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USER'S GUIDE FOR RIOFISH: A COMPREHENSIVE MANAGEMENT SYSTEM MODEL FOR NEW MEXICO SPORTFISHERIES

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USER'S GUIDE

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ABSTRACT

This guide briefly summarizes development and structure of the sportfishery comprehensive management system model, RIOFISH, and describes its use. Following introductory background, the guide is designed to be read as the model is run and should be accompanied by diskettes for IBM compatible desk-top computers. The model user is stepped through menus that access background information, scenario set-up process (user modification of model inputs), model running process, and retrieval of model results. Each of the numerous input and output options is described. Example model runs illustrate how reference-scenario runs are compared to user-modified scenarios to estimate incremental changes in management outcomes associated with management actions. The various model uses are described, with emphasis on comprehensive management planning. Please send model-related comments or queries to Richard Cole, Box 30003, Dept 4901, NMSU, Las Cruces, NM 88003 (505 646-1346) and RCOLE@NMSU.EDU.

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SECTION I. PURPOSE, HISTORY, STRUCTURE AND USES

GUIDE PURPOSE

This guide is designed to introduce you to RIOFISH use and operation. It includes sections covering

- RIOFISH history
- RIOFISH general structure and uses
- running RIOFISH on an IBM-compatible personal computer
- example scenarios of management alternatives for self-paced instruction
- comparison of and inference from example model runs

Although we suggest you read sections I and II before running RIOFISH, it is not necessary to do so. Sections III and IV are intended to be read while running RIOFISH, before you try to run the model on your own. Descriptions of variables and application examples are presented in sections IV and V. Once you are generally familiar with RIOFISH purpose and operational modes, actual software use is facilitated by menus including tutorial explanation.

Unlike many software user manuals, this guide is designed more to convey principles and rationales for use than to describe specific applications. RIOFISH includes help options at each step, which can be referred to as needed during software use. Our intent here is to provide the operations information needed for you to become independent of this guide, relying on the information provided in RIOFISH software. For a more detailed description of RIOFISH, refer to Cole et al. (In Press) and to earlier reports for a historic review (Cole et al. 1986, 1987, 1990a,b; Cole and Ward 1994, Green-Hammond et al. 1988, 1990; Ward et al. 1983, 1992).

WHY RIOFISH WAS DEVELOPED

Fishery System Dynamics

Sport-fishery programs usually emphasize the need for site-specific management because each site has unique qualities as a fishery. Less frequently emphasized are the dynamics that site-specific management can create as site qualities change, anglers redistribute fishing effort, and fish populations are altered by changed mortality.

Anglers choose their fisheries from a system of site possibilities and change sites as site qualities change. Because of fishing mortality effects, changes in fishing pressure also alter management needs as anglers move among substitute sites. Fishery program managers are challenged to adjust tactics as natural and managed changes in site quality occur. These dynamics are complicated by natural variation and variability.

Either managed or natural water-level changes in New Mexico and elsewhere can change relative site attractiveness and alter fishing pressure, often requiring management adjustments. Management effectiveness uncertainty in New Mexico spurred interest in developing improved understanding of cause-and-effect relationships.

RIOFISH Development Goals

In 1980, the New Mexico Department of Game and Fish (NMGF) commissioned New Mexico State University to develop a model to aid policy planning and decision making for the state's sport-fishery program. That model eventually became known as RIOFISH, a River-basin Information Organizer for Fisheries Investigation, Simulation, and Heuristics. RIOFISH structure progressed from an early prototype in 1985 through the present model of a statewide comprehensive management system.

The goals guiding RIOFISH development focused on organizing diverse data into a numeric simulation of a fishery program-management system including habitats, aquatic communities, angler use, angler benefits, and management strategies. The system simulation was to be flexible and refineable as model use provided insight into gross system behavior and as new information became available. The model was to have a predictive planning capability, which allowed model users to assess the consequences of their management decisions and operations in search of cost-effective management.

An emphasis was to be placed on estimating economic measures of angler satisfaction, which could then be used in benefit-cost analysis of management effectiveness. The model was to facilitate communication among managers and researchers representing diverse water-management perspectives. RIOFISH was to be made widely accessible to users through development of personal computing software. It was to be geographically and temporally comprehensive for New Mexico policy analysis. Model structure was to be verified with available information and, ultimately, through agency monitoring of predicted management effectiveness.

The New Mexico Need

RIOFISH development began following an agency examination of its mission, planning environment, planning process and operations during the 1970s. Drought in the 1970s heightened management difficulty in a dry state with a rapidly growing human population. The first NMGF comprehensive plan, completed in 1977, emphasized a mission to serve both present and future publics through conservation and public-service principles.

Agency personnel recognized the difficulty inherent in making mission ideals operational. One problem was estimating fish and wildlife value gained from various management tactics in order to choose the most cost-effective management strategies. No where was this most evident than with expensive habitat development or acquisition.

Because water rights are owned and bartered in New Mexico, where water must be used beneficially, any decision to purchase water for habitat development needed an estimate of the fish and wildlife value gained by those who paid the bill, that is, the license-buying public. A basic issue was how much management revenue should be diverted from prevailing management activity to water rights purchase and leasing access.

Agency managers realized that managing water in one part of a river system had both upstream and downstream impacts. Instream flow issues were growing, for example, but sustaining instream flows to support stream fishery values implied some unknown tradeoff in reservoir fishery values.

They also suspected that some management decisions "robbed Peter to pay Paul" as fishery program benefits were geographically shifted without appreciably adding to the statewide angler benefit. Drought in the 1970s greatly reduced habitat availability and angler access at several large New Mexico reservoirs. When previously accessible fisheries became less accessible, because water levels fell below boat ramp access, angler use shifted to other locations and decreased in total. Fishing pressure was redistributed, altering fish mortality and demanding adjustments in stocking and regulations.

In short, comprehensive planning and drought in the 1970s pressed practical appreciation for the nature of systems underlying fishery management. The comprehensive management system in New Mexico, like elsewhere, was composed of many interactive ecosystems, fishery systems, and management systems, but without great understanding of how they interacted. Fishery personnel were challenged by the dynamics of these interacting systems within the comprehensive (statewide) fishery management framework. They realized that significant managed or natural change in the system caused a chain of effects through the system, requiring management adjustments, sometimes long after and far from the origin. But in many situations the cause-and-effect interactions, especially as they related to management effectiveness, were unclear.

As they considered options, agency managers found that they had no way to directly compare the angler benefits developed from stocked fish, harvest regulations, added habitat productivity or expansion, or any other management tactic used to benefit anglers. They desired a planning aid that would facilitate systematic comparisons of various strategies in search of the most cost-effective management decisions.

RIOFISH DEVELOPMENT HISTORY

Conditions were prime for a model feasibility study in 1979-80, which indicated that developing a comprehensive fishery management model was possible, but would be a long-term investment over a decade or more. One constraint was the limited availability of capable personal computers, which were first produced in 1977. Other constraints included limited model input data for modeled sites and incomplete understanding of the state fishery system. Funding limitations, as usual, also were a practical constraint.

Recognizing these constraints and the possibility of limited success, RIOFISH was developed in stages, each of which could be a termination point if development goals were not met satisfactorily. The first stage resulted in 1985 in a prototype model for six large reservoirs on the Rio Grande. By 1989, RIOFISH was expanded to include watershed inputs, the effects of angler site substitution, and up to 24 fish taxa for 18 major reservoirs in the five main river-basins. By 1994, RIOFISH was further expanded to include another 114 lake and stream fishing sites throughout New Mexico--a comprehensive statewide fishery management model including over 90 percent of the state's fishing activity.

The present version of RIOFISH was designed to analyze the impact of proposed fisheries-related management decisions on fisheries-related hydrology, ecology, and economy. Management scenarios now can be simulated for any combination of 1 to 132 sites, and for up to 10 years. The term, scenario, is used as in planning theory: an alternative possible state. RIOFISH's primary use is to analyze fishery management policy at the statewide sport fisheries program and program area (e.g., stream fisheries) levels. Although RIOFISH is most useful for analysis of New Mexico management policy, it has numerous potential uses elsewhere, especially for analogical planning and instruction. Information about computing requirements is provided in Section III.

WHAT THE USER BRINGS TO RIOFISH

RIOFISH complements fishery personnel experience and insight in the decision-making process. RIOFISH estimates and tracks the myriad consequences of many specific tactical decisions made in aggregate, but it cannot make decisions for model users. Those model users interested in management planning or research issues must choose the appropriate potential management or research decision, modify management inputs, choose the criteria that best meet management or research objectives, carefully analyze output results, and resolve any differences that arise between the model output and other information or intuition.

Resolving differences between the user's view of the correct decision and model output usually requires thought, discussion, and consultation. Model use may point to research needs. RIOFISH may encourage communication that fosters joint solution to complex management and research problems.

Model users must develop skill to design management or research scenarios by altering model inputs in logical and realistic ways. RIOFISH cannot substitute for the model user in the process of developing possible management strategies or alternative coefficients for analysis of research needs. Nor can the model decide which management or research scenario is the best choice for application based on the output information generated.

RIOFISH is one among numerous tools available for sophisticated management and research planning purposes. We assume RIOFISH use will be integrated appropriately with other analytical techniques and professional expertise. When used properly, RIOFISH can be a catalyst for more creative and cost-effective management and research. Although RIOFISH was designed specifically to address New Mexico sportfishery management, we believe that it may be used to gain insights into comprehensive management policy analysis elsewhere. Model users in other states may be able to analyze policies by analogy.

We hope RIOFISH contributes to the growing quantitative understanding of comprehensive management systems and sportfishery policy analysis.

SECTION II. RIOFISH STRUCTURE AND USES

MODEL STRUCTURE

Overview

RIOFISH is a mathematical simulation of water flow and transport of biologically active materials, fish habitat, fish forage production, sportfish production, fish density, fishery management, angler use, angler success, and economic benefits gained from sportfishing.

The mathematics are programmed in a user-friendly format using APL programming language. They link three main components representing the hydrologic, biologic, and economic features of 132 New Mexico sites with high fisheries potential (Figure 1). Each of the three main components requires information input to generate model output via computer screens and printouts. Each of the components can operate independently as well as in combination with other components.

Certain input information is fixed in model structure unavailable for user modification. In this category are site elevation and basin and channel morphology. Other inputs are user adjustable, including all management inputs. Certain inputs to model components may be embedded in a model component or derived from other model component outputs, depending on which combination of RIOFISH components is used. Water volume, flow and surface area outputs from the hydrology component serve as input for other components. Fish catch and harvest rates, simulated by the biologic component, serve as input for the economic component. Angler use rates, output from the economic component, serve as input for the biologic component.

RIOFISH input information establishes a reference state (or default state) for the modeled sites, which is automatically recovered or "defaults" whenever you so choose, through menu choice or when hardware power is interrupted (an exception under user control is discussed later). You can change many of the model inputs to analyze the effect of alternative inputs on model outputs. The changes will remain in place as long as you choose and hardware power is maintained. You can analyze different management strategies; for example, the effects of different combinations of stocking, regulations, water levels and boat ramp access. You can analyze the sensitivity of fish population dynamics to coefficients used in the model, including various mortality, growth and reproduction parameters.

Detailed description of model structure is provided in Cole et al. (In Press).

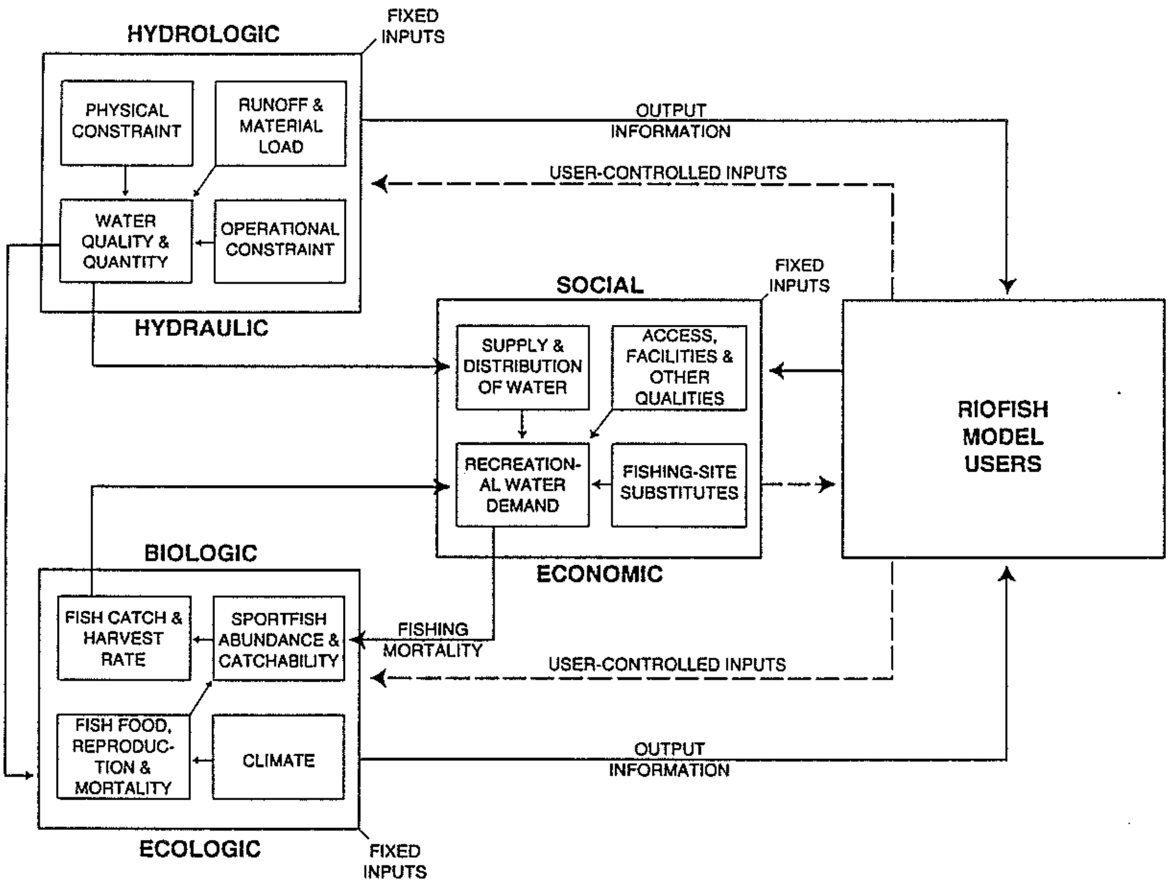

Figure 1. RIOFISH structural overview showing the three main components, which may be operated individually or together. The user develops contrasting scenarios by altering inputs and evaluating printed outputs for management impact.

Hydrologic Component

The hydrologic component is based on data from the U.S. Geological Survey (USGS) and water management agencies. The hydrologic component is generated from flow data largely collected at the USGS stations and averaged over semi-monthly time intervals (about 15 days). It runs independently of or in combination with the biologic and economic components. The hydrologic component can be run alone when only habitat information is of interest.

Data are included that define the shapes of lake basins and stream channels, channel slope, discharge, management constraints and material concentrations. The information for storage ratio and velocity is estimated from flow, morphology, and water management data. Stream substrate particle size is estimated from depth and shear stress. These data generate outputs pertaining to mean loadings (lakes) and concentrations (streams) of total phosphorus, nitrogen, and suspended solids; water elevations, depths, and surface areas; lake volumes and storage ratios; and stream widths and discharge.

Flows may be simulated either as "historic" flows or as "synthetic" flows. Historic flows are simulated for water years 1975-1992. Synthetic flows are based on seven past flow conditions from extreme low runoff to extreme high runoff. Model users can assemble any synthetic flow condition desired to forecast flows or to examine the effects of any one condition. For example, you may use a randomly selected series of synthetic flows for the next eight years following the 1991 and 1992 historic flows. Alternatively, you may choose a constant synthetic low-flow extreme to analyze a "worse-case scenario."

Biologic Component

Important hydrology model outputs that form inputs to the biology model include water volumes and surface area, mean depth, storage ratio, nutrient concentration and concentration of suspended solids. These variables help define habitat conditions that determine ecosystem productivity. The basic time unit in the biology model is semi-seasonal (about 46 days).

In addition to the information derived from the hydrologic component, the biologic component also requires input data for seasonal solar radiation and elevation (determines water temperature); concentration of organic carbon introduced from the watershed; and initial fish density and coefficients for the population dynamics of up to 24 fish species. The fish coefficients and certain other input information are user adjustable. Input to the biologic component also includes economic output in the form of angler site use rates when the economic model is used. Model users can, however, directly determine angler day input and run the biologic component independently of either hydrologic or economic components for special purposes.

The biologic model provides output information about primary productivity, allochthonous organic loading, zooplankton production and benthic production. Productivity also is estimated for herbivorous-detritivorous fish when carp, shad or other species are present. The model user can select output about the density, biomass and productivity of catchable-size fish (fish that can be caught by typical sport methods), harvest rates, catch rates, total catch and harvest for panfish, sport fish, total game fish and other catchable fish (carp and suckers). In addition, the population characteristics (biomass, density, mortality, growth) of up to 24 fish species are estimated in output tables.

Economic Component

The inputs required by the economic component, in addition to the hydrologic and biologic outputs already mentioned, are estimates of angler travel cost, site fees, site closures, road accessibility, boat ramp access, toilet and camping facilities, water clarity, aquatic vegetation, and availability and quality of substitute sites. The basic time unit for computing in the economic component is seasonal.

The economic component integrates these inputs with estimated fish sizes, composition, fish catch rates, fish harvest rates (estimated in the biologic component) and the water surface area (estimated in the hydrologic component). This integration results in computed angler days and angler benefit generated at each reservoir and estimates of regional income. Angler effort (days) causes fishing mortality (harvest and hooking mortality), which changes fish abundance and success rates. The economic component may be operated alone when no user changes in the hydrology or biology are anticipated or when the user wishes to bypass the hydrology and biology and provide input information directly to the economic component.

MODEL OUTPUT AND INPUT CONTROL

Output Information

Appendix Table 1 lists output information that may be selected by the user to compare model scenarios. A variety of economic, hydrologic, ecologic and fisheries outputs are provided. Results are screen viewed or printed once you run the model and request results using a series of menus and question-and-answer screens. The process is discussed in detail as we proceed through the model in Section III.

Only minimum computer skills are required to operate RIOFISH. Once the model is started, you are led step-by-step though the menu choices.

Input Control

RIOFISH allows you to simulate management changes by altering model input information and creating an alternative management scenario to compare with the reference management scenario. For all changes in management inputs, user-induced changes will revert to the default condition when you quit the model or power to the hardware is interrupted. For research or instructional uses, you can create up to three custom files for fish parameter inputs that will persist through power interruptions until you elect to eliminate them. Categories of control include

- water quantity (lake volume, elevation, stream flow)
- water distributions (water transfer)
- water quality (nutrient, light, temperature, etc.)
- harvest regulations (length, number, closures, gear)
- fish stocking rates (in size categories)
- fish introductions and removals
- boat ramp and road access
- camping, toilet and water facilities

Most commonly used management activities may be simulated. Most management changes may be made for any one to all years run in the model scenario. Each option or combination of options will be simulated to determine the impact on the river basin's hydrology, biology and economy over the time period that you choose to simulate. Certain options are not available, however. RIOFISH cannot be used to assess small habitat improvement structures, such as brush piles or log dams. Certain complex regulations cannot be analyzed, such as mixed weight and number limits. A new reservoir cannot be created, nor can old reservoirs be dredged or dams made larger.

RIOFISH also allows you to alter certain background information variables for forecasting purposes, including changes in

- travel cost, human population and fraction who fish
- water runoff conditions (synthetic flows)

These background conditions are among the more important variables affecting New Mexico policy analysis. Model users are, however, responsible for developing their own forecasts and introducing them as new inputs to RIOFISH. The model does not forecast trends or evaluate alternative planning futures without appropriate user input. Other factors also may play a role in forecasting opportunity and benefits derived from fishery management. We leave it up to you to take those factors into consideration when using RIOFISH.

You may change certain model parameters for research and other specialized purposes. These parameters include environmental factors, organic inputs, fish population parameters, and angler effort and performance criteria (e.g., fish catchability). You may develop totally new and unique fish species and fisheries based on the parameter changes you make. Up to 3 sets of fish population parameters can be "permanently" changed by creating "custom" files. These files will persist through power interruption including turning off the computer. The files can be changed back to the original reference state only through explicit choice from the menu system.

The Space and Time Dimensions

RIOFISH allows you to choose any number of sites up to the complete set of 132 sites available. Although multisite analyses are recommended for predictive comprehensive planning purposes, single-site analyses may be appropriate for instruction, research or other special purposes.

Either a "historic" background or a "synthetic" background may be used to set up model scenarios. RIOFISH simulates the historic hydrology of river-basin sites designated in Figure 2 for water years between October 1, 1974 and September 30, 1992. This time period includes a range of hydrologic conditions that occurred in the river basins of New Mexico. Water years 1975 through 1978 were moderate to low-flow years while many years during the 1980s were high-flow years. The synthetic hydrology may be chosen instead of the historic years, or a combination of both historic and synthetic flows may be chosen. You can choose from 1 to 10 years to analyze results.

The time scale used in RIOFISH scenarios is important to determine effectiveness of user input through the changes observed in model output. Because fisheries are not independent, either from year-to-year or from habitat-to-habitat, model users may misjudge full management strategy impact by overly restricting numbers of sites and years. Fingerling stocking could impact the fishery for several years, for example, and the full benefit cannot be estimated without running all years affected by the stocking.

Spacial scale also is important. If fish are stocked in one of a number of other angler substitute waters, effects on angler effort at the other waters cannot be estimated without taking a larger geographical perspective. It is up to the serious planner-model user to analyze the interaction of such effects through reiterative analysis. In this way a planner can estimate the number of sites and years to be included in scenario runs.

RIOFISH provides easy entry of site groups that serve as angler substitutes and these may serve as alternatives to tedious analysis of site interactions.

Setting Up a Reference Scenario

At least two scenario runs are needed to use RIOFISH properly: a reference scenario run and an alternative scenario run that will be compared to the reference run. You must calculate the differences between output values generated by reference scenario and alternative scenario runs. The magnitude of the differences indicate the degree of effect produced by the modeled differences in the two scenario runs.

Except for the management tactics to be evaluated, identical scenario background conditions should be maintained to allow valid scenario comparability. You should return to the original reference scenario condition each time an alternative scenario is developed and compared back to the reference scenario. Certain menu selections in RIOFISH aid recovery of the reference state incorporated in RIOFISH. You do not have to use the existing RIOFISH reference state ("default" condition) for the reference scenario, however. You can create any scenario desired within the software's limits for a reference scenario.

The reference or default states in RIOFISH were designed for common approaches to policy analysis. RIOFISH allows the model user to create either a "historic" reference scenario or a "forecast synthetic flow" scenario without any change on the part of the user. The historic reference state in RIOFISH does not precisely represent an actual historic condition. Even with the best data, uncertainty will preclude exact reproduction of an actual historic condition. Similarly, the forecast scenarios are not intended to represent what will happen, but rather what could happen if the causal conditions included in RIOFISH occur.

Although absolute reality in the historic reference is impossible to create and unnecessary, the model user should make the model reference as realistic as prevailing perception dictates. This may somewhat improve estimates of opportunity and benefits gained by management, to the extent they are affected by the initial conditions. The relative benefits and opportunity estimated with each management scenario should be similar, however, regardless of variation from reality, as long as the reference scenario remains identical for each comparison.

Choices of references depend on modeling purpose. If you are most interested in evaluating how much more effective you can make present management over the next decade, the reference most logically should resemble the management status quo. The RIOFISH reference state represents the status-quo management condition once stocking and regulations are added by a simple selection of menu choices.

If you instead want to illustrate the total benefit of future management activity, you might use a reference that includes the effects of past management, such as past stocking, boat ramps and regulations, but cease all future management. This type of reference will include residual effects of past management.

If you want to eliminate all fishery management, you need to reconstruct the conditions that would exist without previous introductions, stocking, boat ramps and other factors developed by the agency. If you wish to analyze for engineered effects, such as irrigation reservoir construction, they may be eliminated by creating a "run-of-the river" condition. Many choices are available, depending on your needs.

Setting Up a Comparison Scenario

We concentrated on making the responsiveness of the default condition in RIOFISH to model changes representative of the degree of change one might expect in the real world. To do this, an "if--when" statement is defined. "If the modeled fishery has the modeled attributes, what will be the change in angler benefits (harvest, catch rate, etc.) when an attribute is changed by x amount?" This "if-when" run can be followed by a series of runs that address the question: "How would the response generated by a change in attribute A compare to the responses generated by changing attributes B,C,D,...n, singly or in various combinations?" In this way, output responses can be tracked and the most desirable output level can be interpolated to determine preferred strategy.

A simple example follows. Say you wish to estimate the angler benefits and annual harvest lost if all stocking and regulations management were stopped in the future at sites you select. You might choose the random synthetic flow scenario that is the RIOFISH default state and the historic stocking, regulations and other management that occurred in 1990 (the year used as a base for synthetic flows). After the reference scenario is run, you eliminate all stocking and regulations in a second run, record results and find the difference between statewide economic benefits and annual fish harvest. The difference represents the angler benefits and harvest lost as a consequence of your modeled management decision superimposed on the model environment.

Then you may run a sequence of scenarios with alternative amounts of stocking and regulations to compare the benefits of each against the management cost. Using a large range of scenarios, two of the scenarios are likely to bracket the optimum management strategy for maximum benefit:cost.

Some General Limitations

RIOFISH, like any model, is a simplified simulation of what are intended to be the most important elements of the sport-fishery management system. Although the historic hydrology in RIOFISH is close to the observed USGS data at sites where such data were collected, uncertainty exists because of sampling error at monitored sites and because all sites were not equally monitored. The level of uncertainty varies among sites. Other data included in RIOFISH are equally or less certain than the hydrology data. For example, even with "good" data, no one can say exactly what fish community structure existed in a particular site and year because of sampling error.

When using a historic basis for scenarios, RIOFISH is designed to provide a general picture of historic condition and the response to management that would likely occur if the modeled conditions historically occurred, especially when sites are aggregated into larger management units (e.g., large warm-water reservoirs). RIOFISH is intended for analysis of relative changes in economic or biologic output under modeled conditions. RIOFISH indicates the directions of change and, less certainly, the fractional amounts of change in output as a consequence of some user-generated modification of the modeled environment and its modeled fishery.

Historic flows were developed for RIOFISH before synthetic flows. Three reasons for this choice stood out. First, historic flows had to be analyzed to develop synthetic flow categories and a historic flow basis was a natural precursor. More importantly, the model developers could use historic conditions to calibrate RIOFISH and judge model performance. We could, for example, compare estimated harvest rates and angler use to results of a statewide survey conducted in New Mexico and verify model performance. In addition, model users in New Mexico were expected to comprehend "historic" conditions better than forecast conditions based on synthetic flows.

Forecasting conditions based on user controlled assemblages of synthetic flows is, however, more in keeping with planning theory, which holds that the future is uncertain even though it is connected to past events. The synthetic flows allow users to assemble a wide variety of possible future conditions, with some conditions more probable than others. RIOFISH prediction then becomes much more naturally based on probable future events than on actual events. As long as "historic" scenarios are treated like forecast scenarios based on synthetic flows, that is, as probable events rather than actual events, there is little conceptual difference between the two choices. The synthetic flow option, however, allows more flexibility in scenario development.

Site aggregation usually increases the certainty of the hydrologic estimates as well as other model output estimates. This happens because the model parts were estimated from limited time frames and only from a portion of the sites. Certain model parts were estimated based on research conducted at sites other than the model sites. Many parameters used in RIOFISH are averages that are likely to vary among individual sites. Averages are used because precise site-specific information is scarce and model run time would be greatly increased if coefficients for each site differed.

We assume, for example, that the same relationships of mortality, growth and reproduction with habitat, anglers and other fish occur throughout all lake sites. This does not mean the fish behave identically, because habitats, fish diversity and anglers behave differently at the various sites. The chance that average parameter estimates are misrepresentative of mean site conditions will decrease as more sites are aggregated.

Based on similar statistical limitations, generic estimates of fisheries-related outputs are more dependable planning predictors than specific outputs. Changes in total catchable sport-fish biomass and production, for example, are much more reliably estimated than the estimates of age, class size, and production provided for each species in the detailed outputs. The purpose of detailed outputs is to instruct and diagnose systems process; they are not intended to predict the consequences of comprehensive management process on individual fish. Diagnostic and instructional outputs were provided to aid understanding by fishery biologists of how specific biological process links conceptually to comprehensive management process.

Single site, species specific and short-term analysis using RIOFISH, although doubtful for predictive planning purposes, may be useful for many specific purposes, especially for instruction and certain research purposes. RIOFISH provides a template for managers interested in site-specific or population specific management. It reveals the many factors that can play a role in determining management effectiveness at individual sites. Therefore, wherever site-specific information is warranted enough to gather expensive information about fisheries, RIOFISH provides insight into how to spend research funds and allows many coefficients to be tailored based on the new information.

One of the main purposes of RIOFISH is to organize existing information into a systems simulation. The process of adding new information into professional understanding is never ending. It is our wish that RIOFISH will serve to facilitate future improved understanding and possibly serve as a basis for more refined and useful management tools. There are many avenues for improvements.

Selecting Appropriate Outputs

Selecting appropriate RIOFISH outputs is critical and depends on the intent of model use. If you wish to maximize angler satisfaction for the management revenues available, you need to select outputs that best represent angler satisfaction--preferably economic benefit. Because angler use (e.g., recreational days) often is used as a proxy for benefit, with the questionable assumption that all days are equally beneficial, some model users may select angler days as a measure of satisfaction. The benefits measure of satisfaction, unlike the angler use measure, incorporates not only the recreational activity, but the quality of the activity. The benefits estimate not only reveals that some days provide better fishing than others, it puts it in monetary terms that can be compared with management costs.

Although some managers may focus attention on sustaining catchable fish stocks, representing sustained fishing opportunity, that opportunity may not benefit the anglers if some limiting factor impedes use, such as poor access or fishery remoteness. Some combination of angler use rate and the quality of use (angler satisfaction) are preferred measures of fishery objectives accomplishment. Statewide angler benefit is the aggregate measure of use and satisfaction incorporated into RIOFISH.

An output value may be more meaningfully interpreted when a suite of outputs is provided, representing the fishery's general condition. These general outputs are provided in choices 2 (multisite summary) and 3 (basic output for individual sites) of menu 4 (the RESULTS menu). More specific outputs are available for in-depth instructional or diagnostic purposes. We provide comprehensive tables of output information to make calculation of scenario differences easier.

Comparing output results may not always turn out as expected. For complex reasons, anglers are not always benefitted by increases in fish catch rate, or increases in biomass and production of catchable fish. Angler use rates do not necessarily change in proportion to benefits. The best management decision indicated for a single year of model simulation may not be the best decision for all conditions that occur during a five-year period. Also, the conditions existing in any time period you choose may affect your management decision.

MAIN RIOFISH USES

The main uses of RIOFISH include

- forecasting policy effectiveness
- contingency planning and forming objectives
- expanding inventory estimates
- issue management
- operational planning budget allocation
- research planning
- instruction

FORECASTING POLICY EFFECTIVENESS

Comprehensive Management Program Planning

RIOFISH is specifically designed for analysis of comprehensive management policies for a sport-fishery program in a New Mexico setting. With its capacity to track many processes and interactions, RIOFISH helps identify complementary and counteractive trends in proposed planning procedures. The model is best used in concert with other planning aids to analyze statewide cost-effectiveness of fishery program strategies. By strategic analysis, we mean the evaluation of cost-effectiveness for periods that extend well beyond the two- to three-year period usually reserved for operations planning-- up to 10 years using RIOFISH. This time period is in keeping with most contemporary planning horizons.

Comprehensive policy analysis using RIOFISH is based on the premise that thoughtful operations planning flows smoothly from strategic planning. Strategic planning also is constrained by operations, which create new conditions that limit strategic flexibility. Many of this year's operations have long-term impacts that will not fully materialize for many years. Management agencies often end up committing management revenues far beyond the operations planning period when they make keystone management decisions. Keystone decisions are followed by large redistributions of angler use and benefit, which often have far-reaching and long-range impact on management effectiveness.

Opening or closing large sites or major redistribution of habitat surface area are likely to be keystone decisions, which can be made within or outside the sportfishery program. Building boat ramps or providing new road access at sites without previous road or boat access also may be keystone decisions. Although such decisions can produce dramatic long-term angler benefit, a whole suite of costly complementary tactics may be required to fully realize that benefit. Keystone management decisions often attract some new anglers and numerous established anglers from fishing in other sites, changing the balance between anglers and fish populations. The imbalance may require increased stocking, altered regulation and more intense law enforcement, and new toilet and drinking-water facilities to sustain angler satisfaction and make the keystone investment worthwhile.

Such management chain reactions often require a redistribution of revenues from other management activities to sustain and enhance management effectiveness. Cost-effective management is hampered when agencies fail to consider adequately long-term consequences of management decisions. Operational changes often have to be made without enough attention to long-term impact on angler benefits and the supporting tactics needed for management effectiveness. RIOFISH provides a means to address the long-term impact of decisions on sport fishery management effectiveness.

Integrated strategic and operational planning, using aids like RIOFISH, helps managers with long-term conservation imperatives explain their management decisions and respective benefits and costs to the public. Improved integration of strategic and operational planning helps transform conservation bromides about "wise use" into more long-term effective management action.

Program Area Policy Analysis

Sportfishery programs often are subdivided into program areas to share planning process among informed personnel and to encourage application of management specialties where appropriate in the planning process. Sportfishery programs may be divided along functional or geographic boundaries. In either case, the sum of the program areas should cover all program management activities influencing management effectiveness as measured in terms of angler benefit or other measures of angler satisfaction. Functional divisions are usually signified by either species or habitat designations.

In New Mexico, a broad concept of a fishery system underlies the present division into program areas. A fishery system is defined by the interactions among fish populations, anglers, and the fishing qualities of various fishing sites that anglers move among. Substitute fishing sites provide similar enough characteristics for anglers to select fishing sites based on quality and cost considerations. Different gear and fishing skills are required, for example, for fishing lakes from boats and fishing streams by wading. Even an angler who fishes in both ways typically first selects the fishing style and then selects among substitute sites for the most satisfying site destination.

Important parameters determining the suitability of fishing method include flow conditions, site size and depth, and the species composition. Water temperature typically is an important factor determining potential species composition. Site characteristics also contribute to determining ecosystem properties and management possibilities, both important considerations in completing the concept of a fishery system and in identifying program areas.

Based on temperature, size, and flow characteristics alone, a sport-fisheries program can be divided into nine program areas: small, cold streams, large cold streams, small warm streams, large warm streams, small cold lakes, large cold lakes, small warm lakes and large warm lakes. Of course, a region may not include very many of certain site categories and some combining is advised. Other regions might be subdivided further, based on species composition, angler preferences or other factors. Also, as program areas are divided further, anglers become less discriminating and systems boundaries begin to blur. RIOFISH has been tailored to make fisheries in large warmwater lakes, large coldwater lakes, small lakes, and streams quickly accessible to model users for aggregate analysis. RIOFISH is flexible, however, and any combination of sites may be analyzed through a slightly more time consuming process of individual site identification.

A common alternative way to share program planning is via geographical region. Because it is flexible, RIOFISH can be used for policy analysis based on a regional division of program-planning labor, if that becomes the program management choice. This approach seems less likely to naturally subdivide comprehensive program management systems than approaches based on fishery system characteristics, however. Anglers usually ignore management-region boundaries because they have little to do with angler cost or satisfaction in site selection (unless there is a marked difference in how tactics are carried out among regions). Regional program-area planners also must be more tactically and strategically comprehensive across habitat, angler and fish species categories, than planners who can somewhat specialize in developing the most cost-effective strategies for program areas based on functional characteristics.

Modeling Program Planning

The object of program area planning is to transform the most cost-effective management strategy into an operations plan. With many sites and a wide variety of management tactics, program-area planning is best approached first through protocol. The planning process can be divided into a series of steps

1. Consider Keystone Decision effects

2. Determine tactical priorities by benefit:cost

3. Estimate maintenance and expansion budgets

4. Using tactical priority guides and only the economics part of RIOFISH, add, one by one, the most cost-effective tactics until all expansionary budget for the first year is used or marginal benefit-cost is less than 1.0. For now, assume historic catch and harvest is maintained and that some most probable water, travel cost and human population exists.

5. Compare benefit:costs of each program area, adjust budgets accordingly, and run a statewide scenario to compare integrated program benefits and costs to the sums of the program areas. If there are major differences, examine especially the role of keystone decisions.

6. Proceed to the second year and analyses as for the first year with the first years tactics already in place, adjust budgets among program areas, and proceed to the remaining years.

7. Analyze the effects of redistributing stocking, regulations and other operations maintenance budget activity among the program-area sites, year by year as in the first 6 steps, using the full RIOFISH model and run the model for at least a five to ten-year time period. Refer to the tactical marginal benefits table to aid decisions.

8. Coordinate final program-area plans via statewide integrated analysis similar to step 5.

9. Examine the effects of various contingencies on the statewide plans effectiveness. Important contingencies include drought, significant changes in travel cost, or large changes in the fraction of anglers who elect to fish.

10. Annually update the plan as new keystone decisions and other factors indicate need and adapt planning process as planning sophistication grows.

Step 1 identifies any keystone management decisions, such as major access leases coming up for negotiation or major changes in habitat availability because of irrigation diversion or other intents. Whether or not to pursue leases for Jemez Canyon and Eagle Nest lakes fall into this category. The possibility of major water transfers out of Pecos River reservoirs to Texas reservoirs also falls into this category. Such decisions can cause massive redistribution of angler effort and affect the benefits derived from each tactic as revealed in step 2. Keystone decisions may not be limited to program-area effects and are especially important factors in program-area coordination in one of the later steps. If keystone decisions are still in question, alternative plans can be developed with scenario decisions going either way. In this way a decision's economic effect can be analyzed and help determine the most appropriate decision.

Step 2 helps a planner identify tactical priorities. The economics component provides detailed output in the form of a marginal benefits table for all management tactics and natural factors that influence angler benefits. The marginal benefits for each tactic are recalculated each time a new scenario is run. Using this table, a program-area planner can provide the estimated cost of applying the tactic at each site and rank the priority level for each tactic based on benefit:cost. For preliminary analysis, generic cost can be estimated for each tactic. In refined analysis the cost needs to be tailored for conditions at each site. The tactical priority identified in the economics model is contingent on assumptions about habitat surface area and fishing success, which is based on what was measured in the late 1980s. Stocking, regulations, boat ramps, campgrounds, water and other past routine management tactics are incorporated in the default version of RIOFISH. Other recent and experimental management has not been included in the default management history, such as vegetation control and lake mixing through aeration, but model users can choose to insert mixing and vegetation control into their reference scenarios when they get to step 7.

In step 3, the program-area planner needs to estimate coarsely the budget available for program-area tactics in order to approximate the cost incurred for each year's tactics. Dividing the budget into expansion and maintenance operations may be helpful. Each program-area manager needs to estimate the fraction of tactical costs that will be allocated to the program area, usually based on the most recent budget allocation history.

Expanded operations typically require the most detailed cost evaluation. This category includes entirely new boat ramps, campsites, and other site facilities; new hatchery production space; addition of law enforcement personnel; and numerous other examples. Also within this category is any significant contraction of operations, such as closing a fishery, if it requires special cost analysis or results in more budget for expanding operations elsewhere. Operations expansion usually influences the effectiveness of routine management. Building an additional boat ramp, for example, creates new choices for anglers, who redistribute their activity, often requiring a redistribution of stocking, law enforcement and other routine management activity to sustain maximum benefit:cost. Typically, the expansion budget is substantially smaller than the maintenance budget, but its tactical effect is more important.

Operations already in effect need to be maintained. This includes such tactics as law enforcement and education associated with fish harvest regulation, fish stocking, planning, original research, evaluation of management effectiveness, site access and facilities maintenance, administrative functions, and other activities. Generally, a relatively fixed budget is assigned to these activities and it comprises the majority of the total budget. Planning effectiveness depends on the activity distribution, usually with relatively little change in cost. For example, hatchery stocks can be redistributed among sites usually with little change in stocking costs. In preliminary analysis, program-area managers may assume that costs are fixed and the redistribution benefit is the main concern.

In step 4, planners assemble the first year of tactics for each program area. Using the marginal benefits table, they choose those tactics that promise the greatest benefit:cost for the existing state of site qualities. Keystone changes and other tactics are added one by one, and the marginal benefits are consulted for changes each time a tactic is added to sites in the program area. Tactics are added until the approximated budget is exceeded or the marginal benefit:cost no longer exceeds 1.0. Exceeding the budget substantially is desired because there may be a redistribution of budget among program areas when results are coordinated at the program level in the next step. To keep time minimal, the program planners are advised to use only the economics model in this step and wait for a later step to use the entire model. Using the economics model alone, planners assume that habitat and fishing success will be managed to be what they were in the late 1980s, or some variation of that defined by keystone decisions or prediction of natural events.

Step 5 assures proper program-area integration. After thorough analysis and integration, budgets are reallocated among program areas and the program-area planners may proceed to the next step. Program-area coordination and integration includes a full statewide run of the tactics chosen, once budgets have been reallocated and a new first-year plan is proposed. The statewide benefits derived from a statewide scenario should exceed the sum of the program-area benefits. The benefit:costs should be higher than the average program-area benefit costs. If not, a reanalysis is needed to reconcile differences from expectation. Keystone decisions potentially play an important role because some may have the power to draw anglers from one program-area into another program-area. As program area planners gain insights in planning practice, they may decide to integrate steps 1-5 at a statewide level instead of waiting until step 5.

In step 6, planners continue to add tactics in the second year, having already established a basis for the first year in operations and budget. As before, use only the economics model, compare program area results and reallocate budget. Continue this process through the full sequence of years over which it is possible to anticipate major changes that will affect management effectiveness and revenues--at least five to ten years is advised. It is important to add any keystone changes anticipated in the year they are expected. Once this is completed, the planner needs to move to the next phase of analyzing how stocking, regulations and other activities ought to be altered to accommodate the expansionary and keystone changes.

Step 7 is the process of redistributing routine management tactics to sustain or enhance fishing success. This requires more time to run the entire model for each program area. Planners are likely to start by using historic stocking and regulations. They then refer to the marginal benefits table and evaluate the relative benefits associated with more and bigger fish caught and harvested. From that they should gain insight into redistribution of stocking and regulations. Results can be analyzed on a year-to-year basis, as for the expansionary operations, but the model should be run for at least five years or more each time to incorporate the multiyear lags associated with changes in regulations and fingerling stocking. Conditions like those used in the late 1980s are best to run to remain compatible with the economics component inputs. Use synthetic flows to approximate those conditions for hydrologic background in the scenario.

Step 8 is the final statewide reconciliation of program-area plans for conditions like those that occurred in the 1980s. This involves running statewide scenarios. Results may show that maintenance budgets should be redistributed among program areas for greater statewide benefit, for example. Once this stage is completed, operations plans for the next 5 to 10 years may be written in draft form (as one planning operations given the underlying assumptions occur), but emphasizing the need for future flexibility as new situations emerge.

Step 9 emphasizes the importance of planning contingency. Planning effectiveness is contingent upon the underlying assumptions about habitat surface area, travel cost, populations and fractions of anglers fishing, among other things. Final writing of operations plans may be set up based on alternative futures and associated contingency planning, discussed in a later section.

Step 10 emphasizes planning flexibility and the need for continuous updating as events occur. As more certainty materializes, planners may rerun and refine various alternative scenarios to incorporate the changes, especially in keystone events, and adjust tactics and budgets accordingly. As planners become more familiar with planning process, they are likely to refine this protocol to fit their specific needs. This series of ten steps is only suggested as one means of initially attacking the problem of comprehensive management planning using RIOFISH and a program-area approach.

The above approach helps planners avoid a common pitfall in past management, which has often tacitly assumed that it is best to equalize all site opportunity to maximize benefits. This is the main reason that many agencies have sought to manage for a universal harvest rate of 0.5 fish/hour, or seek to put one boat ramp at every possible site before they think of putting a second one at a site. Cole and Ward (1994) have illustrated the fallacy of that thinking, using boat ramp placement. Providing opportunity equally among sites is most beneficial only when the distributions of anglers and opportunities are closely aligned (e.g., evenly distributed over the state) and each site is more or less equal in size and other qualities. Cole and Ward (1994) showed that it is more beneficial to provide several boat ramps at one site when another, usually more remote and smaller, only has one ramp. It also is true that managing for higher catch and harvest rates at some sites may offset other deficiencies, such as poor access, and increase benefits more than uniform catch and harvest rates. The marginal benefits tables provided by RIOFISH should provide much insight into the inequality benefit associated with each tactic applied at each site.

Although managers sometimes think that more management is better as long as benefits exceed costs, there are exceptions. Too much regulation for example, may unnecessarily restrict harvest and reduce benefit, but care is needed in making this assessment. A five to ten year run is recommended because of the delay in effectiveness that is associated with many management tactics. Although a new regulation, for example, may reduce benefits during the first few years, the gain in natural recruitment may increase total benefits derived over a decade.

Coping with Future Uncertainty

Model users interested in program-level planning must also contend with uncertain future conditions and examine the effects of such uncertainty on the cost-effectiveness of proposed planning. RIOFISH is sensitive to environmental factors that influence management effectiveness. Although these environmental factors often remain outside the control of the management agency, they can be among keystone influences. Among environmental factors included in RIOFISH are

- travel cost
- human population and angler fraction
- water surface area, distribution, and quality
- certain road and boat ramp access
- certain campgrounds, toilets, and drinking waters

Potential changes in any one or combination of these factors could influence the angler visit rate and, the fishing opportunity, as anglers interact with the fishery. Because New Mexico, like other states, has a dynamic planning environment, no one future can be reliably predicted. Based on past history, however, the probability of change can be estimated and a series of "most probable" scenarios can be developed. Examples of possible ranges in fishing-related events for New Mexico during the next decade include:

- Human population growth could grow from 0 to 30 percent per decade.
- Water-surface area could range between 60,000 hectares and 15,000 hectares.
- Real travel costs could remain low or increase as much as two times present costs.
- Certain reservoirs could be enlarged and others could be drained or diverted to decrease, maintain, or increase site-surface areas.
- Roads, campgrounds and boat ramps could be built by other agencies that would affect fishery use; others could be closed.

Future human-caused changes, such as from water-management decisions, often are no more predictable than many natural events. Careful agencies keep abreast of other organizations' plans while recognizing that numerous variations of original plans actually materialize. Water scarcity, basic habitat needs and potential water-management conflicts make water surface area a keystone variable in New Mexico management considerations. Perhaps the least certain variable is water level. Variations in water level should be evaluated for their effect on benefits derived from the proposed management. Other factors, listed above, could be important additional considerations.

RIOFISH can be used to evaluate any projected combination of uncertain events for factors that are included in the model. The program manager may wish to seek out the optimum management strategy, the strategy that sustains the highest average benefit:cost ratio over a range of probable water-level and other conditions. The thoughtful program planner can examine present water conditions, for example, set them as the first year of a synthetic sequence, then create various random sequences to evaluate the mean and range of effects on benefits. This approach introduces realistic uncertainty into planning process and encourages managers to seek a consistent, optimum strategy for uncertain conditions.

An alternative approach is to seek the most cost-effective strategy for each possible water-level and other environmental condition and attempt to adapt management as conditions materialize. Because of rapid fluctuation and lags in management effectiveness, this adaptive approach is likely to be more difficult to execute successfully than a more consistent optimum management strategy. When extended change is projected, however, as for drought or travel cost, certain management adaptations may be advised instead of sustaining a constant strategy.

OBJECTIVE DEVELOPMENT AND CONTINGENCY PLANNING

Forming strategic objectives is central to contemporary management planning. Objectives too often are not reached in fishery management because contingencies impede accomplishment. Other objectives are too easily obtained and anglers benefit less than possible. Management objectives need to be challenging but attainable making allowance for contingencies. Clearly defined objectives, which take into account contingencies and constraints beyond management control, communicate more realistically to the fishing public and others. Unrealistic objectives encourage ineffective management. Unambitious objectives encourage inefficient management.

Objectives defined for a planning environment that is greatly different from the future that emerges are not likely to be realistic. Therefore, planning objectives need to be contingent upon any of a number of probable futures that may emerge. For example, the management objective, "increase average angler benefit over five years by 15 percent (tacitly assuming water levels and other factors remain "average"), may be modified for the contingency condition associated with low-water levels: "keep five-year mean benefits from falling more than 20 percent when water levels are low." High water levels would have other contingency objectives attached.

A practical approach is to formulate a compromise objective that is most likely to be reached when some "average" planning environment emerges. While in some years the compromise objective will be exceeded and in other years it will not be reached, objectives based on contingencies anticipate the variation. This approach allows the agency to adjust its expectations based on the management difficulty inherent in the planning environment.

Where water levels are unstable, as they are in New Mexico, any of a variety of conditions are equally probable over the next few years. Objectives must be flexible in such situations to deal with natural constraints realistically. Similarly, travel costs and population changes, and the fraction of people who fish may change for reasons beyond control of the fishery manager. But the fishery manager can anticipate possible changes and have alternative contingency objectives ready if those changes materialize.

Because RIOFISH considers important aspects of the planning environment, objective formulation using RIOFISH can be attached to contingency circumstances, making the objectives more realistic. This type of planning gives fishery managers more responsibility for management effectiveness and more allowance for conditions beyond their control. With RIOFISH, fishery managers may elect to have several contingency plans prepared instead of the one plan that usually is made for the most probable planning environment.

ISSUE MANAGEMENT

Regardless of the care taken in strategic planning and objective formulation, issues may arise that can not or were not anticipated. These issues can grow into crises if not analyzed and contended with in advance. Management agencies are increasingly scanning their planning environments in search of emerging issues that could grow into crisis proportion with the intent of controlling their impact.

RIOFISH is useful for analyzing the potential for issues to grow into more critical proportions. One recent example of such real New Mexico issues was the potential for water diversion from Ute, Caballo, and Pecos River reservoirs. Another example was the potential for fisheries closures or limited harvest at sites where mercury contamination was discovered. Other examples involve decisions related to how much money NMGF should contribute if any to maintaining leases or dam structures.

RIOFISH may be used to estimate how much angler activity and angler economic benefit is potentially involved, and whether or not each issue is primarily social or has hydrologic, biologic, or other physically manageable roots. When the issues can be addressed by physical management, RIOFISH can be used to evaluate strategies for defusing the issues before they grow more critical. Issues can be deflated through research, using RIOFISH and other information, and informing the public about results.

EXPANDING INVENTORY ESTIMATES

State fishery resource inventories usually are estimated by sampling a small fraction of the entire state resource. RIOFISH enables estimates of over 90 percent of the New Mexico statewide fishery resource and habitat conditions in those fisheries for the historic period for water-years 1975 though 1992. The model is designed to be calibrated with actual field surveys as improved information becomes available. The model-estimated resource abundance is only as accurate and precise as allowed by the samples collected to calibrate the model.

Site size and trout stocking are important variables determining the number of fish available to anglers. Both variables are portrayed accurately in "historic" scenarios of RIOFISH and contribute greatly to accurate estimates of total fishing opportunity at individual sites--especially where stocking is the main source of fish recruitment. While fish harvest rates and densities vary by a factor of 4-5 among sites, the total fish abundance and annual harvest varies by a factor about 1,000 times larger. Calibrated model estimates of site harvest rates, while they vary from observed values, generally do so within statistical confidence intervals associated with measured values.

RIOFISH inventories are increasingly reliable as estimates are integrated over more species at individual sites and over more sites. Program area summations or mean estimates for total sport fish, for example, are more reliable than species estimates, especially at one or a few sites. This is the result of sampling only a fraction of the sites over a fraction of possible fishery conditions, then calibrating the model based on that limited data.

RIOFISH provides inventory information for up to 90 percent of the entire state fisheries. It provides estimates of information about the state of water surface area, volume and discharge and other habitat characteristics; status of underlying ecosystem productivity; game fish abundance, catch, harvest and relative size structure; and angler use and benefit.

More important than past inventory, however, RIOFISH can be used to forecast future inventories by extrapolating past conditions up to 1992 into present and future conditions. By starting in a historic year of record, say 1990, and extending 10 years to 1999 using synthetic flows, the user can estimate fishing inventory for future years, given the water and other fishery conditions proposed to exist in future years.

RIOFISH can improve as an inventory forecasting aid as estimates improve for resource densities, population parameters, and angler fish relationships. Using field data from selected sites, fish populations are calibrated for particular years throughout the fishery. Such estimates, however, are prone to substantial error if not conducted with utmost care; otherwise existing model estimates may be more reliable than field "data."

RESEARCH PLANNING

The sensitivity of RIOFISH outputs to various changes made in the model is a useful tool for directing information gathering, ranging from routine management surveys to original research. Virtually all component estimates of the modeled planning system have uncertainty associated with them. Making critical estimates more certain is one of the operational goals for research and for planning evaluation.

RIOFISH also may be used to diagnose those parts of the model in most critical need of improvement. This research sensitivity analysis enables identification of those statistically uncertain model values that have the greatest effect on model outputs of various kinds. Research can then be focused on the most critical uncertainties.

INSTRUCTION

An important use of RIOFISH is for instruction, either in formal classroom settings or in a self-tutorial mode. Comprehensive management systems are complex and therefore inhibit the most cost-effective management. Many fisheries managers have concentrated on biological process early in their careers and have a limited sense of decision making based on non-biological criteria. RIOFISH provides a means for examining the relationships between biological and social management criteria for one statewide case history. Through analogy, RIOFISH should aid any agency or teaching institution that considers alternative approaches to management with a focus on social benefit.

RIOFISH should be useful for conveying comprehensive planning tenets including the importance of inventory information, the linked strategic and operations planning process, the role of planning environments (alternative futures) in contingency planning, and issue management. It should be especially helpful in showing how operational decision-making is logically linked to strategic effectiveness, often with long-term consequences.

RIOFISH also can aid instruction of fish population dynamics in a comprehensive ecosystem and management context. Fish population dynamics and their interactions with habitats and anglers are complex and often are difficult to visualize in field circumstances. Usually only the field result is recognized in the form of indices to fishery status including, among others, relative density, mean size, proportional stock density, and harvest rates. Such indices are not always well understood with regard to underlying population dynamics and their interactions with habitat and fishing effort. RIOFISH can be used to analyze the relationships of population parameters in the modeled populations.

RIOFISH allows fishery managers to do things to the modeled fisheries that are impossible in real fisheries. For example, to examine effects on fish population dynamics, habitats and angler activity can be held stable or varied to simulate instability.

SECTION III. MODEL OPERATION

PROCEDURAL OVERVIEW

Installation and Hardware Requirements

See the READ.ME file on Disk 1 for complete instructions on installing RIOFISH. Permanent program and data files will occupy about 10 MB of hard disk space. You need additional free space on your hard disk for holding transient files, which are created during a model run, but erased at the end of each modeling session. A minimum of 4MB of free hard disk space is needed for learning RIOFISH by running simulations involving only a few sites for one or two years. You will need 8 MB of free hard disk space to run the full model on all sites for 1 year, and 52 MB of free space to run the full model on all sites for 10 years.

A one year run of the full model on all 132 sites takes about 30 minutes on a Pentium 90 system or 90 minutes on a 486DX/33. Run times may be longer, depending on the speed of your hard disk drive. A ten year run of the full model on all 132 sites takes 4 hours 20 minutes on a Pentium 90 system, and 15 hours 10 minutes on a 486DX/33.

Simulations running the full model with only one lake site and 1 stream site for 1 year can be run in less than a minute on a Pentium system, and less than 5 minutes on a 486 system, and are recommended for learning your way around RIOFISH.

Beginning-Booting

To start RIOFISH from DOS, change the logged drive to the pathway containing your RIOFISH files, for example CD C:\RIOFISH. Then use the batch command RUNRIO to start the model. At the end of a session, you will be returned to the DOS environment automatically.

Responses

Whenever you need to provide information or directions to the model, some kind of prompt message indicates the kind of response that would be appropriate, usually a number (for a menu option or a scenario definition) or a letter (Y for yes, N for no, or Q for quit). Use the regular keyboard for letters. To enter numbers, use the top row of the regular keyboard or the numeric pad with NumLock on. In all cases, finish with the Enter key to complete your response.

The most common mechanical mistakes made in user responses are simple typographic errors (e.g., hitting the wrong option number). Experienced model users also tend to get ahead of themselves and answer a question that is not the one being asked. Always read the prompts, then answer appropriately.

Handling Errors

Most mistakes made during user responses can be handled by the program, which will display some kind of message indicating that an entry error has been made. You will have a chance to try again.

If, while the model is running, an error occurs that cannot be handled by the program, a message will appear saying that something has gone wrong, giving instructions if necessary. In this case, the model will stop, any transient files will be erased, and you will be returned to the DOS environment. You can then start completely over and try again.

We will appreciate feedback about software errors or other problems. When an error message appears, print the screen, if possible, and briefly describe your scenario before sending it back. Send to R. A. Cole, Box 30003, Department 4901, New Mexico State University, Las Cruces, NM 88003.

Menus

Four main menus control the software use, namely menus for background information, scenario set up (two versions), model runs, and getting outputs of model results. Each menu consists of a series of options for getting help, taking actions, and moving to other main menus, subsidiary menus or entirely out of (quitting) the model software.

You may take the action or information options in any order, and repeat them as many times as necessary. The selected options may bring up subsidiary menus, sets of questions, screen-face displays for entering several numbers, or a series of numbers which can be reset or left unchanged. To help maintain clarity in the following description of software use, we refer to entries on the main menus as "options," on the secondary menus as "choices" and on the tertiary menus as "selections."

Answering Questions

Questions are always followed by a list of appropriate answers. Simply enter the answer you want.

Series of Numbers

In cases where you may want to change one or more of a series of numbers (for example, monthly maximum reservoir volume, or seasonal ambient light), the current values for the set are displayed, followed by a question of whether you want to make any changes. If you choose to make changes, the numbers are displayed again one at a time (with labels identifying them) followed by a colon. To make a change, enter the new number followed by Enter. To leave the number unchanged, simply depress Enter.

Screenface Numerical Inputs

In some cases, such as fish population parameters, current values of a set of numbers are presented in a table for screenface editing. To make any changes, move the cursor around the screen with the cursor pad (or arrow keys) and make changes by simply typing the new number in the correct place (old numbers will be replaced with new ones). Get rid of any extra old digits by typing over them with blank spaces. Do not erase an old number completely and then leave it blank; put in some new number, even if only 0. If a table of numbers takes more than one screen to be displayed, shift the display up or down with the PageUp and PageDown keys. When all changes are complete (or if no changes are needed) depress the F9 key to finish the screen edit.

Negative Numbers

Usually, if a negative number is needed for a number in a table, the negative sign will already show on the screen. If you need to enter a negative sign, use the shifted-key in the top row of the keyboard. A negative sign should show on the screen.

Printouts

You can get printouts from the background information and output of result menus. Each time a printable result is requested from the menu, you will have a choice of whether or not to print it. If in doubt, look at it on the screen without printing, and then repeat the option to get a printout if you want one.

If you want to save a printout as a file, you will need to supply the directory pathway and file name in proper DOS format (up to 8 letters, numbers, or underlines in the file name, and up to 3 letters or numbers in the extension, with no embedded spaces). A default pathway is provided on the screen, but you may change it. You must enter a file name. An example, using the default pathway, is C:\APLII\RIOFISH\PRINTOUT\results.1, where 'results.1' is the file name 'results' followed by the extension '1'. Printout files are not erased by the model program at the end of a session.

Any requested outputs are sent directly to the printer at the same time they are displayed on the screen.

Learning to Operate RIOFISH

The remaining sections of this chapter are designed to be read as you advance through RIOFISH. They elaborate upon comments and tutorials embedded in RIOFISH and lead you through elementary runs. For an efficient and complete review of RIOFISH, including many informative comments, we suggest that you load RIOFISH and proceed through the entire menu system as you read the rest of this chapter. Actual RIOFISH screens will serve to demonstrate, usually in place of figures provided in the text. Through repeated use for a variety of purposes, you eventually will gain familiarity with all the many possibilities available in RIOFISH. Others of you will likely want to "poke around" the model first. If you do so, take the time to read the brief tutorials once you get into RIOFISH.

INITIAL SCENARIO MENU

The Initial Scenario Menu appears after the title, author, version, and copyright information are viewed and you depress the Enter key as directed at the bottom of the screen. The reference or default state is then loaded, taking a few seconds. You are now ready to use RIOFISH.

The Initial Scenario Menu provides three options. The first option is a brief tutorial about the other two options in the menu. The second option provides entry to the main model functions via the Main Scenario Menu. The third option retrieves the Database Menu, which is used to develop greater familiarity with site attributes and locations. After you have selected option 1 and reviewed the tutorial, select option 3 to review the contents of the Database Menu. We will return to option 2 later.

THE DATABASE MENU

General Information Options

You should first review options 1 and 2, which briefly describe the menu system and the information provided in the Database Menu. Option 3 identifies the version used and certain of its characteristics that differentiate it from other versions.

Option 4 routes you to a selection from four maps showing site locations. Map selection first provides you an opportunity to print immediately, save for later printing or simply view the output (these choices are provided for all outputs). You may choose to print if you wish, but viewing is sufficient for now. When you enter the choice, a schematic map appears. The main purpose of each map is to locate relative positions of sites.

Some USGS recording stations are included for reference to other state maps, if needed.

Historic Flows

Option 5 provides access to either graphic or tabular output for the lake sites, including historic (1975-1992) elevation, surface area, volume, inflow discharges, and outflow discharges. For the river sites, only discharge data is provided. These data provide a general sense of variation that occurred over the period of record.

From the graphic display you may gain insight into the hydrologic behavior of each site, years of high and low runoff and major changes in water management procedures. These data are derived mostly from USGS monitoring stations. Sites not monitored directly by USGS or other entities were estimated using data from analogous monitored sites and climatic data. The tabular display provides detail needed for precise input modifications, as described later in the manual.

Synthetic Flows

Option 6 allows you to review the synthetic flow reference (default) used in RIOFISH over a ten-year period. This flow regime drives RIOFISH when synthetic flow conditions are chosen by the user instead of historic flow conditions, and when no alternative synthetic flow sequence is constructed by the user. The equivalent flow data also are tabularized here and are useful for simulating new flows.

Default synthetic flows for each site were developed from site-integrated statewide analysis of historic flow conditions. Seven flow conditions, from extreme dry to extreme wet, are used to randomly construct the reference conditions for each site in RIOFISH. Conditions for any synthetic flow state chosen are consistent throughout the river basin; it is impossible, in other words, to have extreme dry conditions in a downstream reservoir while an upstream reservoir undergoes extreme wet conditions.

Exiting the Menu

Option 8 routes you out of the software when you are finished with it. Ordinarily you will loose any changes you made in model inputs when you quit RIOFISH or turn off the hardware power (with a user-controlled exception discussed later). If you were to quit now, all site, flow and time changes would have to be reintroduced.

To proceed further with this review, choose option 7, which routes you to the other main menus via the Initial Scenario Menu.

RETURN TO MAIN SCENARIO MENU

Establishing Scenario Background

Once you are back in the Initial Scenario Menu, choose Option 2 to proceed to other model functions. All use of RIOFISH is based on the development of scenarios, which are contrasted with one another to estimate scenario effects on output values.

Each scenario set up in RIOFISH has the same basic elements: a set of background conditions that will remain constant throughout the development of comparable scenarios, and variables that will be changed to test their effect on the model outputs.

The first major steps define flow condition, time frame, and geographic dimensions for your scenario background conditions. First you must choose either a "historic" scenario background or a "synthetic" flow regime, by entering H (historic) or S (synthetic).

Enter S first. Once entered, you will be prompted to enter the number of years for this run, up to ten years. Enter 10 now.

Once the number of years is entered, eight site category choices appear for your consideration. The first choice separately lists all 132 sites on 4 sequential tables, the first 3 tables each representing one of the major river-basin subsystems in New Mexico and the last table being a "catch-all" category (the whole table may not be visible until the screen is rolled up with the cursor arrow). The river-basin maps provided in the Data base menu represent each of these tables. Press F9 to advance through the set of tables. Each table may be simply viewed without change. After the last table is viewed you will be returned to the site choice menu.

Select choice 1 again and this time enter a 1 on the line adjacent to the site name using the cursor for each of the following sites (we will refer back to the results for these sites later in the chapter--so play along). In the first table, place a 1 next to Abiquiu Reservoir and next to Cochiti Reservoir. In Table 2 place a 1 next to Pecos River 1 North. Skip Table 3 (press F9) and enter 1 next to Lake Roberts in Table 4. If you make a mistake, or you wish to cancel a previous selection while keeping others, enter 0 next to the site. Give it a try for one of the sites and then replace the 0 with a 1 before you proceed. Bypass Table 4 (press F9) to return to the menu. Once there, press Q to complete or review the scenario scope. RIOFISH will next ask you if you want to make any further changes in time or place. Press N for No.

When synthetic flow is chosen, you are presented (as shown in the screen) with the model reference condition, which is a random selection of state runoff conditions. You may accept this assemblage of synthetic flows or construct another random or non-random series. You may enter up to seven different flow conditions over 7 or more years. A "worse case" scenario might include a series of extreme dry years, for example. An extreme dry year appears about 5 percent of the time in the record. Two extreme dry years in a row has a much lower probability. You may change each of the reference designations using the cursor and entering the correct numerical code as identified for you on the screen.

Try it. First identify the code number for each synthetic flow regime (1-7) and then move the cursor to each regime number you wish to change. Simply enter the new regime number over the old one. Now when you are asked if you wish to make changes, enter N (no). The regimes you selected will then be loaded into RIOFISH (a few seconds). Next you are asked which bench-line stocking condition you wish to use. For now, Use the default by answering N to the stocking query. The next menu requires you to choose among printer categories. Select which is most appropriate for you. Making this choice routes you to the Main Scenario Menu. Before exploring its options choose option 2 for another place and time modification.

First affirm (Y) that you wish to make a change. Now choose the historic condition, starting with 1989. This time indicate 8 for the number of years. Keep the same sites as you set up for synthetic flows by pressing Q.

When RIOFISH now asks you if you want further changes notice that the time period switches from historic (h) to synthetic (s) after 1992. This allows you to extend a historic scenario forward, perhaps picking those synthetic flows that best represent flows after 1992 including future forecast flow.

Now set up one last background condition for eventual comparison to a management scenario by pressing Y, indicating you wish further changes. To simplify things, keep the same initial year, 1988, but change the number of years to 3. This will make the scenario completely historical, from 1989-1991.

Continue with the four sites already chosen. Confirm that they are Abiquiu Reservoir, Cochiti Reservoir, Pecos River 1 North, and Lake Roberts (Choice 1, see or modify selected sites...). Now return to the site category choices by advancing through the last of the four river-basin tables.

Site Combinations

Choice 2 in the site-category menu allows you to run all lakes and streams together, bypassing individual selections to save time. This choice is important for statewide planning analysis. It requires many hours to run, and we advise avoiding it until familiarity is gained with model attributes. A run of 1 lake site for one year typically takes at least 20 seconds, depending on the hardware used. A statewide run over 10 years requires at least 12 hours for 486/66 machines and equivalents. Faster or slower machines will significantly alter the run times. When you finally decide at some later time to give a statewide run a try, set up a scenario to run overnight.

Choice 3 allows you to cancel all previous sites selections in one simple operation. If you press 3 now to see if it works, please re-enter the sites, time and flow conditions that you last set up. Better yet, forego your curiosity for now.

The next five options allow you to quickly select site aggregates chosen for their utility in New Mexico program-area planning. They include all lakes, all flowing waters (including headwater lakes), small lakes, large and cold lakes, and large and warm lakes. Of the site aggregate options, flowing waters (choice 8) requires the greatest time to run (about 9 hours or more) with 486/66 or slower machines. Options 4, 5, 6 and 7 require at least 6, 2.5, 1.5, and 4 hours each to run on the same machine, respectively. As hardware advances, of course, these run times will be reduced.

Press Q, the last option to continue the scenario development, and answer N when asked if you wish to make further changes. Your should continue to have the four sites originally chosen for years 1989, 1990 and 1991. Once you verify the background flows are what you wanted, the Main Scenario Menu appears.

THE MAIN SCENARIO MENU

Information

The Main Scenario Menu allows you to make input changes that simulate management or examine research issues. Option 1 gives information about the utility of each menu option. Review it first.

Option 4 allows you to review the river-basin maps for general reference if needed. The four maps shown in the Database Menu are shown here with the same option to view or print.

Change Your Mind?

Option 2 allows a change to be made in the site and year selected, which repeats the process just reviewed above for setting up time and sites.

Option 3 allows you to eliminate any previous linkages among model components. This will return you to the model reference condition, thereby "defaulting" to modeled background conditions. So far, you have not changed the default conditions so selecting this option will not change anything. Eventually, however, you will learn that taking this option by mistake can be frustrating once you have set up a complex background scenario. You should be sure all scenarios requiring the same background are completed before quitting the model or remembering and replacing the exact background state in subsequent scenario runs.

Hydrologic Input Changes

Option 5 in the Main Scenario Menu allows you to view or change hydrologic variables and inputs. You have 6 choices once you elect this option.

Return to Default Condition

Choice 1 allows flow and flow-constraint conditions to be returned to the model default state. Flow constraints include any changes in reservoir release and storage operation, for example. Choice 1 is appropriate only after all scenarios to be contrasted against a specific background condition have been completed. Otherwise, the exact background condition has to be reconstructed to complete a scenario series.

Volume Constraints

Choice 2 displays the existing site hydrology constraints and conditions. You are guided through choices in modifying the constraints on maximum and minimum volume. Pick 1 RGR to look at Cochiti Reservoir (42). The initial volume for Cochiti Reservoir in the model, 266,201,380 m^3, may be changed and any maximum volume can be changed for each month to a lower or higher value. When initial and maximum volumes are changed, the reservoir storage ratio (reciprocal of exchange rate) and discharge rate adjust. Minimum historic volumes may be zero or some larger number depending on legal agreement or other constraints. Change Cochiti initial volume as described in the model tutorial to , 200,000,000m^3 (note: avoid commas and enter 200000 because the number is in units of 1000 m^3).

At the beginning of any scenario, the reservoir volume is the measured volume of water contained in that reservoir on the day preceding the date chosen for your scenario. The value used in the model is taken from USGS records and is the best estimate of the actual value. You can change the value for various scenarios concerning water volumes, surface area and elevation.

Maximum lake volumes are the maximum allowable in a lake during any one month. You can reset up to 12 of these values for each year that you model (one for each month beginning in January). For example, set the maximum volume of 619,988,200 m^3 for Cochiti Reservoir in April to 300,000,000 m^3.

Minimum reservoir volumes control the minimum contained in a reservoir on a monthly basis. When the minimum and maximum volumes are set to be identical, water level can be held constant. For example, set the June minimum volume at 100,000,000 m^3. Check your changes. There may be small rounding errors, which are unavoidable.

Inflow and Outflow Modification

Choice 4 enables you to change inflows and outflows. A brief tutorial proceeds the operation. You are given a choice between a quick method that allows constant changes to be made over the various inflows and outflows at each site over the period to be simulated. The quick method is inappropriate when more detailed changes are to be made for individual months.

RIOFISH can be used to model up to three inflows for each reservoir. The inflow designated as number 1 represents the main channel (river). Inflow 2 represents subsidiary and tributary flows. Inflow 3 is a computed watershed inflow from a historic mass-balance of the reservoir.

For example, for Cochiti Reservoir (choose 1RGR and site 29), inflow 1 is the Rio Grande, inflow 2 is the Santa Fe River, and inflow 3 is the watershed for Cochiti Reservoir below the USGS stations located on inflow 1 and inflow 2. The operational form of the modification equation is

$$Qmod = a + bQorig \qquad (1)$$

where Qmod = the modified inflow (1, 2 or 3)
Qorig = the original inflow (1,2,or 3)
a = the constant (in cubic feet per second)
b = the multiplier

You can set the values for a and b for each month. Changing inflows also changes lake loadings of nitrogen, phosphorus, sediment, and allochthonous (watershed sources) organic matter (carbon). The multiplier value, b, in equation 1 does not have units, but it can be used to investigate the effects of fractional changes in inflows. For example, if you decide to increase river flows by 5 percent, the value of b would be set at 1.05 to reflect the increase.

Outflow multipliers and constants serve the same function as the inflow multipliers and constants, except that they are used to modify outflows. As with the inflows, RIOFISH can model up to three outflows for each lake. Outflow 1 represents the main outflow channel (the river), and outflows 2 and 3 represent any other withdrawals from the lake, such as through irrigation channels.

For example, if you want to examine the effect of a proposed irrigation withdrawal from Cochiti Reservoir, you could use outflow 2 or 3 to represent the withdrawal. In this case, you would set the monthly constant, a, of the period modelled to withdraw the specified amount of water for each month modelled. The Database Menu provides a table of hydrologic flows for your reference. You may use that data as a base for simulating new flow conditions. Reference to the graphs and tables of historic and synthetic flows, provided in the Database Menu, may help in scenario development.

Stream Hydrology

Choice 5 extends changes to river reaches. A short tutorial proceeds the operations and should be read the first time through. It too provides a quick method for constant changes over the planning period, and a more specific method, similar to that provided for inflow and outflow, above.

Warning Information

Choice 3 provides information about potential conflicts that may arise from flow modifications. It is important to make flow modifications at the upper-most locations in the sequence of sites. This choice helps to assure the proper location is chosen, otherwise the model will ignore the elected changes. In the Cochiti Reservoir case, if you had selected the reservoir and its tail water, you would need to identify Cochiti Reservoir as the upstream location.

Change Your Mind Again?

Go back to Option 1 and press it. This will eliminate any changes you made in volumes and outflows and reestablish the default condition. Check to see if the default conditions were recovered.

The last choice in this hydrology menu, Q, returns you to the Main Scenario Menu where biological and economic changes are made available.

Biologic Input Changes

Option 6 in the Scenario Menu allows access to biological variables and inputs. Twelve choices are available.

Riparian Conditions

Choice 1 allows certain changes in riparian input values for riparian cover fraction, ambient light and riparian organic input/m^2 of canopy cover over the stream channel. The organic matter input is based on 100 percent canopy coverage over each m^2 identified covering the channel. For example, a 60 percent canopy cover over 5 percent of the channel equals 3 percent cover over the channel, the correct value to enter for riparian cover fraction.

The entire channel may or may not be full at the time of riparian input. A loss parameter (inaccessible to the model user) determines how much of the organic matter will remain by the time dry channel floods with high water and include the riparian matter in the stream organic load.

Setting Historic Fish Population Management

When initial fish population numbers have been changed (not the case so far), Choice 2 allows you to reset them to the default reference condition. The default condition in RIOFISH is a managed state including stocking and regulations as practiced from 1982-1992. Choosing 2 now will make no difference because the default condition is in place.

When stocking and regulations have been changed (not the case so far), Choice 3 "automatically" inserts historic stocking and regulations at all sites back to 1982, the first years of detailed computer records for stocking in New Mexico. Before 1982, you must provide your own estimates. When synthetic flows are used, 1992 stocking and regulations are inserted unless you identify a different year between 1982 and 1992.

As with other reset choices, you need to be careful not to revert to default conditions by mistake when you have taken a lot of time to set up a complex management scenario with different management tactics based in historic management.

Setting Initial Fish Populations

Choice 4 allows you to alter initial fish population densities. You must make changes separately for each site. New taxa can be added or any taxa can be deleted when the initial density is made zero. You can create various communities in this manner either to reflect actual communities more accurately or to examine effects of modeled diversity and competition. The changes you make will be proportionally distributed into each age and size class according to the natural mortality coefficient described later. Each initial fish population is assumed to have had a stable natural mortality and natality history with an age distribution that decreases from young to old at the same rate as the natural mortality.

Press Choice 4 to review the species in Abiquiu Reservoir (1RGR). A table of fish and initial densities is provided. When you are asked if you want to change any of the initial fish densities answer yes. Select any species of interest to you and answer the prompt questions. Go ahead and change a species initial density to any reasonable value you wish, then proceed. Before you continue, however, reset the initial fish population by using choice 2.

Regulations

Choice 5 provides access to fishing regulations. A variety of regulatory changes may be selected. The first four selections provide relevant information starting with a brief tutorial in selection 1. Selections 2 and 3 give you species and site code numbers, which are needed to interpret and change tables generated in some of the following selections. Selection 4 refers you to a site-closure regulation that is handled in the economic component.

Selection 5 first shows a table of statewide creel limits (number of fish allowed), the time periods they existed historically, and the relevant species. You can change these values. Go ahead and make changes as you wish. Pressing F9 will advanced the screen to another table, which summarizes site-specific creel limits. They also may be changed. Go ahead and change some site regulations for the practice.

Selection 6 provides a table of statewide size-limit regulations, which also may be changed. The reference values are all zero because no statewide length limits existed in New Mexico. Change a couple of species at a site to see how it is done. A minimum size limit allows all smaller fish to be harvested while a maximum size limit allows all larger fish to be harvested. Slot limits may be simulated by entering numbers in both maximum and minimum size categories. F9 advances you to a second table with specific historic length limits. Try changing some of these too.

Selection 7 provides an opportunity to change specific site catch and release regulations. The values are zero in the reference condition because no site has been managed for catch and release in New Mexico. Pick any one of the four sites in the scenario and make it a catch and release site.

Selection 8 provides access to specific gear regulations. A series of specific gear type codes is provided for interpreting the table, which gives the gear regulation history at specific sites. Four sites in New Mexico had special gear regulations; they comprise the default condition used in RIOFISH. Make a change or two in the regulations at one of the four sites. Review your changes for this selection and previous selections to be sure they were made as you planned.

Selecting Q returns you to the general options menu for biological variables and inputs.

Stocking

Choice 6 in the menu for biological inputs allows you to see and change stocking. You are given 3 selections; number 1 is the most detailed. Select it first. Stocking is viewed or changed site by site. Once a site is identified, you may select from a variety of stocking tactics. Selection 1 provides a brief tutorial about the stocking tactics. Selection 2 shows what stocking is presently in place in the model. Selection 3 eliminates any stocking indicated for the site. Selection 4 allows you to quickly adjust stocking rate by a simple multiple of present rates. Selection 5 provides a table that allows you to make detailed changes in stocking for each species. You must provide the species code; the month, day and year of stocking; the length of stocked fish; and the numbers stocked. Species code numbers are provided. You may accept the model stocking as it stands in selection 6 or select Q to return to the RIOFISH default condition. Practice making stocking changes at one or two of the sites. Review your changes to be sure they were made as planned.

Now return to the previous menu. Selection 2 will allow you to make proportional changes in statewide stocking for the particular level of stocking that presently exists in RIOFISH. You must enter a multiplier. If you wish to avoid change, enter 1.0. Try making some changes before returning to the menu. Selection 3 allows you to copy stocking at any site to any other site, replacing the previous stocking. Before continuing with this review, reinsert historic stocking and regulations (choice 3) if you have made changes.

Lake Environment Changes

Choice 7 in the general biological options allows you to change certain lake environmental factors. When you take this choice, you are first informed of the possibilities with a brief tutorial. Special care is required to use this option. Before you take this option, run the hydrology model alone to establish the hydrologic setting for environmental changes. Then use this option to modify the hydrological setting. Then run the biology model alone, or the biology and economic models combined. Do not run the hydrology model again, since it will override the changes you have made with this option. Try this option at a later time.

For now, proceed through the choices without making modifications.

Two special environmental management selections are provided first. You may simulate the mixing of lakes or hypolimnetic aeration if you select "aeration." This selection destratifies any lakes that stratify and saturates the water column with oxygen. Oxygenation increases secondary production to various site-specific extent. You may also define the macrophyte contents of lakes and estimate the percentage that will be removed following vegetation control. In New Mexico, oxygen and vegetation management are most relevant for small lakes. You are not limited to small lakes, however.

If you wish to create a detailed historic condition for New Mexico sites, you must enter the historic mixing and macrophyte status. The model reference always assumes zero conditions despite management history because aeration and macrophyte management have had an uncertain history.

A series of lake environment tables follow, presenting the existing model conditions and change alternatives. Temperature firstly may be altered by season and year or by some annual constant. Experiment with making changes. Respond to the questions asked of you below the table. You must respond to the questions in order to advance to the next table. For this review, simply select 3 to advance through the tables without making changes.

You may elect to change concentrations of total (persulfate) phosphorus, total nitrogen (Kjeldahl nitrogen plus ammonia nitrogen) and suspended solids, each in its own table. The ambient light energy may be changed, thereby altering primary production estimation. Allochthonous carbon (organic matter imported from somewhere upstream from the site) concentrations may be varied both for perennial streams and for intermittent watershed runoff. The two sources of allochthonous organic loading were separated because they vary independently of each other and large differences exist in concentrations. You will be returned to the biological input menu after you answer the questions posed for the last table.

Custom Files

Choice 8 in the biological-input menu allows you to create "permanent" custom files for up to 3 sets of fish population parameter values, which you will view in a moment, when we describe Choice 10. Ordinarily, any changes made by the user will default to model reference conditions when you quit the model or the hardware is turned off. Creating a custom file allows you to carry over certain parametric changes. This choice is limited to a small fraction of all potential changes because of high software demands.

Resetting Input Values

Choice 12 is appropriate when you want to eliminate custom values to develop a new custom set, to reestablish model default values, or to establish new but temporary values. It will not affect any temporarily altered input values.

Except for your custom files, Choice 9 allows you to reset all temporarily changed fish parameter values included in Choice 10 back to model default values. Both Choice 9 and Choice 2 need to be pressed to recover all biologic default values. Another way to reset all hydrologic, biologic and economic parameter values, except for the custom changes (Choice 8), is to quit the software or turn off the machine.

Population Dynamics

Choice 10 enables you to view and change 14 groups of fish population parameters, starting with natural mortality. Whole new species may be created using this menu choice because a species behaves according to the user-accessible population parameters. This choice enables copious exploration of population dynamics phenomena as long as certain model limitations are recognized. The tables of input values were designed for maximum user flexibility. Model default values sometimes do not vary much, usually because available data do not indicate a need. In many cases data for each species are scarce.

Please make exploratory changes as you proceed through the parameter review. Do not worry about changing them back to the original value. Also create your own custom files at some point. Check to see if you were successful by erasing all temporarily changed parameters using Option 9 in the biological inputs menu. After checking to see if they persisted, you should erase them using option 12. Now return to option 10, the fish species parameters.

Natural Mortality of Fish Age One and Older

Selection 1 in Option 10 allows you to view or change the natural mortality of all fish age one and over in each taxon. This measure of mortality excludes fishing mortality, which shows up elsewhere. It is the equivalent of the total mortality in an unfished population that is not exposed to certain extreme conditions.

The natural mortality coefficient also determines the relative abundance of fish in each age group of an initial population, as if the population were in a stable state previous to the model run. The initial population structure also changes when you change the mortality value. The coefficient in the table is the slope of the natural log.

Because the natural mortality is constant, RIOFISH populations over age one will not respond to certain extreme conditions imposed upon them. They will not starve to death, nor will their mortality change if an extraordinary population of predators is stocked. Such extremes are rare in New Mexico and model operations were streamlined by assuming constant natural mortality of age one and older fish. Mortality of younger fish is variable and is addressed in later choice descriptions.

A second table (advanced by pressing F9) provides fish-kill refuge values. Other lethal events associated with extreme temperature and habitat loss do occur in New Mexico and are addressed in RIOFISH. These sources of mortality frequently are not 100 percent, however. We assume in the model default that a small percent of the fish population escapes kill conditions associated with temperature and drying at all sites (an assumption made primarily because of insufficient data to show otherwise).

The third table allows you to determine the fishery history for each species. If you assume there was no fishing before the scenario period, all fish species should be assigned a 0 value and their numerical distribution among age and size classes would reflect natural mortality alone. If you assume that fishing was intense enough to affect initial fish numbers, a 1 is inserted and the distribution reflects fishing mortality of catchable size fish.

The fourth table (Press F9) in the series includes maximum and minimum lethal temperatures and the minimum oxygen tolerated. Cold-water species like trout often are forced into cool hypolimnia in New Mexico lakes, but only survive if sufficient oxygen exists. Winter cold kills threadfin shad in most New Mexico waters.

RIOFISH does not directly simulate fish kill conditions that sometimes occur when low oxygen occurs in the surface waters of lakes as a consequence of eutrophication and the right climatic conditions. Neither does it simulate kills from toxic spills or other pollution. However, you may create scenarios that simulate the results of such kills, by reducing the initial number of fish down to the level you estimate would occur with such kills, and thereby estimate the angler benefits lost from such kills.

Maximum P/B--A Population Growth Coefficient

Selection 2 in choice 10 enables access to the maximum P/B ratio. The P/B is production/biomass, which is equivalent to the maximum mean growth coefficient (natural log of the population weight increment) for the population. This value represents a physiological maximum growth/ half-season interval when all environmental conditions are optimum and have been estimated from rapid growth rates reported in the literature.

A maximum P/B is provided for larval fish and juvenile fish in the first table and for older fish in the second table. In the second table, the first number is the intercept value for age 1 fish and the second number is the relationship with larger fish.

The maximum P/B is the tie between underlying ecosystem productivity and the growth of life stages in individual fish species. Within a specific feeding category (guild), fish with higher P/B ratios will garner the greater productivity for their initial biomass and grow faster than competitors. This parameter can be considered to be a resource partitioning coefficient based on results of differences in consumption and metabolism. The physiological maximum is most related to fish size. Although some differences may exist among species, we assume they are relatively small differences in the default version of RIOFISH, especially for young fish.

Sex Ratio and Sexual Maturity

Selection 3 allows you to view and change adult sex ratio and weight at maturity for each species. Sex is presumed to be equal in the default version for all species. Sex ratio contributes to determining how many eggs establish the next generation. Both sexes are assumed to grow and die similarly in RIOFISH. The second table in this selection allows you to modify the weight of fish when they first reach sexual maturity.

Egg Survival

Selection 4 is a regression relationship for egg survival as affected by water-level fluctuation (both up and down)in lakes and in streams (two separate tables are provided) during the reproductive seasons. The intercept represents the egg survival when there is no water-level fluctuation under optimum natural conditions. The second number is the slope of the kill proportion with respect to the degree of water level fluctuation. Intercept values in the default version vary mostly with respect to spawning habit, whether eggs are protected or not. RIOFISH does not account for water temperature changes or other factors that might alter variability of water-level effect (water temperature is determined by mean air temperature, which is constant within each two-week period of each year).

Larval Growth Rate

Selection 5 includes growth rates needed by larvae in each species to survive the larval period. Larvae must attain the weight associated with a 20-mm length within a half-season, otherwise they are assumed to die from starvation or other natural causes connected with slow growth. RIOFISH does not contain explicit predator-prey components because of the complexity required. With the RIOFISH approach, fast growing larvae are assumed to be less likely to be eaten and food availability is assumed to be limiting. The number provided here is the multiple of the "birth" weight to reach the 20-mm weight.

Juvenile Winter Mortality

Selection 6 includes the minimum over-winter survival weight needed to enter the age one category. Any individuals not attaining the minimum weight are deleted (die). Juvenile fish otherwise have a natural mortality like older fish.

Minimum Catchable Size

Selection 7 estimates the common entry size into the fishery, including fish likely to be returned because they are too small. It is not intended to be the smallest size ever caught fishing. Catch rates estimated by RIOFISH are sensitive to this value and mortality may be affected by hooking (described later). Fish not normally caught are given impossibly high default values.

Birth Season, Birth Weight and Fecundity

Selection 8, in the first table, provides information on the proportions of fish born in each season in lakes. A second table (press F9) provides seasonal information for streams. This information determines the total food available and temperatures that affect larval growth as described later.

A third table (Press F9) provides information on the larval "birth weight" following yolk absorption. This is the weight measure that is divided into the weight at the 20-mm length to define the larval growth rate to juvenile size in selection 5.

The fourth table provides the fecundity as eggs/kg/female. This determines the egg number before any egg mortality occurs and it is affected by any factor that determines the size of females, including length-weight relationship and length at maturity.

Initial Fish Sizes

Selection 9 shows the lengths by age class used for initial fish populations of each species. These may be changed to create different initial population structures in combination with choice 4, which allows you to change initial fish numbers in existing or newly introduced species.

Length-weight Relationship

Selection 10 provides the length-weight relationship for each species. The first number is the intercept and the second number is the slope of the relationship.

Production Partitioning

Selection 11 provides access to coefficients that reduce the maximum P/B of each age class in each species according to tolerances to various environmental factors. They are provided for different tolerances to illumination, temperature, oxygen, velocity, depth, and particle size within the context of the model. The values shown in these tables are first and second points at 5 and 95 percent of the way across a logistic relationship, depending on age-class and species tolerances. Values of -11 and -10 indicate that factor has no limiting effect on that species or life stage.

Selections 3 and 4 may be most obvious, so pick selection 3 first. This table shows coefficient values for the rising legs of temperature tolerance curves. The left-hand value indicates the low 5 percent value end of the curve and the right-hand value is the high 95 percent end of the curve. When water temperature is below the lowest value in the curve, the maximum P/B is reduced to zero and fish growth is reduced to zero, as it is in winter for warm water species at most New Mexico sites. At the 95 percent value, the P/B is reduced by 5 percent and above that point is an optimum.

The descending curve, in selection 4, starts with the 95 percent value on the left and the 5 percent value on the right. The temperatures between the ascending 5 percent value and the descending 95 percent value are close to or at optimum with little decrease in the maximum P/B.

A table is provided for each life stage. Although the RIOFISH default inputs usually do not discriminate much, lots of flexibility is left to the user to make changes. Some values may not seem intuitively clear. Larval fish, for example, are not believed to be limited by depth or velocity because enough shallow depth and slow velocities occur even in fast streams to provide refuge. RIOFISH hydrology structure is too coarse to pick up small fractions of the environment crucial to larval fish performance. Older fish, on the other hand, need some depth and are sensitive to different velocities.

Mean values are assumed to relate closely to extreme values. For example, a mean depth of 0.2 m will typically be up to 0.5 m deep in 10 percent of a stream. User modification should take these assumptions into consideration. By reducing the maximum P/B, these coefficients reduce the efficiency with which food resources are converted to fish production, individual growth, and biomass. Intolerant species gain less of the production available in a food category than tolerant species, at least during that specific half-monthly period. Over the year, a cool water species and a warm-water species may partition equal food production, depending on how temperature changes over the annual cycle.

Extreme environments not only reduce the efficiency of individual species, but also reduce the efficiency of the total fish community in using food resources. The available food production is not all available for fish production under any circumstances. Even when fish biomass is high and the P/B is at maximum under optimum conditions, a maximum of 40 percent of the food production is converted into fish production. This 40 percent is what is left after assimilation inefficiency and respiration cost take 60 percent of the consumed food production.

Low fish biomass can limit the use of food production even when conditions are optimum and the P/B is at maximum. Rapidly growing fish populations occur in RIOFISH under these conditions.

Setting maximum P/B to zero does not necessarily kill the fish. Although larval fish will be killed and juvenile fish may be killed, because both life stages must grow to survive, older fish are assumed to persist without growth indefinitely through starvation periods. RIOFISH does not starve fish over age one; natural mortality is assumed to be constant (selection 1) unless intolerable dry, hot or cold conditions occur.

Catchability Coefficients

Selection 12 first provides a table of catchability coefficients for different species and terminal gear types. The catchability of fish varies among species and among types of gear. Certain fish that are relatively easy to catch on baits are much less likely to be caught on an artificial fly, for example.

Catchability coefficients link fish density to angler success. They contribute to determining the catch and harvest composition given a certain fish composition in the habitat.

New Mexico presently has no game fishing based on gears other than angling, and RIOFISH does not allow any form of fishing other than angling. Because netting, for example, is not included, net fishing for species like smelt cannot be analyzed.

Fish Retention

The second table in Selection 12 includes an estimate of fish harvest likelihood for each species when no harvest regulations exist. Certain species are more likely to be retained (harvested instead of returned) than others because they are more suitable food or more suitable trophies, regardless of size differences.

The fish retention factor influences the fishing mortality effect. Highly desirable species suffer higher fishing mortality when their catchability is equal to that of less desirable species. Even the least desirable species may suffer some fishing mortality from hooking mortality, however.

Hooking Mortality

The third table in Selection 12 provides the model default values for hooking mortality using different terminal gear. These values contribute to the total mortality and have greatest impact where catchability is high and retention is low. The default version does not discriminate much among species, but you are allowed the flexibility of unique changes among species.

Fraction of Gears Used

Selection 12 summarizes the fraction of anglers fishing with each gear type at each site. Changes in gear fractional use affect both fish catchability and hooking mortality.

Diet

Selection 14 provides the relative fraction of foods in the diets of each age category of each fish. One table each for lakes and streams represent the two habitat conditions.

The relative fractions of food found in fish stomachs guided development of the default version. These are average and fixed fractional values. No model provision is made for changing the fractions consumed based on relative availability or size of food. A feeding guild (group with similar ecological behavior) may cross both species and age divisions. All fish categories assigned to a feeding guild (e.g., zooplantivore) compete for food. When food production is low for the biomass present, growth and young fish survival also may be low. Older gizzard shad and Kokanee Salmon, for example, may compete with larval fish of all species for zooplanktonic foods.

Other Biological Constants

A number of parameters pertaining to basic trophic-level process and resource partitioning are user accessible. Option 11 provides 6 selections in addition to return to other menus. Selection 1 allows you to alter the ratio of total nitrogen and total phosphorus that determines which of the two variables limits primary production. The second table is the exponent value used to define the relationship between primary production and limiting nutrient concentration. Table 3 contains the intercept and slope for temperature regulation of primary production. Table 4 provides the intercept and slope for suspended sediment influence on primary production. The next table provides intercept and slope for the relationship between days required to flush a lake and primary production.

Selection 2 controls availability of allochthonous organic matter. The first table allows you to change the rate of organic carbon loss from dry stream-bed storage. Table 2 allows you to modify the degree days required for organic matter entering lakes to become consumable following microbial conditioning. The third table provides intercept and slopes for the relationships between allochthonous organic carbon loading and herbivore consumption rate of allochthonous organic matter.

Selection 3 treats trophic-level efficiency. Table 1 allows you to change the oxygen concentration thought to exclude all consumption when oxygen falls below that value. The second table includes 3 parameters defining the relationship between temperature and herbivorous trophic-level efficiency. The third table contains the coefficient for the effect of organic load rate on herbivore efficiency.

Selection 4 provides access to parameters that affect partition of food resources among ecological groups (guilds). Table 1 relates the fraction of food going to all suspension feeders and to all bottom feeders as a function of mean water depth. Table 2 relates the fraction of invertebrate and vertebrate suspension feeders to organic concentration (organic load/volume). The constant fraction of deposited organic matter going into crayfish and vertebrate production is available for user modification in Table 3.

Selection 5 contains the maximum possible carnivore trophic-level efficiency. Selection 6 provides access to production-biomass ratio used for simulating phytoplankton biomass exported from lake production to tailwaters.

Reset and Return to Main Scenario Menu

That completes one of the most detailed parts of RIOFISH. Q returns you to the main biological inputs menu. But before you leave the biology menu, make certain that you have the historic scenario set up. The easiest way to do that is to press choice 9 to return fish and biological parameters to default values. Then go back to Choices 2 and 3 to reset all stocking, regulations and initial fish populations to the default values. Check to see if values actually had returned to default conditions. This exercise shows how easy it is to eradicate time-consuming changes.

To return to the Main scenario menu you must press Q again.

Setting Angler Days

Option 8 in the Main Scenario Menu allows you to assume control of the number of angler days fished by diverting control from the economics component of RIOFISH. A short tutorial proceeds your selection of a table for existing angler days.

The model reference values in the table typically are zero. When zero, no fishing is assumed to exist until you designate alternative values. A model user can experiment with effort and harvest interactions using this option. However, when you use this option you will be precluded from making any changes in the fishery system via the economics component, which follows.

Economic Inputs

Angler Day Control

Option 9 in the scenario set-up menu allows changes in economic inputs and other values. Before the economics component can be used, however, you must turn back control of angler days to the economic component (a reminder is provided when you forget). Option 9 provides six choices including Q, which returns you to the main scenario set-up menu.

Resetting Economic Inputs

The first economics choice resets all previously changed economic values to the main scenario menu. This eliminates all changes you have made in the economics component. As with other reset choices, be sure you want to do this before pressing the button. Complex scenarios will disappear with one stroke.

Site Characteristics Changes

By site, you may change fish number/day caught and harvested and average weight/individual of harvested fish. Choice 2 allows you to change site characteristics that determine site attractiveness to anglers and their willingness to pay for fishing. When the biology and hydrology components are not run you may change the fish harvest and return values and site surface area here. Otherwise, the biology and hydrology components determine these input values.

You may change the seasonal surface area, macrophyte fraction of the water volume (from 0 to maximum of 10), water clarity (muddiness) from 0 to 10, the number of concrete boat ramps, the percentage of shoreline easily accessed from a vehicle, whether or not a site is open to fishing, and the availability of drinking water, campsites and modern toilets. The last selection, Q, returns the user to the economic input menu.

As you proceed through each of the selections, answer the prompt questions and make some of your own changes to see how each is done. Don't worry about replacing original values. You can do that later with the economic input reset choice (choice 1). When site quality values change, site attractiveness is altered, changing angler days of effort and the economic benefits. When linked to the biology component, changes in angler days change fishing mortality and fishery status. When run independently, anglers do not effect fish numbers.

Human Population Changes

The first selection provided with Choice 3 enables you to change or reset the entire state population with the assumption that change will remain proportional in all counties. For more detail, you may forecast different rates of change in each county. The fraction of the total population who fishes also may be changed. With these choices, you can analyze the consequences of different rates of demographic change on fishing rate, fishing impact and angler benefit generated by various changes in management inputs.

The benefits and biological impacts of fishing are influenced by demographic characteristics, which you can alter via selection 2 (zone Demographics variable). The fractional composition of 9 different demographic measures can be changed by the user. Now return to the economic input menu by selecting Q.

When you make forecasts, don't forget that management revenues also are a function of fishing population size when you estimate revenues available for management practices and the benefit-costs. However, you should consider other limitations. Hatchery capacity, for example, may not be very expandable at any price in New Mexico. Private hatchery purchase may be much more expensive and also have limits.

Travel Costs

Choice 4 in the full economics menu allows you to change any site fees charged, such as state park fees. Values for average car mileage, price/gallon of gas, and other travel costs may be accepted, altered or reset to reference values. The travel costs contribute to determining extent of angler use and the benefits derived from that use.

Angler travel costs are equivalent to the variable cost paid by anglers to fish (in contrast to more or less fixed costs for fishing equipment, license and so on). The variable cost helps anglers decide where they will fish among a reasonably similar set of substitute sites. Management that reduces angler travel costs by managing closer substitute sites more intensively for better fishing quality are likely to benefit anglers more than providing the same quality and sites that are more costly to fish.

Lastly in this choice, you can review the average per capital income in each of the zones of origin for each year modeled. Income is one of the variables determining angler willingness to pay the cost to fish.

Benefits and Costs

Choice 5 provides a brief tutorial explaining how to determine the value of a site by way of its closure. As with other evaluations made with the model, valuing site closure requires two runs, which are the same except for the site being open and closed. Full model runs are more likely to give a better estimate of value than running the economics model alone because a full run includes the impacts of anglers on the fishery.

Choice 6 provides the planner concerned about benefit-cost analysis the opportunity to change cost estimates for all management activities. Because cost estimates are only approximate and highly variable, we advocate that the default version be used only for preliminary analysis. Cost estimates pertain to the calculation of benefit-cost ratios, which are provided among economic outputs once a run is completed.

After you complete this part of the review return to the Main Scenario Menu by pressing Q.

Completing a Set-up for Historic Scenario

Now prepare your scenario for a model run. First check to be sure that you have Abiquiu, Cochiti, and Roberts lakes and the Pecos River 1 North for the historic period 1988-1990. Insert historic stocking, regulations and initial fish populations if you have not already done so. You are now ready to run a scenario based on a reference run defined by the conditions entered into RIOFISH. Option 10 in the Main Scenario Menu directs you to the Model.run Menu, which drives model calculations of output results.

MODEL.RUN MENU

The Model.run Menu provides nine choices, starting with a tutorial. RIOFISH can be run in all but one possible combination of the three main components (hydrology, biology, economics); there is no hydrology-economics choice. Whenever one or two components are excluded, built-in reference files are used in place of component outputs for required component inputs. For example, the biology model has the historic hydrology embedded within it, where it is inaccessible to the model user. The only way for you to alter input values (e.g., water discharge) is through running of the component that includes those input values.

Generally, model use for comprehensive planning purposes will involve all three components (option 2 in the menu) because you will have to alter input values in all three components. Option 3 is of use when you wish to set your own angler effort, are not interested in the economic outputs associated with management, but are interested in various water management scenarios. Option 4 is of interest when hydrologic variation is of no interest. Options 5-7 are used only for component specific input and output scenarios.

The biology component is the most time consuming to run and little time is saved by deleting hydrology or economics for scenarios involving biology. For most scenarios, Option 2 is recommended unless quite specific needs dictate otherwise.

Options 8 and 9 allow you to proceed to other menus. Ordinarily you will run the model via Option 2 before you proceed to the results menu via Option 9. A single site run for one year will require less than a minute to run. A complete run of 132 sites for all ten years will typically require about 9 hours (based on the speed of 486/66 hardware). Overnight runs are recommended for statewide analysis.

Before you proceed, be sure all values are model default values, if your results are to compare to ours. If you wish to be sure, you need to return to the Main Scenario Menu. Select Option 3 in the Main Scenario Menu. This will reset all temporary parameter values back to the default values while it maintains the site locations and years selected (three synthetic years). You can check the sites and years if you wish by returning to the Initial Scenario Menu, picking the second option, and reviewing, without changing, the sites (Heron, Cochiti, Van and Cimarron) and years (three synthetic years). Also select the biological inputs option (Option 7) and from that menu, press Option 11, which eradicates any custom files you may have created.

Now proceed to Option 9 in the Main Scenario Menu, which will route you back to the Model.run Menu. Choose Option 2, running all three components in tandem. The run will take a few minutes to complete.

RESULTS MENU

Multisite Overview

The results menu provides both general and specialized output options. After you read the tutorial in Option 1, enter Option 2. It provides a multisite summary output statement for comprehensive management purposes. As with all other outputs, you have the choice of printing immediately, printing at a later time, or simply viewing the results. You are given the choice of printing an abbreviated output or a full output. The abbreviated output includes measures most commonly of interest to fishery managers. For this review, please print the full output whenever the choice is offered. Print the results now. You will use them to compare with a management scenario later. Printing will take a few minutes.

Multisite summaries allow program-area or other multisite comparisons to be made more easily because site mean or total values are calculated for you. River sites and lake sites are separated in multisite summaries because some characteristics of the two habitat types cannot be summed or averaged over the two habitat types. Mean or sums over several to ten years often are more usefully compared than individual years.

Total values are provided for statewide economic benefit, water volume, water surface area, total angler hours fished per year, total catch per year, and total harvest per year. A program-area manager for large, cold lakes, for example, can quickly retrieve the total benefit, lake surface area, and fish catch and harvest over a decade for analysis of fingerling stocking effectiveness.

For many parameters, mean values are more meaningful than totals. Surface area was chosen to weight the mean because density, production, catch and harvest are expressed in areal units, and large habitats have proportionally greater effect than smaller habitats on the statewide total production, catch and harvest. Surface-area weighted mean values are provided for site elevation; annual lake storage ratio; spring season storage ratio; lake or stream mean depth; stream mean width; secchi depth; lake loads of nitrogen, phosphorus and suspended solids; stream concentrations of nitrogen, phosphorus, and suspended solids; percentage of the bottom depleted of oxygen; percentage littoral zone; primary production; allochthonous organic loading; total available organic load; zooplankton production; zoobenthos production; herbivorous fish production; and the mid-summer weight, number, production, mean individual weight, and proportional stock density of catchable fish in several categories.

Weighted averages based on angler days of activity are provided for catch/hour and harvest/hour, expressed either as number or weight. Angler activity was used to weight the average because there are site differences and site use is not always closely correlated with surface area.

If you have not retrieved your printout, do so now and follow it as you proceed through the next few sections.

Multisite Economic Benefit

Statewide economic benefit is the lead parameter in the multisite output. The benefit value in the output is a relative economic value without clear meaning until it is compared to another scenario result. Once the difference between two scenarios is determined, you have an estimate of the benefit associated with any scenario change in managed or natural events. Differences may be either negative (lost benefit) or positive (gained benefit). Model users typically are interested in the total benefit derived over the entire model period. For example, stocking fingerlings in the first year of a scenario sequence will typically generate benefits for several years thereafter.

Multisite Habitat Characteristics

Certain habitat characteristics are summarized, both for quick reference to background conditions and for analysis of habitat management effects. Elevation is the mean water surface elevation, which will vary from year to year and with changes in water distribution. Mean volume is the reservoir content at the mean elevation. Mean surface area is mean water surface (hectares) at the mean elevation. These values will change when certain hydrologic changes are made; the differences between scenarios will reflect the degree of change.

Storage ratio is the inverse of exchange rate, the mean volume divided by the discharge volume. High values represent high water retention and low flushing rates. Spring season values are especially meaningful because most fish species spawn during spring and require planktonic resources vulnerable to flushing. The mean lake depth is equivalent to volume divided by surface area. Secchi depth is estimated to be 0.25 (depth of 1 percent surface illumination). Minimum and maximum temperature are two-week mean values that are less extreme than maximum and minimum daily values.

The plant nutrient and sediment loads provide an estimate of annual areal inputs to lakes of ecologically important materials. Because areal input is less meaningful in streams, average plant nutrient and suspended solids concentrations are provided for streams.

The percentage of bottom area with less than 2 mg/liter of oxygen in late summer (August) provides an index to site eutrophication and oxygen demand. This represents the areal extent that precludes use by fish populations when stratification occurs in lakes or when oxygen depleted waters are carried downstream in certain reservoir tailwaters.

The average percentage of lake or stream bottom in littoral zone is based on the depth to which one percent of surface light is transmitted. It provides information about the average extent of illumination. Spatial variation is likely to be much less in small habitats than in large habitats. Considerable temporal variation occurs as well.

Multisite Ecosystem Support for Fisheries

The primary production is that portion of the total organic loading produced by photosynthesis. This is determined by solar radiation, water-level fluctuation, nutrient concentration, temperature, lake storage ratio or stream-bottom particle size.

Organic inputs from watershed sources comprise the allochthonous load. Both forms of organic load provide food for zooplankton, zoobenthos, and herbivorous fish (like carp and shad). Allochthonous loads require conditioning by bacteria; available organic load typically is less than the actual load as a consequence.

Zooplankton, zoobenthos, and herbivorous fish production is the total annual population growth, including growth of individuals before they died. For streams, zooplankton production always is zero. Reservoir tailwaters, however, receive loadings of zooplankton from upstream reservoirs, often in substantial quantities.

Multisite Angler Catchable Fish

By catchable is meant all sizes of fish above those sizes usually caught with sport-fishing gear. The minimum catchable sizes assigned to each species can be seen in the population parameters selection (The Biological Inputs of the Main Scenario Menu) and can be changed by you, if you wish, in subsequent scenarios. Fish that are not considered sport catchable are not included, such as gizzard shad and cyprinids. Categories include panfish, sport fish, game fish (panfish plus sport fish), other catchable fish (carp and suckers), and total catchable fish. The categories are somewhat arbitrary and based on angler general perceptions. Gamefish include those species that typically have regulated harvests (small sunfishes are included even though they are not regulated in New Mexico).

Panfish include sunfishes, crappie, bullheads, and yellow perch. Sport fish include all black basses, walleye, pike, whitebass, striped bass, channel catfish (including other large catfishes) and salmonids. The sum of the two is total game fish.

The numbers, weights and production of all fish greater than the catchable length are reported for each category. Catch (includes kept and returned) and harvest (kept only) rates are expressed for both number and weight. The PSD and the mean fish weight are measures of fish size. The PSD is the percentage of stock size fish numbers made up of quality size fish.

Multisite Angler Effort and Success

Total annual angler hours and total annual catch and harvest, in numbers and weight, are summarized at the end of the output table. These provide information on total estimated use, success and possible impact on the fishery.

Individual Site Outputs

Option 3 provides information like that on the multi-site output, but individually for each site, except for Statewide Angler Benefit. The individual contributions of each site to economic benefit are not estimable except when a single site is run. This information is available when individual parameter values are of interest, but remember that site interactions help determine the benefits of management and single site measures of benefit are only as good as the assumption that all other site conditions for substitute sites remain constant. Take the time to view the outputs and print them out for future reference.

Scenario Fishery Parameters

Option 4 provides information about the regulations, stocking and fish population parameters that were used in the model run. This output should confirm changes you made before the run was executed and provide background information for interpreting your outputs. View the outputs. It is not necessary to print the outputs.

Detailed Hydrologic Outputs

Option 5 provides detailed hydrology outputs for each of the sites run, including graphic outputs for lake inflows, outflows, volumes, surface areas , elevations, water residence time, and concentrations of nutrients and suspended solids. This information is especially helpful when you wish to view the temporal variation that occurs. It does not generate multi-site mean or total values. View the outputs. You may print them if you wish, but we will not refer back to them in the scenario contrast.

Detailed Biologic Outputs

Option 6 yields numerous tables describing fish populations in detail for instructional purposes, not for comprehensive planning purposes. In each case you must select the specific information needed, followed by the site and the species category. Information is provided for fish density and yield by size class; total fishing effort; and biomass, density, average length, mortality, and production by age class. Also the numbers, weight and harvest/day are provided in tables that list all taxa.

These tables are of greatest value for self-instruction and special research purposes. Given the model inputs, these outputs can improve your understanding of factors controlling fish population dynamics and the relation of those controls to habitat and management within the model limits. The outputs presented here are not intended to be used for comprehensive planning purposes. Average estimates of catchable fish numbers, biomass and production over several years and sites are more appropriate for planning purposes (see Option 2).

At least view each of the outputs. At the beginning of certain tables, a column labeled 0 proceeds the annual values. This initial value is calculated for late summer of the year proceeding the run. You may wish to print certain ones for later comparison.

In Option 7, the first selection allows a detailed review of seasonal production in fish feeding categories. This information is primarily of diagnostic value to track seasonal changes, which are caused mostly by temperature effects.

Selections 2 to 4 in Option 7 provide detailed information about lake organic loads at two-week intervals. These outputs are of diagnostic value to evaluate specific patterns of input.

Selection 3 combines primary production and conditioned organic matter to reveal the pattern of organic food available to herbivore-detritivores at two-week intervals.

Selection 4 shows the amounts of organic carbon stored rather than consumed at 2-week intervals. Stream parameters are summarized for 2-week intervals of primary production, allochthonous riparian input, any zooplankton input for an upstream lake, secondary production and storage of organic input in a dry channel is summarized. This output may be used as diagnostic information to verify basic stream model operation.

Detailed Socioeconomic Outputs

Option 8 provides detailed socioeconomic results, including angler days, income and benefits to anglers for New Mexico's different zones (selection 1). Also included here is information about income and employment. Once again these outputs have little meaning in themselves. The difference is found between scenario runs that provide useful information about state income and job gains and losses as a management consequence. Site-specific value and marginal benefits information also is provided. Selection 3 provides detailed information about the per capita number of fish trips from each zone.

Selection 4 provides a marginal benefit table summarizing the benefit associated with various management and natural events. This table is critically important for establishing planning priorities. For each scenario run, new benefits are estimated. When developing a long-term management strategy, those tactics with the greatest benefit:cost are applied first, then subsequent tactics are added in order of their benefit:cost ratios. Lists of site quality variables and their numeric codes are provided in selections 6 and 7. Model users should estimate tactical costs to complete priority ranking and replace the default values whenever better cost data is available. Only an approximate benefit-cost estimate can be made with the default data.

Continuation Run

RIOFISH allows you to save results at the end of a run and insert them as the initial values in a subsequent run. This allows you to make runs of any length you wish beyond the ten years maximum included in any single run.

PREPARING FOR THE NEXT SCENARIO

Options 10 and 11 route you back to the scenario set-up menu and the model.run menu. If you were running the hydrology component in advance of the biology-economics, as you would to introduce certain environmental changes into RIOFISH, this option allows you a direct route back to running the model again. In the next section you will be shown how to create a scenario to compare with the one just completed.

SECTION IV: COMPARING SCENARIOS AND MAKING INFERENCES

THE BASICS

Background

In this comparison, say someone has proposed that Cochiti Reservoir, because it is so close to many state anglers, should be managed more intensively to benefit state anglers more than previously. In this run, you will use two different tactics. Our intent with this example is to illustrate the basic approach used in RIOFISH scenario comparisons and to show a common management tenet based on limited resources.

Most changes in management must make due with the same total management resources available in the past. There is, for example, only a set volume of water available during a particular year, and that water is distributed for a number of purposes, possibly including recreational fishing. Similarly, hatchery production limits, generally restrict the total number of catchable-size rainbow trout that may be stocked in New Mexico.

Resource limitation often requires that resources be redistributed among sites, rather than the total resource increased. In this scenario we will presume the management resources are constant statewide and redistribution of management resource is our only management option. If someone proposes to store an extra 50,000 acre-feet (61.5 million m^3)of water in Cochiti Reservoir, the water must be moved from some other storage site, such as Abiquiu Reservoir. If the winter trout fishery is to be expanded by 10,000 catchable-size rainbow trout, then those fish must be redistributed from other sites such as Lake Roberts and Pecos River 1 North. Because any redistribution of water or fish may be "robbing Peter to pay Paul", we want to be certain that the new management scenario has a higher statewide benefit:cost than the existing management.

Setting Up Comparison Scenarios

When you select Option 2 in the Initial Scenario Menu and are asked if you wish to change sites or times, the answer should be N. You need to keep all background conditions similar to properly judge the management effect of interest to you, in this case, the redistribution of water and stocked fish. You will be routed to the Main Scenario Menu once N is entered.

Your first management change is to move water stored in Abiquiu Reservoir to storage in Cochiti Lake. One way to do this is to increase the release of water from Abiquiu through the main outlet. Plan each tactic before doing anything with the model. You will move storage of the equivalent of 61,500,000 m^3. This will be done in the fall of the year, specifically October of each year, to sustain higher water levels during winter months. The flow will enter Cochiti Reservoir through the main river flow. You first need to know what the existing flows are during October because you will add the additional flow to the existing flow. Go to the Database menu and examine the tables of data provided. Find the average flow for October in each year by summing the half-monthly values and dividing by two.

Now return to the Main Scenario Menu without changing existing scenario. Elect Option 5 in the Main Scenario Menu (see/reset hydrology). In Option 5, elect the 4th choice, which routes you to outflow changes (see RGR, river system 1). The inflows and outflows are expressed in cubic feet/second (CFS) because USGS data are in the English system. Convert 61,500,000 m^3 to CFS by multiplying by 35.2 and dividing by the number of seconds in October. The result is about 808 CFS. This is the flow needed to transfer water between the two reservoirs. The 808 cfs needs to be added to the main outflow (Chama 3 South) constant for Abiquiu Reservoir and the main inflow constant to Cochiti Reservoir (Rio Grande North at Otowi), estimated for each October of the scenario water years 1987, 1988 and 1989. Do not use the quick method which is for constant changes over the whole time period). Instead, advance through the inflow and outflow records until you get to the appropriate one.

Do Abiquiu first. The mean existing outflow amounts can be determined from the tabularized data for main outflow provided in the database menu (choice 5). They are for October 1988, 102.8; for October 1989, 91.3; and for October 1990, 159.3 cfs. When 808 is added to each, the new flow constants become 910, 899, and 967 cfs for October 1988, 1989, and 1990. The multipliers for the same months and years also must be changed from 1.0 to 0. Check to be sure that multipliers equal 0 and constants are as indicated above for the respective October outflows. To complete the scenario, water must be added to Cochiti Reservoir via the main inflow. We will assume that there is a 100 percent transfer of water and add 808 cfs to the historic flow in October of 1988 through 1990. The new inflow constants become 1330, 1117 and 1548 cfs and be sure to change the multipliers to 0 just as you did for the Abiquiu outflow.

Now you will redistribute stocked fish. Elect Option 6 (change biological inputs) in the Main Scenario Menu. From that select Choice 6 for stocking. You need selection 1 to change stocking details. From selection 1, choose Cochiti Lake, which is in river system 1 (RGR). Then select number 5 (make detailed change) from the stocking menu to make detailed stocking changes. A table will appear. You will add 10,000 catchable size rainbow trout 230 mm long to the lake. Do so on October 15 of each year for 1989-91. The stocking directions in RIOFISH will tell you how to expand table size (go to the bottom with your cursor and enter Alt-F3). Add the three stockings at the bottom of the table. Enter the data code numbers: fish 8, month 10, day 15, years 1989,1990,1991, length 230 and number 10,000. Press F9 to enter the new inputs. Check your results by selecting number 2 in the stocking menu. Finally enter number 6 in the stocking menu to affirm your changes and return to the biological inputs menu.

Next you need to eliminate fish stocking at the Pecos River North 1 and Lake Roberts so that the total adds to 10,000. This is equivalent to redistributing fish of roughly the same size to Cochiti Reservoir. First Select river system 2 (PEC) and selection 5 from the stocking menu (detailed changes). A long stocking table will appear. Get out your calculator and reduce stocking by a total of 3000 catchable rainbow trout during the fall months of each year, 1989, 1990, and 1991. Remove fish only between 220 and 280mm. The amounts you remove from specific dates may slightly differ from what we removed but the effect on the results shown in Table 1 should be small. Proportional reduction is least disruptive but whole stockings may be diverted. Once the new data are entered and checked, go to river basin 3(OTH) to reduce stocking in Lake Roberts. Take 7000 from fall plantings similar to the Pecos reduction above. Enter and check the new data.

Now recheck you management strategy. First you plan to redistribute 50,000 acre-feet (61,500,000m^3) from Abiquiu storage to Cochiti storage by moving water in October for each year. Then you plan to divert 3,000 catchable stocked trout (220-240mm) from Pecos River North 1 and 7,000 from Lake Roberts to stock 10,000 in Cochiti Reservoir in the fall of each year. All background conditions in the second scenario run (management alternative run) should otherwise remain the same as in the first scenario run (management reference run).

Proceed to Option 9 once you have checked the scenarios. From the Model.run Menu, elect Option 2, which runs all three components in tandem just as you did in the first scenario run.

Interpreting Results

When the run is complete. Elect first to examine the multi-site output (Option 2). Print the results for easy comparison with the previous scenario. You should be able to lay the two printouts next to each other for easy comparison across categories. Now, using a hand calculator, find the differences between the total and mean values for each of the output values. Compare your results to those in Table 1. Your results may vary slightly from those in Table 1, depending on exactly how you transferred trout.

First note results at the beginning and end of the table. Statewide angler benefits were higher in the second run than in the reference run, implying that angler satisfaction would be enhanced by this strategy. This strategy might be acceptable if the costs are less than the benefits and no other strategy has higher benefit:cost.

As expected with a satisfactory strategy, total angler days and total annual harvest increased. Note that the decrease in fishing activity and success at Pecos River 1 North was more than compensated by positive change at the lake sites. A request for individual site outputs would reveal changes at each of the lakes.

Table 1. Change in multisite output values estimated by difference between the reference scenario (Scenario 1) and the alternative management scenario (Scenario 2). The model was run from 1989-1991 for Abiquiu, Cochiti, and Lake Roberts reservoirs and for the upper Pecos River as described in the text.

Output Category	Lake Sites	Stream Site	All Sites
Mean annual statewide benefits ($) catchable fish			74,000
Catchable all fish (means)			
weight (kg/ha)	0.9	-0.9	
number (# /ha)	18.1	-11.7	
production (kg/ha/yr)	3.1	0.3	
individual weight (kg)	0.0	0.0	
catch/ hour (#)	0.1	-0.0	
harvest/hour (#)	0.0	-0.0	
Annual hours fished	1,189	-349	840
Annual fish harvest (#)	15,390	-1,178	14,212
Annual fish harvest (wt)	5,703	-132	5,571

Based on results in Table 1, fish population number, weight and production changed little at the stream and increased at the lakes. Mean fish size, catch rate, and harvest rate changed little. In general the fishery changed little, indicating it would be sustained. However, a longer run is needed to confirm long-term effects.

Do the results shown in Table 1 indicate that management changes should be made? Perhaps, but other issues need consideration. Management costs may be high with respect to benefit derived. Also important, the results may change dramatically if other natural and management events are considered at other substitute sites in the fishery system.

PROGRAM-AREA PLANNING SCENARIOS

Now that you have made two runs and compared scenarios, we will describe a more complex analysis, which you may try as well. This analysis is more comprehensive; designed to anticipate and account for what happens within a larger fishery system that supports the cold-water program area.

In this analysis we make some assumptions that are based on the protocol described on page 19 in the section on comprehensive planning. First, we estimated the relative benefit:cost values associated with a reference state (we ran the economic component alone with the reference state in place), for which we assumed that management conditions existed at the end of the last decade. This condition is the basis for the economic component when it is run alone. Cost estimates were based on past cost assessments and information about specific site circumstances. The benefits estimate was obtained from the marginal benefits table produced following the run. We also output the multisite estimate of statewide economic benefit for future comparison. This step, because it involves estimating costs for tactics at each site, is the most time consuming for the serious planner-manager.

Second, we assumed no keystone decisions were likely, such as opening or closing a large site. A possible keystone decision not to lease Eagle Nest Lake, was considered and rejected--Eagle Nest was included in the analysis as an open site.

Third, we assumed that $160,000/year was available to expand ramps and facilities at each site and that the same number of stocked fish would remain available as was stocked in 1990. We also assumed all other operations allocated to the cold-water program area would remain available in the future, such as the law enforcement time spent at the sites, leasing costs, and so on.

Fourth, we began to evaluate the most cost-effective tactical operation. Based on the reference run marginal benefits, a new ramp at Navajo Reservoir and a new Toilet at El Vado Lake were installed. These two expansionary activities used our budget.

The fifth activity was skipped; we did not compare to other program area results, assuming that the budget allocation was appropriate.

Sixth, we proceeded to the next scenario run, determining that a second boat ramp at Navajo Reservoir and a toilet at Eagle Nest Lake were the most cost-effective decisions. A third year was run with a third ramp indicated at Navajo Reservoir and a second toilet at El Vado Lake. We stopped with the third year. More serious planners would continue for several more years. Over the three years, the added benefits were estimated to be nearly $900,000 annually. Over the 15-year life expectancy of each facility, the expected benefit cost was about 80:1, the most cost-effective strategy we could find.

Seventh, we examined the effect of the new tactics on angler distribution. This information is output for each site via the economic component. As expected, the tactics caused anglers to redistribute among sites, with most growth in use at Navajo Reservoir, accompanied by decreased activity at most other sites. This led us to believe that rates of fish stocking should be redistributed. Using the changes in angler days, we set up reference run with all three model components fully integrated. The reference used the synthetic flow scenario over three years. We inserted historic stocking as it was in 1990 and assumed facilities were as they were in 1990, like the reference run with the economics model alone. Then we ran a second scenario, with the new facilities in place as indicated by the economic analysis of facilities expansion. Multisite analysis indicated an even larger benefit than estimated by the economic component alone and suggested small decreases in fishing success, suggesting benefits from redistributing stocking. Based on the changes in angler days at the sites, we multiplied fish stocking at Navajo by 1.5, at Heron by 0.8, at Eagle Nest by 0.8 and at El Vado by 0.88. By reviewing the stocking rates in the model in 1990, this action resulted in a redistribution of the total stocked among sites without much change in the size composition. Therefore the stocking costs were held constant as in 1990.

The redistribution of stocked fish added another $250,000/year to the statewide benefit, indicating that redistribution was appropriate. This was as far as we carried the analysis. We suggest you try a similar analysis, following the pattern described above, once you are familiar with RIOFISH operations. This latter example is more typical of the comprehensive planning that RIOFISH was developed to facilitate.

Serious model users would continue to refine the estimates to generate the greatest benefit possible for the costs. This would include examining the effects of regulations, possibly enabling less reliance on stocking. The time frame over which biological management is analyzed is critical, since there are lags in stocking and regulation effects. For serious analysis, we advocate full ten-year runs of the integrated model.

POSTSCRIPT

RIOFISH was developed to be as complex as needed for comprehensive planning purposes, as accurate as our understanding of complex systems allows at this time, and as precise and complete as funding allowed. As with any model, the predictiveness is as good as the incorporated information. There is room for model improvement as more and better information becomes available, understanding improves, hardware capability increases, and planning skills increase. We hope that model limitations will not obscure the potential utility of such tools for comprehensive management system planning, and that the advancements made through RIOFISH assembly will contribute to improved planning process.

Feedback to model developers is always welcome. Contact authors through Richard Cole, Department of Fishery and Wildlife Sciences, New Mexico State University, Las Cruces, NM 88003 or RCOLE@NMSU.EDU.

REFERENCES

Cole, R., T. Ward, F. Ward, and R. Deitner. 1986. A simulation model for managing fisheries in reservoirs of the Rio Grande of New Mexico. Pages 18-28 In G.E. Hall, ed. Reservoir Fisheries Management Strategies for the 80's. Allen Press, Inc. Lawrence, Kansas.

Cole, R.A., F. Ward, T. Ward, R. Deitner, J. Fiore, S. Bolin and K. Green-Hammond. 1987. Model for optimization of socio-economic value on the Rio Grande. WRRI Report No. 23. New Mexico Water Resources Research Institute. Las Cruces, NM. 196 pp + 28 pp Appendix.

Cole, R.A., F.A. Ward, T.J. Ward, R.M. Wilson. 1990a. Development of an interdisciplinary model for water and fishery management. Water Resources Bulletin 26 (4):597-609.

Cole, R. A., T. J. Ward, F. A. Ward, R. A. Deitner, S. M Bolton and D. Green-Hammond. 1990b. RIOFISH, A fishery Management Planning Model for New Mexico Reservoirs. WRRI Report No. 252. Water Resources Research Institute, New Mexico State University, Las Cruces NM 225 p.

Cole, R. A. and F. A. Ward. 1994 Optimum fishery management policy: angler opportunity verses angler benefit. North American Journal of Fishery Management 14:22-33.

Cole, R., T. Ward, F. Ward, R. Deitner, R. Rodden, S. Bolton, and K. Green-Hammond (In Press) RIOFISH, a statewide comprehensive management system model for New Mexico sportfisheries. WRRI Report No.___ Water Resources Research Institute. New Mexico State University, Las Cruces, NM

Green-Hammond, K., R. Cole, F. Ward, T. Ward, S. Bolin, R.Deitner, J. Fiore. 1988. A user's guide for RIOFISH. Special Report. Agricultural Experiment Station, New Mexico State University, Las Cruces, NM 132 pp.

Green Hammond, K., R. A. Cole, F. A. Ward, T. J. Ward, S. M. Bolton, R. A. Deitner, J. Fiore. 1990. User's Guide for RIOFISH--A Fishery Management Model for Large New Mexico Reservoirs. WRRI Report No 253. Water Resources Research Institute, New Mexico State University. Las Cruces, NM 48p.

T. J. Ward, R. A. Cole, S. M. Bolton, F. A. Ward and K. A. Green-Hammond. 1992. RIOFISH: An interdisciplinary planning model for water and fishery management. Pages 611-625 In P. Zannetti (Ed) Computer Techniques in Environmental Studies IV. Elsevier Applied Science, NY, NY

APPENDIX

TABLE 1. OUTPUT INFORMATION GENERATED BY RIOFISH

General summary outputs[1]
Statewide benefit to anglers ($)
Lake elevation (m)
Lake volume (1000 m^3)
Lake surface area (hectares)
Lake annual and spring storage ratio
Lake, stream average depth (m)
Lake, stream average Secchi disk depth (m)s
Minimum and maximum mean daily temperature (C)
Lake total nitrogen load (g/m^2/year)
Stream total nitrogen concentration (mg/liter)
Stream total phosphorus concentration (mg/liter)
Lake total phosphorus load (g/m^2/year)
Total suspended solids load (g/m^2/year)
Late summer anoxic bottom fraction
Average percent littoral zone
Primary production (gC/m^2/year)
Allochthonous organic load (gC/m^2/year)
Benthos production (gC/m^2/year)
Zooplankton production (gC/m^2/year)
Catchable panfish, sport fish, carp-sucker (kg/hectare)
    weight (kg/hectare)
    density (#/hectare)
    production (Kg/hectare/year)
    mean individual weight (Kg)
    proportional stock density (%)
    catch/hour (number/hour)
    catch/hour (weight/hour)
    harvest/hour (number/hour)
    harvest/hour (weight/hour)
Total Angler hours/year
Total catch (numbers/year)
Total catch (weight/year)
Total harvest (number/year)
Total harvest (weight/year)
Statewide angler benefits ($1000s)

Detailed Hydrologic Output[2]
Semimonthly (graphic output):
Volumes of up to three inflows
Volumes of up to three outflows
Lake volumes
Lake area
Lake elevation
Suspended sediment concentration

TABLE 1 (CONT)

Phosphorus concentration
Nitrogen concentration
Water residence time

Detailed Biological Output[2]

For any of 24 species:
Density by size class
Catch by size class
Biomass by age class
Density by age class
Average length by age class
Mortality by age class
Production by age class
Total number and number/ hectare
Total kilograms and kg/ hectare
Harvest/ angler day
Seasonal primary production
Seasonal production of zoobenthos and zooplankton
Semimonthly allochthonous organic loads
Semimonthly total organic load consumed
Semimonthly unused, stored allochthonous organics

Detailed Economic Outputs[2]

Total angler days by site and statewide
Total angler benefits by county group and statewide
Change in income statewide
Change in jobs statewide

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1. Site and multisite weighted means and sums
2. Individual sites only

IMPORTANT FIXED INPUTS

Overview

Other than the user accessible inputs, RIOFISH includes numerous "fixed" inputs that cannot be changed by the user. Most of these fixed inputs are in the hydrologic and economic components. They are briefly described below.

Hydrology Inputs

Fixed Reservoir Input Values

Four sets of permanent hydrologic input values cannot be interactively modified by the model user. These inputs include

- evaporation pan coefficients
- the elevation-area-content tables for reservoirs
- the values that relate stream discharge to nitrogen, phosphorus, and suspended sediment concentrations, and
- the values that relate upstream flows to downstream flows.

Evaporation pan coefficients

Pan coefficients relate the evaporation from the Class A pans located at a reservoir weather stations to the evaporation of reservoir water. While a pan coefficient for each month is permitted, in practice a single value is used. The values used in RIOFISH have been set at 0.7, a commonly accepted value. A pan coefficient at 0.7, however, may not accurately reflect the lake's evaporation regime. Therefore, the pan coefficients should be updated as better information becomes available.

Elevation-area-contents

Elevation-area-contents are lists of corresponding reservoir surface areas and contents determined at approximately two-foot elevation increments. The most recent published data were used to develop these lists. These data lists are linearly interpolated in RIOFISH to find the area and elevation from a computed volume. The lists can be updated as new data become available.

Loading and Streamflow into Reservoirs

These relationships are similar to those discussed in the reservoir section. If the river section is downstream from a reservoir, the chemical concentration in the reservoir outflow is used to estimate the chemical concentration in the river section. However, if the river section is not immediately downstream of a reservoir, the same type of relationship that is used for estimating stream flow loading is used to calculate river concentration. Each river section has a set of coefficients used to compute concentration based on river flow.

Streamflow relationships

Modifying the upstream reservoir operation may have effects on the downstream river flow into a reservoir. To simulate the effects of such changes, existing data were analyzed to relate downstream flows to upstream flows. Relationships between upstream river flow and downstream flow for each river segment were then developed. Our analyses indicated that these relationships should be computed on a month-by-month basis rather than on a seasonal or annual basis. The relationships are linear and can be expressed in the mathematical equation:

$Q_r = a + bQ_u$ where

Q_r = the flow of the downstream river segment in cubic feet per second

Q_u = the upstream flow (or combination of flows) in cubic feet per second to which Q_r is related

a = a constant in cubic feet per second often equal to 0.0

b = the multiplier (not expressed in units) often equal to 1.0

The values for a and b were determined from data existing for water years 1975 through 1990. There was little change from previous analysis using fewer water years. These values will be changed as the database is updated.

Fixed River Values

All hydrological values for the river simulations within RIOFISH are fixed and unavailable for interactive modification. These inputs include values that relate

- river geometry and flow,
- stream discharge to nitrogen, phosphorus and suspended sediment concentrations, and
- upstream flows to downstream flows.

River geometry

Each river segment has values set for the average slope of the river bed and the bed's roughness. There are also coefficients for expressing the relationship

$$d = aQ^b \tag{4}$$

where
d = the maximum depth in feet
a = the coefficient
Q = the cross-sectional discharge of the channel in cubic feet per second
b = an exponent

River geometry is used to predict conditions in the river such as velocity, area, width and depth.

Loading streamflow relationships

These relationships are similar to those discussed in the reservoir section. If the river section is adjacent to a reservoir, the chemical concentration in the reservoir outflow is used as the basis for estimating the chemical concentration in the river section. However, if the river section is remote, the same type of relationship that determined reservoir loading is used to calculate river concentration. Each river section has a set of coefficients used to compute concentration based on river flow.

Streamflow relationships

Modifying the upstream reservoir operation or stream flow may have effects on the downstream river flow. To simulate the effects of such changes, existing data were analyzed to relate downstream flows to upstream flows. Relationships between upstream river flow and downstream flow for each river segment were then developed for each river segment. Our analysis indicated that these relationships should be computed on a month-by-month basis rather than on a seasonal or annual basis. The relationships are linear and can be expressed in the mathematical equation as discussed above

$$Q_r = a + bQ_u$$

Values may be updated as new data become available.

Biological Inputs

Trophic Efficiencies

The efficiency with which solar energy is used for primary production is fixed at 2 percent. Also, the variations from optimum for total phosphorus or total nitrogen, water temperature, suspended solids concentration, lake flushing rate and stream substrate particle size are fixed model inputs.

The efficiency with which organic load is transformed to secondary production of zooplankton, zoobenthos and herbivorous fish is determined by the temperature and oxygen content and is a fixed input. The maximum efficiency of fish in first and second carnivore levels is 40 percent, based on assimilation efficiency and respiratory cost under optimum field conditions. It is a fixed input.

The efficiency with which piscivorous fish consume detritivorous fish production is a fixed input and dependent on the production level of detritivores.

Resource Partitioning Coefficients

The partitioning of deposit feeding consumers and suspension feeding consumers is a fixed function of lake depth (There are no suspension feeders in RIOFISH streams. The fraction of the suspension feeding done by fish is a fixed function of organic concentration. The maximum fraction of benthic feeding done by fish is a constant 90 percent that is a fixed input.

Other Inputs

The loss functions for allochthonous organic loading are fixed, including the loss rate in stream channels before flooding and the loss rate in lake bottoms because of storage.

Among fish populations, the distribution of juvenile fish sizes that enter winter conditions and the size a juvenile has to be to survive winter is not available to casual users. This function and minimum survival length contributes to determining the age one and older cohort strength in RIOFISH.

Economic Inputs

Quality Variables

The partial effect on the number of angler days resulting from a change in each of several quality variable at any site is fixed. These site quality variables for which changes have fixed effects on angler days include average weight of fish harvested, number of fish/day caught, and number of fish/day harvested.

Also included are fixed parameters for number of boat ramps, number of developed campsites, presence of drinking water, macrophyte density, seasonal precipitation at the site, number of modern toilets at the site, surface area of water, presence of tailwater fishing, seasonal average temperature at the site, and water turbidity.

There are also fixed parameters for several general geographic site quality variables. These include presence of a large cold stream, whether or not the site is a lake on a national forest, whether there are Kokanee salmon at the reservoir, and moderate elevation reservoirs (4000-7000 feet above sea level).

Demographic Variables

Fixed parameters also were estimated for measuring the effect of a county's demographic factors on angler days to a fishing water. These demographic factors include percentage of Hispanic persons in a zone, percentage of people over age 65, percentage of people under age 25, and percentage of households headed by a single female with children. Other demographic factors include percent of households with married couples without children, percent of households with married couples with children, and percent of households headed by a single male without children.

Substitution Effect

The fishing quality-adjusted elasticity of substitution among any two fishing sites is also fixed. The elasticity of substitution measures the sensitivity of percentage changes in demand proportions across sites to changes in price proportions across sites. When the elasticity of substitution is high, it means that small increases in price or decreases in quality at a given site have large effects on redistributing anglers to substitute sites. When the elasticity of substitution is low, large changes in price or quality at a given fishing water produce little reaction in redistributing anglers to substitute sites.

The numerator of the elasticity of substitution is the percentage change in proportion of angler days at the ith site to angler days at a base site (Elephant Butte reservoir). The denominator is the percentage change in proportion of angler travel cost at the ith site to the travel cost at the base site. For given levels of site quality and demographic factors, the elasticity of substitution is constant.

Angler Expenditure

Total angler expenditure on vehicle travel cost over all sites also is fixed. While this is doubtless a simplifying assumption, considerable analysis of the data could find no relationship between angler expenditure and any site quality or demographic or travel cost factors. Angler expenditure is defined as the sum of travel costs per trip multiplied by the observed number of seasonal trips to all 132 sites. Because angler expenditure does not increase in the face of fishing improvements, the benefits of fishing improvements are likely understated.