many cases, angler consumption of fisheries resources threatens to exceed managers' ability to supply angler-days of the desired quality.

Management policies have been designed to *respond* to consumptive trends but rarely to shape them. If fisheries management policies were designed to *regulate* angler consumption, greater benefits might be accrued from fisheries resources. Regulation of angler consumption could be achieved by limiting licenses, but such a tactic is often not politically or culturally acceptable. A less dictatorial approach based on subtle relationships between individual management activities and angler consumption might also be effective and perhaps more politically palatable.

Angling regulations, information distribution, and education programs address human components in fisheries management, but such efforts alone cannot be relied upon to direct resource consumption in a desirable direction. One or two actions in a complex management system are invariably inadequate to achieve the desired change. For example, while information and education efforts are working to direct angler consumption along a particular course, other agency activities may be working subtly against that course. Multiple actions, each moving in the same direction and with coordinated timing and emphasis, are needed to successfully regulate angler consumption.

OPERATIONS RESEARCH

Operations research (roughly synonymous with the term management science) can be used effectively to identify optimal decision policies for complex management systems. Performance of a potential policy is evaluated through a mathematical model representing the system under study. The effectiveness of operations research techniques for optimizing management of complex systems in many disciplines has been well established in the past several decades. Rapid, recent progress in operations research has been due, at least in large part, to the parallel development of digital computers. Computer computational speed and information storage capacity have enabled workers to address the large-scale analytical problems typical of operations research. The current wide application of operations research techniques in industry, the military, and government serves to emphasize their effectiveness (Schmidt and Taylor 1970).

Operations research is characterized primarily with the use of mathematical models, which can be divided into two categories: mathematical programming and computer-implemented simulation. A mathematical programming model is a set of symbols which represent the relevant decision variables of a system (Taha 1971). The solution to most mathematical programming models defines the values of decision variables which maximize or minimize a given objective function. A simulation model is a digital representation which imitates the behavior of a system. Statistics describing measures of change in the state of the system are accumulated as the simulator advances (Taha 1971). The performances of alternative decision variables is evaluated based on their effect upon system statistics.

The complexity of natural resource management systems (i.e., fisheries) makes operations research techniques potentially useful for evaluating management decisions and policies. MAST is one example of a mathematical programming model developed for wildlife management (Lobdell 1972). In MAST, linear programming techniques are used to define optimal budget allocation for two common managerial objectives: (1) minimize management cost subject to production requirements; and (2) maximize the value of management subject to capital constraint.

The deer hunter participation simulation (DEPHAS) developed by Bell and Thompson (1973) is an example of a computer simulator for predicting outputs resulting from state wildlife agency activities. DEPHAS is designed to allow state wildlife administrators to analyze interaction between input and output of their proposed management policies. Many other examples of operations research models for use in natural resources management are given by Titlow and Lackey (1974), Mills (1974), and Bare (1971).

Operations research in general, and computer simulation in particular, were chosen as the approach to fulfilling the objective of this study because:

(1) Operations research techniques force formal problem definition, and formulating the *exact* problem under review is a substantial step toward its solution.

(2) Operations research techniques include ways of structuring and measuring uncertainty, a universal characteristic of fisheries management systems.

(3) A computer simulator allows experimentation with various decision alternatives and policies without suffering consequences for mistakes.

(4) Computer simulators are more flexible than mathematical programming models, and hence, may be used more easily to represent a system as complex as a fishery.

(5) Simulation methods can be applied in systems, such as fisheries, where much information is lacking, incomplete, and of questionable accuracy.

(6) Once constructed, a mathematical programming model optimizes a management system for a single set of objectives and constraints, but a simulator can be used to evaluate the management system using different objectives and constraints.

PROCEDURES

Tennessee's state fisheries management system was used as a case study for simulator development. The Tennessee Wildlife Resources Agency literature, planning reports, and budget allocation records were analyzed to gain an understanding of the management system. Personal communication with Agency personnel was an integral part of the study.

A computer-implemented simulator, PISCES, was developed in four phases: (1) system components were identified; (2) important interactions between the components were identified; (3) mechanisms for the interactions were quantified; and (4) components and interactions were arranged in a logical order.

GENERAL DESCRIPTION OF PISCES

In its present form, PISCES is a computer-implemented model of the inland fisheries management system of Tennessee, but it can be modified for use by a similar agency in any state. Decisions which constitute the fisheries agency's management policy for a fiscal year are treated as input. Simulator output includes a prediction of the number of angler-days (man-days of angling) which will occur within the year and predictions of how resource consumption (also measured in angler-days) will be affected by the management policy.

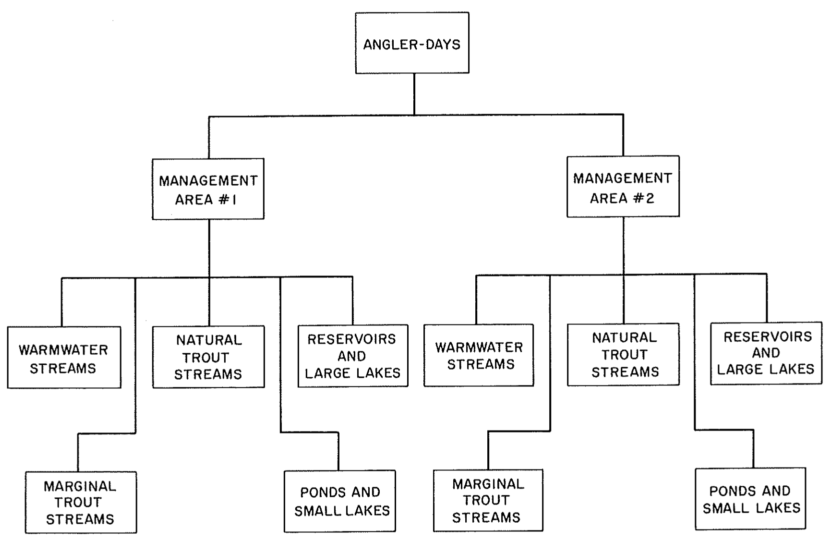

Figure 2. Classification of angler-days used in PISCES by physical location (management area) and fisheries type.

Management activities may produce angler-days, cause angler-days to decrease, or cause angler-days to be displaced from one location to another. One example of an agency activity which produces angler-days is catchable trout stocking. A decrease in angler-days will probably result from decisions such as increasing the license fee. Access area development is an example of an activity which causes angler-days to be displaced from one location to another.

Angler-days are classified in PISCES by their physical location (i.e., management area) and fisheries type (Fig. 2). Fisheries types considered in PISCES are typical of many states: (1) warmwater streams; (2) marginal trout streams; (3) natural trout streams; (4) ponds and small lakes; and (5) reservoirs and large lakes. In the simulator output, an angler-day in one part of the state can be distinguished from one in another part, and an angler-day on a natural trout stream can be distinguished from one on a reservoir.

In fisheries planning, evaluations of management decisions and policies should be based on their performance towards reaching objectives and their cost of implementation. Angler-day predictions in PISCES are designed to serve as performance measures for management decisions and policies, and the cost of implementation can be ascertained from simulator input. The planning sequence recommended for identifying *best* management policy with PISCES is similar to other modes of decision analysis (Fig. 3).

PISCES was programmed and tested on an IBM/370 computer. The program is written in FORTRAN IV, has an execution and compilation time of less than 5 min. on a level "G" FORTRAN compiler, and requires 120 K bytes of storage.

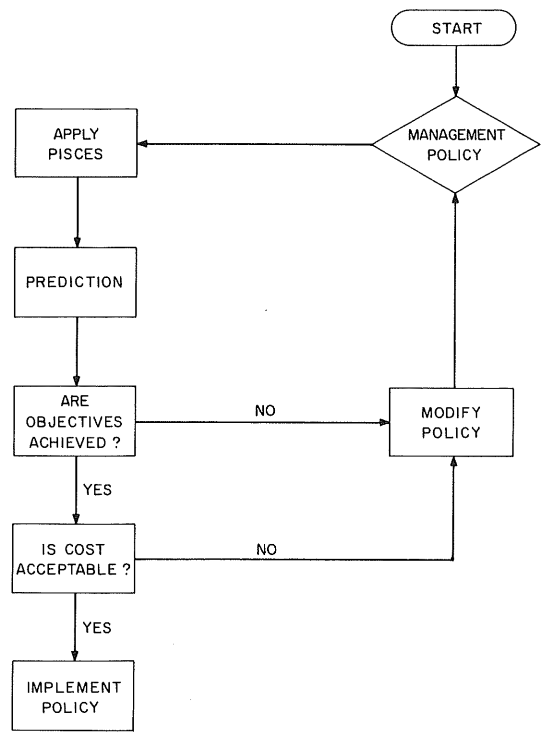

Figure 3. Recommended sequence of steps for use of PISCES for identifying the best management policy.

MATHEMATICAL TECHNIQUES

Fisheries management systems contain many variables and complex relationships which are poorly understood. Some variables, such as weather, appear to act randomly from year to year. In years with good weather, more anglers take to the field than in years with poor weather. Thus, the accuracy of predictions of the number of angler-days to be realized in a year depends, in part, upon the weather, a random variable. It is difficult to obtain accurate angler-day predictions under such uncertain conditions, but management decisions must be made, regardless. Two techniques which can be applied to account for random variation in formulating predictions are the use of statistics and Monte Carlo simulation. PISCES is designed to use both techniques.

Statistics

Present-day statistics may be defined as decision-making under uncertainty. A range or pattern of possible values of a random variable can sometimes be determined on the basis of past experience or from experimental data (Hicks 1964). A measure of uncertainty associated with a given prediction can then be calculated and the risks ascertained for basing management decisions upon various predictions.

Unfortunately, many of the random variables in a fisheries management system describe events which have never occurred or for which very little or no data exist. Traditional statistical techniques for assigning objective probability distributions cannot be applied to such variables. PISCES uses a technique of subjective probability assignment developed by Lamb (1967) which quantifies Weibull probability functions by utilizing best available subjective and objective information about variables. Low, most probable, and high estimates of the variables are used to quantify Weibull probability distributions.

Monte Carlo Simulation

Monte Carlo simulation, as used in PISCES, is the process of producing frequency distributions for simulator outputs. One iteration of a simulator produces one set of output values, but iterating a number of times in a simulator containing random variables produces frequency distributions on output variables.

Output for PISCES includes predictions of angler-day change. Producing frequency distributions for these predictions allows calculation of an expected value (mean) and standard deviation. Expected values are considered as the actual predictions and standard deviations are considered as a measure of risk associated with basing decisions upon the predictions. A measure of *risk* in decision-making is an extremely important statistic. For example, two different decision alternatives may produce the same predicted results, but the result may be much more certain for one alternative than for the other. If the costs of implementing each of the two alternatives are equal, then the alternative with the lesser risk is the better choice.

PISCES employs 50 iterations to produce an expected value and standard deviation for each prediction.

PROGRAM SEGMENTS

The activities of inland fisheries management agencies in most states can be encompassed in the following categories: (1) trout hatcheries; (2) access area development; (3) information and education; (4) land acquisition; (5) regulations; (6) research; (7) warmwater hatcheries; (8) pollution control; and (9) water development. Each category may influence fisheries resource consumption and is considered in PISCES (Fig. 4).

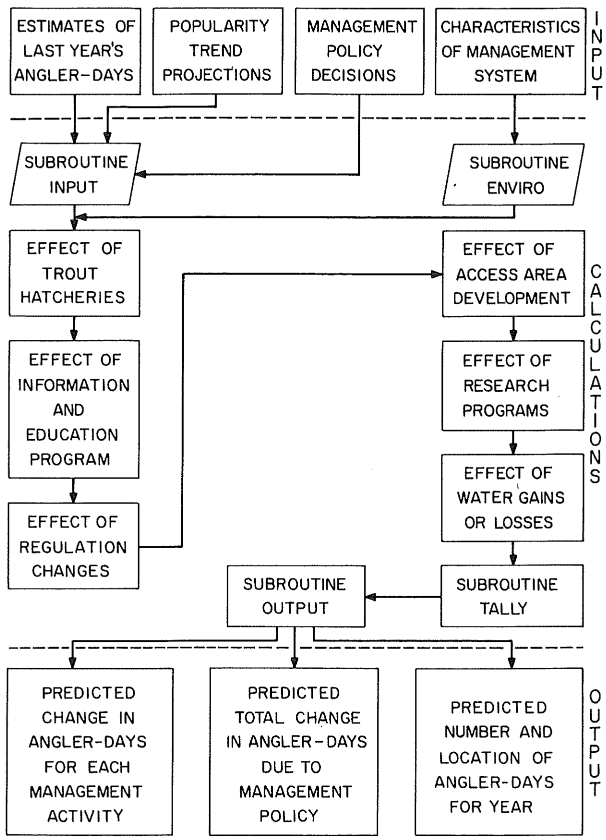

Figure 4. Sequence of input, calculations, and output in PISCES.

Many factors influencing resource consumption are totally or partially independent of fisheries agencies. PISCES directly accounts for several of these factors (such as reservoir construction, federal trout stocking programs, and popularity trends). Other independent factors, such as weather, are not directly addressed in the simulator, but are considered to be the cause of the random variation described in the probability distributions.

OBJECTIVES FOR STATE FISHERIES MANAGEMENT AGENCIES

A reasonable objective for a state fisheries management agency is to maximize total angling benefits derived from the state's recreational fisheries within the limits of its budget. Total angling benefit is a function of a number of factors, but the most significant and encompassing factors are probably the quantity and quality of angler-days.

$$\text{TOTAL ANGLING BENEFITS} = f\left(\begin{matrix}\text{QUANTITY OF} \\ \text{ANGLER-DAYS,}\end{matrix} \quad \begin{matrix}\text{QUALITY PER} \\ \text{ANGLER-DAY,...}\end{matrix}\right)$$

Maximizing "angling benefits" in an operations research model requires definition of the above function and precise measurement of both quantity and quality of angler-days. Unfortunately, no universally acceptable definition of the functional relationship or method for measuring the quality aspect of angler-days has been developed. Research efforts will eventually yield acceptable formulas and methods, but managers cannot stop and wait for the answers. One immediate solution for managers would be to use other, more quantifiable objectives to approximate maximizing angling benefits. Two such objectives are maxmizing quantity of angler-days and minimizing crowding of realized angler-days.

Before discussing the objectives of maximizing quantity and minimizing crowding of angler-days, it is desirable that a functional relationship, however imprecise, between quantity and quality of angler-days be defined. Many natural resource managers accept the premise that crowding reduces the quality of an outdoor experience (Stankey 1973, Moeller and Engelken 1972, Shafer and Moeller 1971, and Lime and Stankey 1971). If this premise is correct, crowding or quantity of angler-days occurring simultaneously in a fishery has some form of inverse relationship with quality. Thus, the quality of each individual angler-day would probably decrease as the quantity of angler-days increases (Fig. 5).

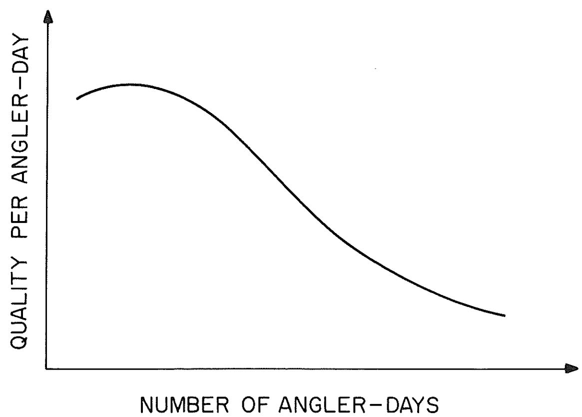

Figure 5. Probable general relationship between the number of angler-days sustained within a fishery and the quality per angler-day.

If the general relationship described in Fig. 5 is correct, two general shapes for the curve relating total angling benefits derived and the number of angler-days realized within a fishery in a given time period are possible (Fig. 6). Which relationship, I or II, is true depends upon the slope of the curve in Fig. 5. Present inability to measure the quality aspect of angler-days prevents exact determination of that slope, so the true relationship between total angling benefits and number of angler-days cannot be specified.

MAXIMIZING ANGLER-DAYS

Maximizing angler-days has one very important advantage as a management objective: the performance of management policies is relatively easy to measure and evaluate. Intuitively, maximizing angler-days appears to approximate maximizing total angling benefits, but close inspection reveals that maximizing angler-days has several undesirable ramifications. First, if the true relationship between total benefits and number of angler-days follows curve II in Fig. 6, maximizing angler-days may produce angler-day numbers greater than the number corresponding to maximum benefits. Second, the relationship between quality per angler-day and number of angler-days (Fig. 5) shows that maximizing the number of angler-days is equivalent to minimizing the quality per angler-day. And finally, maximizing number of angler-days may accelerate deterioration of fisheries resources through excessive use, a condition all too characteristic of "quality" fisheries.

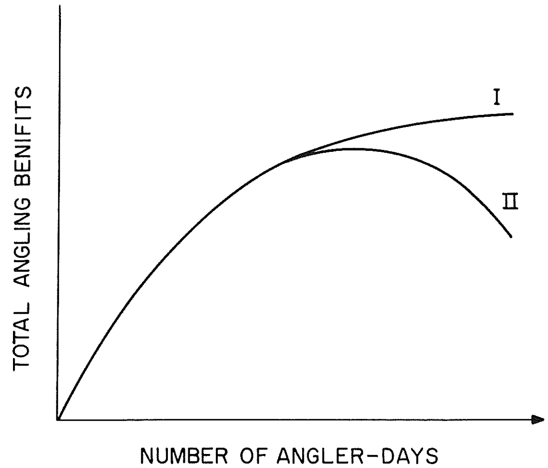

Figure 6. Two possible relationships between total angling benefits derived and the number of angler-days realized within a fishery in a given time period.

MINIMIZING CROWDING

Minimizing crowding consists of dispersing *existing* angler consumption in proportion to available fisheries resources in a state. If the inverse relationship between quantity and quality of angler-days is accepted (Fig. 5), then by minimizing crowding of a specific or *fixed* number of angler-days, the quality per individual angler-day is maximized.

Maximizing quality per angler-day of a number of angler-days, say X, is equivalent to maximizing the total angling quality derived from the X angler-days. Total angling quality defined as:

$$\begin{array}{c}\text{TOTAL ANGLING QUALITY}\\ \text{FOR X ANGLER-DAYS}\end{array} = \text{X ANGLER-DAYS} \bullet \begin{array}{c}\text{QUALITY PER}\\ \text{ANGLER-DAY}\end{array}$$

If the quantity of angler-days and the quality per angler-day are accepted as the major components of total angling benefits, it seems reasonable to assume that total angling quality approximates total angling benefits. Thus, minimizing crowding approximates maximizing total angling benefits for a given number of angler-days. That is:

MAX TOTAL ANGLING BENEFITS FOR X ANGLER-DAYS	=	MAX TOTAL ANGLING QUALITY FOR X ANGLER-DAYS
MAX TOTAL ANGLING QUALITY FOR X ANGLER-DAYS	=	MAX QUALITY PER ANGLER-DAY
MAX QUALITY PER ANGLER-DAY	=	MIN CROWDING OF X ANGLER-DAYS

Minimizing crowding as a management objective is not without problems and complexities. For example, one fishery may accrue more benefits per angler-day than another fishery, regardless of crowding. Thus, if angler-days are displaced from the former fishery to the latter fishery, total benefits may be reduced. Despite complexities, minimizing crowding warrants serious consideration as an objective in fisheries management for two reasons: (1) it is a readily quantifiable objective dealing with the human component of management; and (2) it probably approximates maximization of angling benefits.

EVALUATION OF SIMULATOR UTILITY

The utility of PISCES was evaluated by test runs using hypothetical data and discussion with fisheries agency personnel, but our evaluations should only be considered preliminary. The best method for thoroughly evaluating the utility of PISCES is an application study where actual management problems can be addressed.

Test runs under realistic, hypothetical situations show that PISCES may help fisheries agencies in several ways. First, PISCES should improve budget allocation decisions. Many of the decisions which constitute the total state management policy (input for PISCES) are budgetary in nature, and most other decisions can be traced to a budgetary base. PISCES allows experimentation of alternative allocation policies, and thereby, identifies the best policy.

Second, PISCES can be used to formulate multiple-action decision policies for regulating resource consumption. Fisheries resource consumption might be manipulated at levels significant enough to allow achievement of objectives, such as minimizing crowding.

Third, regional fisheries development may be enhanced through use of PISCES. Fisheries resource consumption predictions may clarify how fisheries development in one area affects resource consumption in other areas, information which can be used in deciding where to locate access areas and state ponds.

A meeting was held with personnel from the Fish Division and Planning Section of the Tennessee Wildlife Resources Agency to discuss PISCES. Some skepticism was expressed concerning the effectiveness of PISCES in predicting trends in resource consumption. Fish Division personnel doubted that the Agency significantly influenced resource consumption. Aside from these criticisms, planning section personnel were very receptive to PISCES. Evaluations concerning simulator utility are inconclusive and concrete results can only be obtained through further investigation.

DISCUSSION

Even if PISCES is not used to formulate management policies, it is hoped that some of the modeling techniques employed will prove useful in future efforts to model natural resource systems. For example, the technique of subjective probability assignment used in PISCES has potential for improving decision analysis in many areas of resource management. Modeling natural resource systems is often hampered for two reasons: (1) system data may be incomplete; and (2) experimental analysis of system variables may be impractical. Subjective probability assignment helps overcome these two problems by utilizing the best available information about the system.

Operations research models, such as PISCES, can be powerful fisheries management tools, but management expertise must include modeling skills in order to use them effectively. While understanding how to use a particular model is fairly simple, obtaining the best results with it usually requires a degree of skill. Some models may be "one man dogs" with regard to producing desirable results, and the man such a model "obeys" is usually its creator. The conclusion is that operations research models can be utilized to best advantage in fisheries management if the manager and model builder are the same person.

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