December, 1990 WRRI Report No. 252

USER'S GUIDE FOR RIOFISH A FISHERY MANAGEMENT MODEL FOR LARGE NEW MEXICO RESERVOIRS

Technical Completion Report

Project Numbers, 1423612, 1423688, 1345677

USER'S GUIDE FOR

RIOFISH

A FISHERY MANAGEMENT MODEL

FOR LARGE NEW MEXICO RESERVOIRS

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December 1990

New Mexico Water Resources Research Institute
in cooperation with
Department of Fishery and Wildlife Sciences
Department of Agricultural Economics and Agricultural Business
Department of Civil, Agricultural and Geological Engineering

NEW MEXICO STATE UNIVERSITY

The research on which this report is based was financed in part by the U.S. Department of Interior, Geological Survey, through the New Mexico Water Resource Research Institute.

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INTRODUCTION

RIOFISH is a simulation model designed to analyze the impact of proposed fisheries-related management decisions in the hydrology, ecology, and economy of river basins. It has been expanded from the original version, developed by Cole et al. (1987) and Green-Hammond et al. (1988). The primary use of RIOFISH is for the development and contrast of planning alternatives. Although RIOFISH can be used to estimate optimum management decisions, based on estimates of maximum benefits generated, it is not a linear optimization model. In addition to the Rio Grande, which was modeled in the original version, RIOFISH includes reservoir fisheries of the Canadian, Pecos, and San Juan rivers in New Mexico. Numerous other modifications have been made to expand model utility.

This guide is designed to help you use RIOFISH. It includes sections covering

- RIOFISH structure and uses,
- how to run RIOFISH on an IBM-compatible microcomputer or the Data General computer at New Mexico Department of Game and Fish,
- an example scenario of management alternatives for self-paced instruction,
- the variables used in RIOFISH and information on how they influence model simulation, and
- further potential uses for RIOFISH.

We suggest that you read Sections I and II, and that you run the example scenario in Section III before trying to run RIOFISH on your own.

Descriptions of the variables that make RIOFISH run as well as other examples of applications are presented in Sections IV and V.

The computer hardware necessary to run RIOFISH includes an IBM-compatible microcomputer with a hard disk and 640K of RAM. The model requires about 2.5 megabytes of space on a hard disk. Additional software necessary to run RIOFISH includes MS DOS 2.0, or higher, and the APL program available from the authors.

This guide does not include descriptions of modeling philosophy, model development, model limitations, or the mathematical structure of RIOFISH. For a more detailed description of RIOFISH, refer to Cole et al. (1990).

SECTION I. THE RIOFISH MODEL AND ITS USES

Model Structure

Overview

RIOFISH is composed of sequences of mathematical equations that simulate

- water flow and the transport of biologically active materials,
- fish habitat and fish forage production,
- sportfish production, biomass and angler activity, and
- economic benefits generated by sportfishing.

These mathematical equations are programmed in a user-friendly format using APL programming language. They link a series of submodels that represent the hydrologic, biologic, and economic features of the New Mexico reservoirs included in the model (Figure 1). Each of the three main submodels requires information on management options used to generate output in the form of computer printouts and screens. Some of the input information is derived from calculated modeled products, while other required information is collected from various data inventories.

The hydrologic submodel, shown in Figure 1, is based on data from the U.S. Geological Survey (USGS) and runs independently of the outputs generated by the biologic and economic submodels.

Operating the biologic submodel requires output from both the hydrologic and economic submodels as shown in Figure 1. This output includes information on reservoir volumes, stream discharges, water-surface areas, and concentrations of phosphorus, nitrogen and suspended solids that are calculated in the hydrologic submodel, as well as the estimates of angler effort (days fished) that are calculated in the economic submodel.

The economic submodel uses output calculated in both the hydrologic and biologic submodels. This required output includes estimated water surface area and fish biomass.

Hydrologic submodel components

The hydrologic submodel is generated from flow data largely collected at the USGS stations. Data defining the shapes of reservoir and tailwaters, lake evaporation,

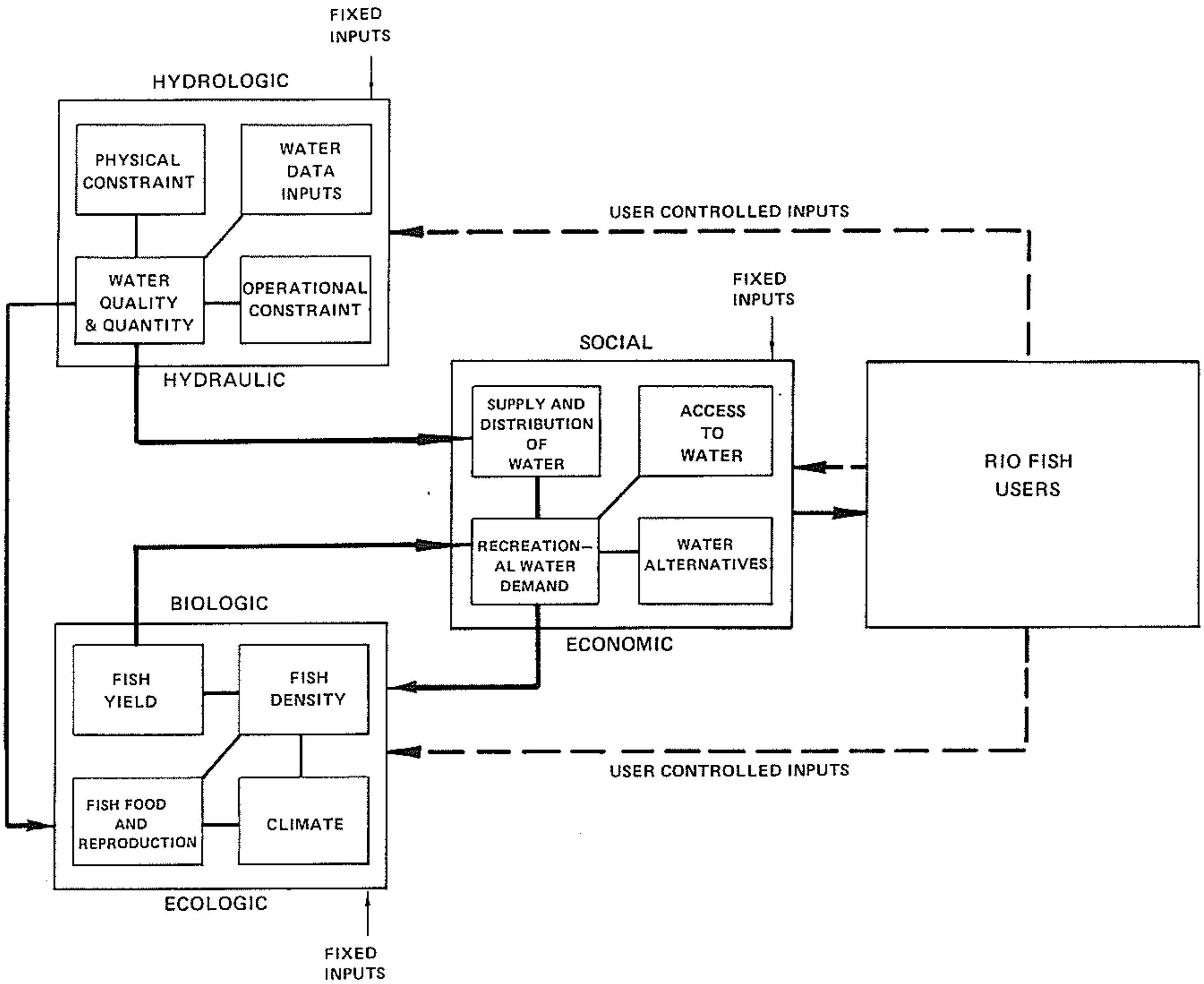

Figure 1. Schematic illustrating the interactions among the major model components and the model user. Solid lines indicate information flow whereas, dashed lines indicate user feedback control of model properties.

and operational constraints are also included. These data generate outputs pertaining to

- mean concentrations of total phosphorus, nitrogen, and suspended solids, and
- the relationships of reservoir depth, area, and contents.

The river flow information for tailwater fish habitat is calculated from flow rate and channel shape.

<u>Biologic submodel components</u>

In addition to the information derived from the hydrologic and economic submodels, the biologic submodel requires input data representing

- mean seasonal solar radiation,
- mean seasonal air temperature,
- mean seasonal concentration of organic carbon introduced from the watershed, and
- initial fish density.

The biologic model provides information about the density, biomass and productivity of catchable fish, catch rates and population characteristics of 23 fish species. Additional information is provided about reservoir productivity with regard to primary productivity and the zoobenthos and zooplankton. For tailwaters, the fish production in major ecological groups is the only output information provided.

<u>Economic submodel components</u>

The inputs required by the economic submodel are estimates of

- angler travel cost,
- road accessibility,
- boat ramp access, and
- availability and quality of substitute sites.

The economic submodel integrates these inputs with the estimated biomass of fish (calculated in the biologic submodel) and the water surface area (estimated in the hydrologic submodel). This integration results in computed angler days and angler benefit generated at each reservoir.

The Model-User Interaction

Model outputs and user control

Table 1 lists specific examples of outputs that may be used to aid management decisions once modeled management alternatives have been compared. The outputs are provided after you run the model using a series of menus and question-and-answer screens. Only minimum computer skills are required to operate RIOFISH. Once the model is started, you are led step-by-step though the menu choices.

Much greater skill is required to set up the alternative management scenarios. RIOFISH cannot think for you as you consider possible management strategies, nor can the model make decisions on which scenario is best.

The time period simulated

RIOFISH simulates the hydrology of river-basin segments designated in Figure 2 for water years between October 1, 1974 to September 30, 1987. This period includes a range of hydrologic conditions that occur in New Mexico river basins. Water years 1975 through 1978 were low-flow years, but most years since 1979 were high-flow years.

To test a management strategy -- for example, a new harvest length regulation for largemouth bass -- run the model for one to five years in sequence. You can choose any sequence of years from the 12 years simulated in the model. RIOFISH allows you to make changes in

- water quantity
- water distributions
- water quality
- fish harvest regulations
- fish stocking rates
- fish introductions
- fish removals
- boat ramp access
- road access
- travel cost
- human population sizes

The 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 period that you choose to simulate. Outputs from the first sequence run can be inserted into a second sequence run. In this manner, the entire sequence of years can be run.

Table 1. Output information generated by RIOFISH

General summary outputs(choice 2 in menu 4)

- Lake elevation (feet)
- Lake volume (acre feet)
- Lake surface area (acres)
- Lake exchange rate (annual)
- Catchable sportfish (kg/hectare)
- Total angler days (days/year)
- Fish catch rate (number/hour)
- Primary production and allochthonous organic load (g C/M2/year)
- Benthos production (kg/hectare/year)
- Zooplankton production (kg/hectare/year)
- Panfish production (kg/hectare/year)
- Gamefish production (kg/hectare/year)
- Carp and sucker production (kg/hectare/year)
- Statewide angler benefits ($1000s)

<u>Detailed Hydrologic Output (choice 3 in menu 4)</u>

Semimonthly:

- Volumes of up to three inflows
- Volumes of up to three outflows
- Lake volumes
- Lake area
- Lake elevation
- Suspended sediment concentration
- Phosphorus concentration
- Nitrogen concentration
- Water residence time

<u>Detailed Biological Output (choice 4 in menu 4)</u>

For any of 24 species:

- Density by size class
- Yield by size class
- Biomass by age class
- Density by age class
- Average length by age class
- Mortality by age class
- Growth by age class
- Number per hectare
- kilograms per hectare
- Harvest per angler day
- Final volume and fish density at end of run
- Density and biomass summaries for all species
- Seasonal primary production

Table 1. Continued.

Seasonal production of zoobenthos and zooplankton
Semimonthly allochthonous organic loads
Semimonthly total organic load consumed
Semimonthly unused, stored allochthonous organics
<u>Detailed Economic Outputs (choices 5 and 6 in menu 4)</u>
Total angler days by county
Total angler benefits by county
Change in income by county
Change in jobs by county
Per capita trips to the fishery site
Combined per capita trips to all substitute sites
Site use fees
Travel costs/mile
Percent easily accessible shoreline
Number of concrete boat ramps
Relative fishing quality index
Fraction of the county population that is anglers
Percent of county population in urban areas

```
MENU:        BEGINNING
LEVEL:       1
CALLED BY:  STARTUP FUNCTION
OBJECTIVE: INTRODUCE MENU SYSTEM, EXAMINE HISTORICAL DATA BASE

           1 HELP INFORMATION ON THE MENU SYSTEM

           2 HELP INFORMATION ON THIS MENU

           3 VERSION OF THE MODEL

           4 LOOK AT THE MAP

           5 PLOT USGS MEASURED IN AND OUT FLOWS AND OTHER DATA

             FOR ANY RESERVOIR

           6 PLOT USGS MEASURED FLOW DATA FOR ANY STREAM

           7 MAKE HARD COPY OF REQUESTED PRINTOUTS NOW

           8 PROCEED TO MENU FOR SETTING UP A SCENARIO

        9 QUIT

PLEASE CHOOSE (1 2 3 4 5 6 7 8 9) ===>
```

Figure 2. The beginning menu seen on the screen after a river basin is chosen by the model user.

Testing management decisions

To find the best management strategy, based on the outputs you have selected to judge management results, the model should be run repeatedly using different strategic alternatives for each run. For example, to examine the effects of different length limits, run the model once for each length limit selected. Record and compare the output information, and, using the output criteria of your choice, choose the optimum management strategy.

Only you can choose the criteria that indicate the optimum management strategy. In the case of a fish regulation change, the criteria you choose to judge decision effectiveness could be a single model output or a combination of model outputs. For example, fish yield per angler may be chosen as the only criterion for making certain management decisions. Alternatively, a combination of factors may be chosen, such as catch rate, total angler effort, catchable fish biomass, and fishing-related economic benefits.

Comparisons of 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. 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.

Your responsibility in model use

The RIOFISH model helps, but does not replace, your experience and intelligence in making management decisions. You must

- choose the appropriate potential management decision
- choose the criteria that best meet your management objectives
- carefully analyze the output results, and
- resolve any differences that arise between the model output and other information or intuition.

Resolving differences between your view of the correct decision and model output usually requires thought, discussion, consultation and possible research. Used well, RIOFISH can encourage communication and foster solution to complex management problems.

As a RIOFISH user, you are the best judge of how comprehensive and accurate the model should be in order to help you make decisions. We have tried to make RIOFISH only as complex as needed for comprehensive planning purposes and as accurate as our understanding of complex systems allows. There is room for model improvement as better information becomes available, understanding improves, hardware capability increases, and planning skills increase.

SECTION II. MODEL OPERATION

Mechanics of Running the Model

RIOFISH can be run on the Data General computer system at New Mexico Game and Fish, or on a properly configured IBM-compatible microcomputer. Operations are the same unless otherwise noted.

Beginning

On the Data General, use the CLI command RIO_FISH_MODEL to start the model.

On an IBM-compatible microcomputer, first make sure you are in the drive containing the model, then use the batch command RIOFISH to start the model.

On either system, the model prompts you to select a river system (Rio Grande, Canadian, Pecos, or San Juan). After the selection is made, the model displays messages indicating that it is getting set up, and then displays the first menu (background information menu). When the first menu appears, you are ready to begin using the model.

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; do not use the shift key. To enter numbers, use the top row of the regular keyboard, or the numeric pad. In all cases, to complete your response, use the New Line (Data General) or Enter (microcomputer) key.

The most common mechanical mistakes made in user responses are simple typographic errors, using the shift key unnecessarily, and accidentally turning on the Caps Lock Key. 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 an error occurs while the model is running, 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 CLI (Data General) or DOS (microcomputer) environment. You can then start over and try again.

Menus

There are four menus that control the model, namely menus for background information, scenario set up, model runs, and getting outputs of model results. The uses of these menus are discussed below. Each menu consists of a series of options for getting help, taking actions, and moving to other menus or quitting the model. 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.

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, then 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 New Line or Enter. To leave the number unchanged, just depress New Line or 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 (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 Cancel/exit/Bye/F11 key (Data General) or F9 key (IBM-compatible microcomputer) to finish the screen edit.

Negative Numbers

Usually, if a negative number is needed for a table, the negative sign will already show on the screen. If you must enter a negative sign, use the shifted hyphen key (as though you wanted an underline) in the top row of the keyboard. A negative sign should appear 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 the information on the screen without printing, and then repeat the option to get a printout if you want one.

On the Data General system, you can get printouts as you work or save printouts in a file for later printing and/or electronic mailing. If you want to save a printout as a file, you must supply the file name as any combination of letters, numbers, or underlines up to 30 characters long, but no embedded spaces (FISH1 or FISH_1 are acceptable; FISH 1 is not). The file will be placed in your root directory.

On a microcomputer, any requested outputs are sent directly to the printer at the same time they are displayed on the screen.

Main Menu Structure

Beginning Menu

The first menu (Figure 2) allows you to examine stored data on the hydrological history of the selected river system. Options 1 and 2 provide on-line information for using the model. Option 3 provides notes on the current model version.

Option 4 displays a map showing reservoirs, flow gauges, and reaches in the river system. The map can be printed.

Option 5 allows you to see graphs of reservoir inflows and outflows, reservoir volume, and rainfall and evaporation rates by half months for the 1975 through 1987 water years. Up to 4 variables may be plotted together. You select the reservoir, the time period, and the variables. The horizontal axis is the value of the variable ranging from minimum to maximum over the time period selected. The vertical axis is time. Graphs can be printed.

Option 6 is similar to option 5. Half-monthly flows can be plotted for any selected flow gauge point in the system, up to four together.

If you have requested printouts, you can print them immediately on the system dot matrix printer using Option 7. This option applies to the Data General system only.

Option 8 moves to the second menu. Option 9 leaves the RIOFISH model entirely.

Scenario Setup Menu

The second menu (Figure 3) allows you to set up all the conditions for a particular run, known as a scenario. All of the changes or inputs accessible to the user are reached from this menu. Any of the options can be selected to see the present

```
MENU:        SCENARIO
LEVEL:       2
CALLED BY:   BEGINNING MENU
OBJECTIVE:   SET INPUT CONDITIONS DEFINING THE SCENARIO FOR A
MODEL RUN

         1 HELP INFORMATION ON THIS MENU

         2 LOOK AT THE MAP

         3 SEE / RESET RESERVOIRS, YEARS FOR THIS
           SIMULATION

         9 RETURN TO BEGINNING (DATA BASE) MENU

PLEASE CHOOSE (1 2 3 9) ===>
```

Figure 3. The scenario menu is called by beginning menu. It allows you to orient yourself and to reset (if you have previously made changes) or change variables in RIOFISH.

settings of the user-controlled variables without making any changes. Of course, the options can be used to make changes as well.

Options 1 and 2 obtain help information and a map, as in the beginning menu.

The only action option available the first time this menu appears is Option 3, used for setting up the physical scope of the run. With Option 3 you select one or more of the reservoirs in the river system to be included in the model runs, as well as the time frame of one to five consecutive water years for the run. This option must be completed before any other scenario setting options become available.

Option 4, the reset option, negates any modifications to the standard hydrology, biology, or economic inputs that you may have made using the remaining options in the menu. It leaves the selected time and place unchanged, but otherwise returns all settings to the values they would have when the model session starts. Use this option when you have made various modifications for designing scenarios, and wish to start over.

Use option 5 to examine or modify reservoir initial volume and volume constraints, and the water-flow regime. Option 5 calls up a subsidiary menu which allows you to make the different changes or to undo any previous changes you have made.

Use option 6 to examine or modify any of the biological model inputs for the reservoirs, including initial fish populations, fish population parameters, fish stocking and fishing regulations, and reservoir light, temperature, and nutrients. Option 6 calls a subsidiary menu which allows you to make, or undo, selected changes.

Use option 7 to examine or modify any of the inputs to the economic model, including factors affecting the cost of fishing trips, variables reflecting recreational quality of reservoir sites, and angler population characteristics. Option 7 calls a subsidiary menu which allows you to make, or to undo, selected changes.

If you need more background information before making decisions about a scenario definition, option 9 allows you to return to the beginning menu. After your scenario definition is complete, option 8 moves you to the third menu where model runs are made.

Model Run Menu

The third menu, used for making actual runs of the model, is shown in Figure 4. Option 1 provides help information on this menu, and option 8 allows you to return to the scenario development menu.

Action options, 2 through 7, allow you to run any part of the RIOFISH model that makes sense, from the individual hydrological, biological, or economic submodels through the full model with all submodels linked. Your choice depends on your objectives for a particular scenario run.

Once you select one of options 2 through 7, the model run starts automatically. Messages appear on the screen to indicate the run's progress. The length of time needed for a model run depends on the computer system you are using and the complexity of the scenario you are running. The biological model is the most time consuming of the three submodels. When the model is complete, a prompt to depress New Line (or Enter on a microcomputer) appears. When you do so, you will automatically go to the last menu to look at results of the model run just completed.

Results Menu

The last menu, shown in Figure 5, enables you to look at the results of the model run just completed in as much detail as you wish. Only options which make sense are actually available; you cannot, for example, look at fish population results following a run of the hydrology model alone.

Option 1 provides on line help about the results menu.

Option 2 is a general summary output applicable to all runs, and should always be taken. It summarizes inputs that define the scenario for the run and standard outputs that allow quick comparisons to be made between different scenarios, including lake size, biological production, fishing effort and yield, and general economic benefits as appropriate. With this option you may put a label on the output describing the scenario chosen.

Option 3 provides more detailed hydrological model output, including plots of flows and reservoir volume, area, and elevation.

Option 4 calls a subsidiary menu that provides several different tables of fish population changes during the run. For individual species you can select length,

```
MENU:           MODEL.RUN
LEVEL:          3
CALLED BY:      SCENARIO MENU
OBJECTIVE:      RUN ALL OR PART OF THE MODEL BASED ON SELECTED
                SCENARIO

          1 HELP INFORMATION ON THIS MENU

          2 RUN HYDROLOGICAL, BIOLOGICAL, AND ECONOMIC MODELS
            LINKED

          3 RUN HYDROLOGICAL AND BIOLOGICAL MODELS, LINKED

          4 RUN BIOLOGICAL AND ECONOMIC MODELS, LINKED

          5 RUN HYDROLOGICAL SUBMODEL ALONE

          6 RUN BIOLOGICAL SUBMODEL ALONE

          7 RUN ECONOMIC SUBMODEL ALONE

          8 RETURN TO SCENARIO DEVELOPMENT MENU

          9 PROCEED TO MENU FOR EXAMINING RESULTS IN DETAIL

     PLEASE CHOOSE (1 2 3 4 5 6 7 8 9) ===>
```

Figure 4. This menu, called by option 8 in the Scenario Menu, allows the RIOFISH user to run RIOFISH as different combinations of model components or it allows the results of a previous model run to be examined (Option 9).

```
MENU:          RESULTS
LEVEL:         4
CALLED BY:     MODEL.RUN MENU
OBJECTIVE:     EXAMINE  ADDITIONAL  INFORMATION  FROM  MODEL
               RESULTS

          1 HELP INFORMATION ON THIS MENU

          2 SCENARIO DESCRIPTION AND BASIC OUTPUT, LABEL
            PRINTOUT

          3 EXAMINE HYDROLOGICAL MODEL RESULTS IN DETAIL

          4 EXAMINE FISH POPULATION RESULTS IN DETAIL

          5 EXAMINE RESERVOIR, STREAM PRODUCTION RESULTS IN
            DETAIL

          6 EXAMINE ECONOMIC MODEL RESULTS, ANGLER DAYS AND
            BENEFITS

          7 EXAMINE ECONOMIC MODEL TRIPS, INPUTS IN DETAIL

          8 MAKE HARD COPY OF REQUESTED PRINTOUTS NOW

          9 RETURN TO MENU FOR SETTING UP A SCENARIO

          10 QUIT

     PLEASE CHOOSE (1 2 3 4 5 6 7 8 9 10) ===>
```

Figure 5. The Results menu is called by Option 9 of the model-run menu or it appears following a model run. Various results are made available.

numbers per hectare, weight per hectare, and mortality and growth rates by age class. You can also select density, catch rate, and unexploited yield by size class for individual species, as well as total fishing effort in angler days for the lake. For all the species in a lake (age classes lumped instead of separated), you may look at numbers of weight per hectare, and catch rate. The last choice is a summary of final conditions for the fish populations which may be used as initial conditions for a run beginning in the next water year.

The reservoir production results from option 5 are seasonal light, nutrients, and primary and secondary production by feeding guild and habitat. A similar summary for the tailwaters immediately below the reservoir outflow is the stream production part of option 5.

Option 6 is the general output for economic model runs, and includes total angler days for all recreational sites in the statewide model, and total benefits for New Mexico counties with a statewide total.

Option 7 provides more detailed economic results, including a summary of the inputs to the economic model and fishing trips to selected sites by county of angler residence.

Option 8 is for an immediate printout of any results you have previously requested, and applies to the Data General system only.

Option 9 allows you to return to the scenario development menu, to modify the scenario definition for a comparison run.

Option 10 is the way to end the modeling session.

Scenario Definitions Modified by Subsequent Runs

In some cases, your inputs to define a scenario can be changed by subsequent model runs, resulting in a run of a different scenario than the one you expect. Each such case is discussed here, along with suggestions for avoiding the problem.

Reservoir environment, temperature, nutrients

The ambient temperature and the concentrations of phosphorus, nitrogen, and suspended solids in the water column used as inputs for the biology model are calculated by the hydrology model. They can be specified by the user also. The values actually used in a scenario run will be the ones set most recently. If you specify reservoir temperature or nutrients, and then do a run that includes the hydrology model, the model will rewrite temperature and nutrients, effectively wiping out the changes you have made. To avoid this problem, set up any hydrology model inputs and run the hydrology model alone. Then, using the scenario development menu again, make the desired modifications to the reservoir environment. Finally, run the biology model (and the economics model, if desired) without running the hydrology model again. In this way, the desired scenario with reservoir environment as you specified will be run.

Economic model reservoir volume, area, fishing

The reservoir volume and area used as inputs for the economic model are calculated by the hydrology model. The fishing quality variable used as an input for the economic model is calculated by the biology model. Each of these economic model inputs may also be user-specified. The values used when the economics model is run for a scenario will be the ones set most recently. If you set lake volume, area, or fishing quality, and then perform a model run that includes the hydrology or biology models, the model will recalculate those inputs to the economic model, effectively erasing the changes you made. To avoid this problem, you should set up the desired scenario definitions for the hydrology and biology models, and run those models alone. Then return to the scenario development menu and select the desired lake volume, area, and fishing (along with any other modifications to the economic model scenario) and then run the economic model alone. This will insure that the scenario that you want is the one that is run.

SECTION III. EXAMPLE SCENARIO

Overview

RIOFISH allows a fishery manager to test a variety of management strategies in different environmental conditions by creating modeled management scenarios. These scenarios can be designed to address many approaches to accomplish planning objectives. The more you use RIOFISH, the more you will learn to take advantage of its capabilities.

This section leads you through an approach for which RIOFISH is best suited. First you will run a reference scenario. Then you will run an alternative management strategy scenario. The results of these scenarios are printed in Figures 6-10. Using what you know from Section II about how to run RIOFISH, set up and run the example scenarios. Then check your results against those printed in Figures 6-10.

The example scenarios in this section compare the results of increasing the minimum pool size of Cochiti Reservoir to 100,000 acre-feet with the present 50,000 acre-feet storage. Because the water will be held in Cochiti Reservoir rather than Elephant Butte Reservoir, Elephant Butte is included in the scenario.

Starting the Program

Turn your computer on and follow the instructions provided with your copy of RIOFISH for booting DOS, APL and RIOFISH. The beginning menu will appear on your computer screen after a short wait.

TIME AND PLACE COVERED BY SIMULATION RUN:
COCHITI
ELEPHBUT
FOR 1975 1976 1977 1978 1979

****

INCREASE MINIMUM POOL SCENARIO

****

3/2/1990 12:37

************** COCHITI	1975	1976	1977	1978	1979
LAKE ELEVATION - MAXIMUM	5348.0	5356.7	5350.7	5354.0	5394.2
(feet) - AVERAGE	5329.3	5352.0	5350.1	5349.8	5356.4
(feet) - MINIMUM	5284.2	5350.8	5349.2	5347.7	5345.5
LAKE VOLUME - MAXIMUM	72968	89599	77877	84180	198400
(acre-ft) - AVERAGE	49642	80376	76816	76317	93128
(acre-ft) - MINIMUM	10074	78083	75174	72576	68847
LAKE AREA - MAXIMUM	1730	2110	1856	1984	3685
(acres) - AVERAGE	1223	1904	1831	1813	2082
(acres) - MINIMUM	496	1861	1794	1719	1623
AVERAGE EXCHANGE RATE	19.6	11.0	5.5	8.5	18.0
CATCHABLE PAN,GAME FISH(kg/ha)	28.0	28.6	33.3	101.6	102.1
CATCHABLE PAN,GAME FISH(#s/ha)	56.1	59.5	58.1	505.7	218.3
CATCHABLE FISH AVE. WEIGHT(kg)	0.5	0.5	0.6	0.2	0.5
CATCHABLE o/o OF TOTAL FISH	10.0	12.3	9.1	18.5	24.5
TOTAL ANGLER DAYS	10308	22114	22182	38496	40890
FISH CATCH/HOUR	0.11	0.18	1.04	1.25	1.03
PRIM PROD + ALLOC (gC/m2/yr)	1277.4	516.3	331.8	397.1	1693.3
BENTHOS PRODN (kg/ha/yr)	826.5	312.7	196.9	189.8	1065.4
ZOOPLANKTON PRODN (kg/ha/yr)	16643.8	6503.3	4434.7	4544.6	20883.8
MAXIMUM POTENTIAL FISH PRODUCTION:					
CARP,CRAY PRODN (kg/ha/yr)	51.0	30.0	36.8	49.7	35.0
SHAD PRODN (kg/ha/yr)	0.0	0.0	0.0	0.0	0.0
BENTH.CONS. PRODN (kg/ha/yr)	145.9	54.5	38.7	35.8	168.5
ZOOPL.CONS. PRODN (kg/ha/yr)	2882.0	1115.0	836.5	810.1	3286.2
FISH CONS. PRODN (kg/ha/yr)	542.5	215.5	180.1	175.8	549.8
ACTUAL OR REALIZED FISH PRODUCTION OF CATCHABLE SIZE FISH:					
PAN FISH PRODN (kg/ha/yr)	7.1	7.9	10.8	12.9	7.4
GAME FISH PRODN (kg/ha/yr)	17.4	22.1	85.9	155.2	112.3
CARP, SUCKER PRODN (kg/ha/yr)	54.7	37.4	45.1	57.8	33.0

***************** ELEPHBUT	1975	1976	1977	1978	1979
LAKE ELEVATION - MAXIMUM	4336.8	4353.5	4326.2	4319.4	4360.5
(feet) - AVERAGE	4331.8	4338.9	4316.6	4306.9	4327.1
(feet) - MINIMUM	4324.5	4319.6	4296.7	4291.3	4291.5
LAKE VOLUME - MAXIMUM	468508	710947	345662	277758	836097
(acre-ft) - AVERAGE	408712	507372	262343	180885	410897
(acre-ft) - MINIMUM	328188	279154	110193	83321	84520

Figure 6. Option 2 in the Results Model provides summary information like this example from Cochiti and Elephant Butte Reservoirs.

LAKE AREA - MAXIMUM	12636	16685	10609	9515	18705
(acres) - AVERAGE	11625	13294	8957	7162	11329
(acres) - MINIMUM	10346	9546	5476	4439	4492
AVERAGE EXCHANGE RATE	1.6	1.3	1.5	2.1	1.4
CATCHABLE PAN,GAME FISH(kg/ha)	218.6	204.4	303.3	361.7	282.9
CATCHABLE PAN,GAME FISH(#s/ha)	365.8	373.5	522.9	668.4	595.0
CATCHABLE FISH AVE. WEIGHT(kg)	0.6	0.5	0.6	0.5	0.5
CATCHABLE o/o OF TOTAL FISH	14.3	16.6	17.7	18.9	21.5
TOTAL ANGLER DAYS	118725	103513	103504	87461	109688
FISH CATCH/HOUR	2.82	2.49	1.98	2.26	2.24
PRIM PROD + ALLOC (gC/m2/yr)	717.1	827.5	1059.3	589.4	856.1
BENTHOS PRODN (kg/ha/yr)	249.8	427.9	624.3	360.7	501.0
ZOOPLANKTON PRODN (kg/ha/yr)	8961.6	11922.2	14568.9	8857.3	11950.6
MAXIMUM POTENTIAL FISH PRODUCTION:					
CARP,CRAY PRODN (kg/ha/yr)	229.6	208.1	228.8	165.2	145.3
SHAD PRODN (kg/ha/yr)	84.2	21.9	32.4	40.9	26.9
BENTH.CONS. PRODN (kg/ha/yr)	49.5	90.7	126.6	79.6	106.4
ZOOPL.CONS. PRODN (kg/ha/yr)	1643.8	2362.2	2788.5	1851.4	2364.9
FISH CONS. PRODN (kg/ha/yr)	379.5	540.2	621.3	450.8	536.9
ACTUAL OR REALIZED FISH PRODUCTION OF CATCHABLE SIZE FISH:					
PAN FISH PRODN (kg/ha/yr)	39.9	52.4	83.0	83.0	69.8
GAME FISH PRODN (kg/ha/yr)	95.0	76.2	127.2	127.2	109.9
CARP, SUCKER PRODN (kg/ha/yr)	228.6	155.1	170.0	142.1	99.0

IN 1975 TEMPERATURE AND OXYGEN CONDITIONS CAUSED KILLS OF
SPECIES 20 THREADFN SH

IN 1976 TEMPERATURE AND OXYGEN CONDITIONS CAUSED KILLS OF
SPECIES 20 THREADFN SH

*************** SYSTEM WIDE	1975	1976	1977	1978	1979
STATEWIDE BENEFITS, $1000s	-231,256	-190,946	-157,989	-119,051	-69,623

Figure 6. Continued

```
CALCULATED ELEVATION IN FEET      E
4291.3     TO 4365.6     BY 2.5641

PHOSPHORUS IN MG/L                P
4E²3       TO 1.254      BY 0.04310

    MIN                         MAX
OCT : P           E:              :
 74 : P            E              :
NOV : P            :E             :
 74 : P            :E             :
DEC : P            :E             :
 74 : P            : E            :
JAN :-P------------:-E------------:
 75 : P            :  E           :
FEB : P            :  E           :
 75 : P            :   E          :
MAR :     P        :   E          :
 75 :   P          :  E           :
APR :  P           :E             :
 75 : P            :E             :
MAY :   P          :E             :
 75 :      P       :  E           :
JUN :      P       :   E          :
 75 :    P         :   E          :
JUL :      P       :   E          :
 75 :     P        :   E          :
AUG : P            :  E           :
 75 :   P          : E            :
SEP :              :P E           :
 75 : P            :   E          :
OCT : P            :   E          :
 75 : P            :   E          :
NOV : P            :    E         :
 75 : P            :     E        :
DEC : P            :      E       :
 75 : P            :       E      :
JAN :-P------------:--------E-----:
 76 : P            :         E    :
FEB : P            :         E    :
 76 : P            :          E   :
MAR :  P           :         E    :
 76 : P            :        E     :
APR : P            :       E      :
 76 :  P           :      E       :
MAY :   P          :     E        :
 76 :   P          :     E        :
JUN :   P          :    E         :
 76 :  P           :  E           :
JUL : P            :E             :
 76 :  P           E              :
AUG :  P          E:              :
 76 :   P        E :              :
SEP :  P         E :              :
 76 : P          E :              :
OCT : P          E :              :
 76 : P          E :              :
```

Figure 7. RIOFISH allows users to graph hydrologic-limnologic variables. Total phosphorus and lake elevation is shown here for two years.

ELEPHBUT 2 WHITE BASS

NUMBERS/HA IN LATE SUMMER

AGE CLASS	1974	1975	1976	1977	1978	1979
0	128.25	244.05	271.72	411.93	974.22	1.31
1	64.97	53.80	156.48	237.72	261.53	118.80
2	32.92	27.29	34.55	137.09	151.13	31.93
3	16.68	13.83	17.53	30.26	87.16	18.45
4	8.45	7.01	8.88	15.35	19.24	10.64
5	4.28	3.55	4.50	7.78	9.76	2.35
6	2.17	1.80	2.28	3.94	4.94	1.19
7	1.10	0.91	1.15	2.00	2.51	0.60
8	0.56	0.46	0.58	1.01	1.27	0.31
9	0.28	0.23	0.30	0.51	0.64	0.15
10	0.14	0.12	0.15	0.26	0.33	0.08
11	0.07	0.06	0.08	0.13	0.16	0.04
12	0.04	0.03	0.04	0.07	0.08	0.02
13	0.02	0.02	0.02	0.03	0.04	0.01
14	0.01	0.01	0.01	0.02	0.02	0.01
9/30 AREA	4,144	4,997	3,943	2,280	1,817	7,539

TOTAL NUMBERS FOR ENTIRE LAKE, LATE SUMMER

AGE CLASS	1974	1975	1976	1977	1978	1979
0	531429	1219540	1071369	939258	1770169	9907
1	269231	268868	617007	542041	475201	895589
2	136397	136397	136213	312586	274608	240745
3	69101	69101	69101	69008	158362	139122
4	35008	35008	35008	35008	34961	80229
5	17736	17736	17736	17736	17736	17711
6	8985	8985	8985	8985	8985	8985
7	4552	4552	4552	4552	4552	4552
8	2306	2306	2306	2306	2306	2306
9	1168	1168	1168	1168	1168	1168
10	592	591	591	591	591	591
11	300	300	299	299	299	299
12	152	151	151	151	151	151
13	77	77	77	77	77	77
14	39	39	39	39	39	39

ELEPHBUT 2 WHITE BASS

AVERAGE LENGTH IN MM IN LATE SUMMER

AGE CLASS	1974	1975	1976	1977	1978	1979
0	152	183	183	183	183	183
1	259	274	310	310	310	310
2	333	336	345	367	356	359
3	381	384	385	389	396	391
4	417	415	416	416	413	420
5	442	439	437	438	433	432
6	442	458	456	453	450	448
7	442	458	470	468	463	461
8	442	458	470	479	475	472
9	442	458	470	479	486	483
10	442	458	470	480	486	492
11	442	458	470	480	486	492
12	442	459	471	480	486	492
13	442	458	470	479	485	491
14	442	458	470	480	486	492

Figure 8. Among the detailed fish data provided in Option 4 of the results menu is the number and length per age for each fish species. In this example white bass is shown for Elephant Butte Reservoir.

COCHITI

TOTAL NUMBERS PER HECTARE

	1974	1975	1976	1977	1978	1979
1 LARGEM BASS	10.6	119.7	158.4	206.8	233.2	252.5
2 WHITE BASS	130.0	27.3	44.6	56.5	63.7	38.8
3 WALLEYE	24.0	6.8	12.8	19.2	28.2	18.4
4 SUNFISH	228.7	68.7	176.5	283.2	300.4	195.0
5 CRAPPIE	187.0	90.1	228.3	255.1	263.2	157.0
6 CATFISH	33.7	6.6	170.1	236.2	134.1	397.4
7 N. PIKE	4.8	0.8	0.7	0.7	0.7	0.8
8 RAINBOW TRT	43.6	3.6	697.4	562.5	309.8	267.5
9 BROWN TROUT						
10 KOKANEE SAL						
11 LAKE TROUT						
12 SMALLM BASS	33.9	6.5	13.1	97.4	51.7	256.0
13 STRIPE BASS						
14 LNGNOSE GAR						
15 BULLHEAD						
16 YELLW PERCH						
17 CARP,SUCKER	507.6	85.2	93.3	112.8	117.3	114.6
18 WHITE SUCKR	236.0	24.7	451.0	692.4	654.4	471.9
19 GIZZARD SHD						
20 THREADFN SH						
21 GOLDEN SHIN						
22 CYPRINIDS	132.5	22.5	54.4	42.7	44.0	12.5
23 SMELT						
24 CRAYFISH	1873.7	70.2	22.2	8.4	2.7	1.0
SEPT 30 AREA HA	121	691	753	726	797	663

TOTAL NUMBERS FOR ENTIRE LAKE

	1974	1975	1976	1977	1978	1979
1 LARGEM BASS	1278	82752	119311	150225	185828	167367
2 WHITE BASS	15701	18886	33622	41043	50739	25682
3 WALLEYE	2900	4696	9677	13918	22453	12180
4 SUNFISH	27630	47510	132952	205682	239359	129251
5 CRAPPIE	22587	62278	172014	185261	209700	104058
6 CATFISH	4066	4539	128125	171552	106852	263390
7 N. PIKE	580	551	519	533	541	530
8 RAINBOW TRT	5264	2491	525476	408561	246856	177319
9 BROWN TROUT						
10 KOKANEE SAL						
11 LAKE TROUT						
12 SMALLM BASS	4099	4497	9861	70762	41218	169637
13 STRIPE BASS						
14 LNGNOSE GAR						
15 BULLHEAD						
16 YELLW PERCH						
17 CARP,SUCKER	61317	58880	70272	81920	93482	75925
18 WHITE SUCKR	28506	17100	339809	502875	521389	312761
19 GIZZARD SHD						
20 THREADFN SH						
21 GOLDEN SHIN						
22 CYPRINIDS	16009	15571	41009	30997	35049	8297
23 SMELT						
24 CRAYFISH	226344	48488	16707	6085	2153	643
ALL SPORT FISH	18187	99526	792969	815551	603748	790423
ALL PAN FISH	65918	128674	338588	431986	499798	258991
CARP, SUCKERS	89823	75980	410081	584795	614871	388686
ALL OTHER FISH	242353	64059	57716	37082	37202	8940
ALL FISH TOTAL	416281	368239	1599354	1869414	1755619	1447040

Figure 9. Density (number/hectare) and total numbers are provided for all species present in Cochiti Reservoir. The first column is equivalent to the initial density either used as the default value (as shown here) or equivalent to what was entered by the model user. The Elephant Butte display is not shown here.

COCHITI

HARVEST PER ANGLER DAY

	1975	1976	1977	1978	1979
1 LARGEM BASS	0.003	0.001		0.003	0.001
2 WHITE BASS	0.210	0.222	0.470	0.387	0.488
3 WALLEYE	0.020	0.040	0.115	0.130	0.252
4 SUNFISH	0.004	0.003	0.001	0.035	0.007
5 CRAPPIE	0.018	0.015	0.003	0.013	0.003
6 CATFISH	0.010	0.005	3.308	3.098	1.496
7 N. PIKE	0.001	0.001			
8 RAINBOW TRT	0.026	0.232	0.034	1.176	1.695
9 BROWN TROUT					
10 KOKANEE SAL					
11 LAKE TROUT					
12 SMALLM BASS	0.007	0.006	0.001	0.001	
13 STRIPE BASS					
14 LNGNOSE GAR					
15 BULLHEAD					
16 YELLW PERCH					
17 CARP,SUCKER	0.118	0.208	0.208	0.170	0.100
18 WHITE SUCKR	0.014	0.004	0.001		0.094
19 GIZZARD SHD					
20 THREADFN SH					
21 GOLDEN SHIN					
22 CYPRINIDS					
23 SMELT					
24 CRAYFISH					

Figure 10. The daily catch rate for each species is one of the many fish outputs available.

Scenario 1. Reference Conditions in 1975-79.

Description

This scenario simulates the hydrology, biology and economic benefit of anglers from 1975-79 using the historic water regime, stocking records and regulations. At that time, 50,000 acre-feet minimum was stored in Cochiti Reservoir. This scenario will provide a reference for comparisons to a modified storage with a 100,000 acre-feet minimum in Cochiti Reservoir.

How to Run the Scenario

The first screen display gives a brief description of the model version and provides a choice of river basins. You must know where the reservoirs to be modeled are located. For this scenario, Cochiti and Elephant Butte Reservoirs are in the Rio Grande Basin so Option 1 is chosen to answer the question "Which River System?" The model then creates transient files, necessary for scenario development. This takes about one minute, then the BEGINNING menu appears on the screen.

From the BEGINNING menu, go to the first SCENARIO menu by selecting Option 8. Four options are provided in the first SCENARIO menu. Options 1 and 2 provide background information about the scenario menu, whereas Option 3 allows you to establish which reservoirs will be modeled. Option 9 allows you to return to the beginning menu. Choose Option 3.

For this scenario, you will choose Options 4 and 5 representing Cochiti and Elephant Butte Reservoirs. Enter both numbers, remembering to enter a space between them: **4 5**. Next you are asked if you wish to run the tailwaters. For this scenario enter **N** for **No**. Then you must enter the first year to be modeled, 1975, followed by the number of years, **5**, to be run in sequence.

The next screen will confirm the time and place to be covered by the simulation: **Cochiti and Elephant Butte from 1975-1979**. You are finished with the place and time because your answer to the next screen question is **N (NO)**. The model linkages are then assembled and the SCENARIO menu is displayed.

For this run you wish to create a reference using historic hydrologic condition stocking and regulations. Therefore, you will not want to change hydrologic variables (Option 5) or economic variables (Option 7). Because you want to introduce the historic stocking rate and regulation, you choose Option 6 to change the biologic variables. Otherwise, the model run will assume there was no stocking or regulations.

The new screen that comes up, when Option 6 is entered, offers a variety of possible biological modifications. Among them, Option 3 allows you to stock and regulate as done historically. Choose it. A message should appear on the screen confirming the action taken. Because no other changes are desired, you enter Q to return to the main SCENARIO menu. Enter **Q**.

Now you wish to proceed to the menu to run the model; Option 8 is the appropriate choice.

The MODEL.RUN menu allows you six alternative combinations of the hydrologic, biologic, and economic submodels. The most complete run (Option 2) includes all three submodels linked. Although it takes the longest time to run, it is often the best sequence to run for general purposes. For more specific purposes, each of the submodels may be run alone. Choose Option 2. The screen should indicate model run operations step by step. Depending on the computer used, this run will take about 15 to 30 minutes to complete.

Viewing and Printing Results

After the model has completed its run, you will be cued on the screen to **continue.** Depress **Enter.** The Results menu is now displayed. You have a number of option choices to display general results (Option 2) and more specific hydrologic (Option 3), biologic (Option 4), and economic (Options 5 and 6) results. Figure 6 shows some of the general results. Other results, not shown here, provide information about stocking and regulation and water regimes. Figure 7 shows some of the graphics provided from the hydrologic option. In total, 13 choices are possible. Figures 8, 9, and 10 show some of the detailed results for the biologic model. Try other choices and view them for yourself. You probably will wish to print the results in order to compare more readily the reference scenario and the management scenario. When you are asked whether to PRINT or NOT, press Y (YES). Be sure the printer is turned on and ready.

Scenario 2

Description

This scenario simulates the effect of an alternative water management scenario. Instead of holding a minimum pool at 50,000 acre-feet, as is now done in Cochiti Reservoir, a 100,000 acre-feet pool is proposed. What will be the effect as measured by comparison with the reference run?

How to Run the Scenario

It is not necessary to start the model at the beginning choice of river basins because the comparisons are to be made within a river basin at the same sites. The SCENARIO menu is called up by either Option 9 or Q, depending on which menu you have on the screen. If, however, you restart the computer, follow the same directions as you did for the first Scenario, described above to get to the BEGINNING menu. From the BEGINNING menu, select Option 8 and go to the SCENARIO menu. Of the four options made available in the SCENARIO menus once again select Option 3. The screen display shows you that Cochiti and Elephant Butte are still identified for year 1975-1980. Therefore, you do not need to change the reservoir configuration or the years and you answer N (NO) to the screen question asking if you wish to change site or year.

After model linkages are assembled, the scenario menu returns to the screen. Because you have already inserted historic stocking and regulations you need not insert them now. Thus, you may bypass Option 6, the biologic variables. You will not need to change any economic variables either (Option 7).

Option 5 (changing hydrologic variables) must be chosen to change the minimum pool. The screen display offers three options, Option 2 is appropriate. The Initial Volume of the reservoirs for the run is left as it was by pressing the Enter Key.

You are provided an opportunity to change the reservoir's maximum volume. Because that is not part of the scenario you should bypass that option.

Next you are provided the opportunity to change the minimum pool size from 50,000 acre-feet to 100,000 acre feet for each month of the year. This change keeps the minimum pool size from falling below 100,000 as long as enough flow sustains the volume.

You are given the opportunity to change other basins. Because there are no others to be changed, you enter N (No) and return to the main SCENARIO menu.

You are now ready to proceed to the menu to run the model; Option 8 is the appropriate choice. From the MODEL.RUN menu you again choose Option 2 to maintain the comparison with the reference scenario (Scenario 1). Once again, the model run will take 15 to 30 minutes to complete, depending on your hardware.

Viewing and Printing Results

Follow the same procedures as for Scenario 1, the reference scenario. Only the general results are presented in Figure 10 for comparison to Figure 5. The differences in the output values are measures of the management effect of instituting a new 100,000 acre-feet minimum pool.

Other Results Options

View the other results options available to you. There are numerous sources of additional information. You may or may not need them, but familiarization may suggest scenarios you had not previously considered.

SECTION IV. IMPORTANT MODEL INPUTS

Overview

The model requires input values to simulate reservoir fisheries. The model input values within RIOFISH are either inaccessible to you (they are fixed), or you can control them (user-controlled). The user-controlled input variables allow you to design planning scenarios to estimate the effects of your management strategies on model outputs. The following section describes both kinds of variables in more detail.

User-Controlled Hydrologic Inputs

Beginning reservoir volumes

The volume of a reservoir is expressed in acre-feet. 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 reservoir volumes

Maximum reservoir volumes are the maximum allowable acre-feet that can be contained in a reservoir 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, if you want to model a maximum volume of 200,000 acre-feet for Elephant Butte in April, you set the April value at 200,000.

Minimum reservoir volumes

Minimum reservoir volumes control the minimum acre-feet 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. If you want the minimum volume of a reservoir to be no lower than 50,000 acre-feet in June, for example, set the June minimum volume at 50,000 acre-feet.

Inflow multipliers and constants

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, 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. For example, to examine the effects on Elephant Butte of withdrawing 5,000 acre-feet of inflow from the Rio Grande in June, July, and August, set the value of b at

$$\frac{-5{,}000 \text{ A-F}}{(30)\ (1.98)} = -0.84 \text{ cfs} \qquad (2)$$

where A-F = acre-feet

cfs = cubic feet per second

30 and 1.98 = the conversion values used to change acre-feet to cubic feet per second

The minus sign indicates that this is a reduction in flow. Reducing the inflows also changes the reservoir 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

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 reservoir. Outflow 1 represents the main outflow channel (the river), and outflows 2 and 3 represent any other withdrawals from the reservoir, such as through irrigation channels.

For example, if you want to examine the effect of a proposed irrigation withdrawal from Elephant Butte Reservoir (similar to the example presented above), you could use outflow 2 or 3 to represent the withdrawal. In this case, you would set the monthly constant, a, of the period modeled to withdraw the specified amount of water for each month modeled. However, if you want to examine the overall effects of decreasing the outflow in Abiquiu Reservoir by 5 percent, you would set the value of the multiplier, b in equation 1, at 0.95 for each month modeled and apply it to the only existing outflow.

Fixed Reservoir Input Values

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

- 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.

Pan coefficients

Pan coefficients relate the evaporation from the Class A pans located at 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 used value. A pan coefficient at 0.7, however, may not accurately reflect the evaporation regime of the lake. Therefore, the pan coefficients can be changed as better information becomes available.

Elevation-area-contents

Elevation-area-contents are lists of corresponding reservoir surface areas and contents calculated at 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

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 to estimate 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 may have effects on the downstream river flow. In order 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 1983. These values will be changed as the database is updated.

Fixed River Values

All of the hydrological values for the river simulations within RIOFISH are fixed and unavailable for 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 roughness of the bed. There are also coefficients for expressing the relationship

$$P = aA^b \tag{4}$$

where
P = the wetted perimeter in feet
a = the coefficient
A = the cross-sectional area of the channel in square feet
b = an exponent

These inputs are 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. In order 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

$$Q_r = a + bQ_u$$

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 1983. These values will be changed as the data base is updated.

User-Controlled Biologic Values

Nutrients and suspended matter

The values for nutrients and suspended matter can be used to examine the effects of increasing or decreasing concentrations of the four primary water-quality components in RIOFISH. For example, if you want to examine the effects of a 10 percent increase in the phosphorus concentration at Elephant Butte Reservoir, you would change the phosphorus value by 10 percent of the existing value in the inflows. Similar changes can be made for nitrogen, organic carbon and suspended solids.

Each season has an assumed constant value for the mean concentration of nutrient, suspended solids and organic matter entering each reservoir from river flow and from the adjacent watershed. These values are based on data obtained from USGS and other sources. For each season, the concentration is multiplied by the discharge.

Therefore, the seasonal organic loading varies only as a function of the variation in discharge.

The watershed contribution is the third inflow to all reservoirs. Concentrations of materials in watershed inflows are much higher than concentrations in river inflows. Years with high estimated watershed inflows contributed greatly to the material concentrations. In many years, little water or material is contributed by the adjacent watersheds. You may vary both the estimated watershed inflow and the material concentration.

Solar Radiation and Temperature

Each season has an assumed constant solar radiation and water temperature. The values used in RIOFISH are averages derived from weather records. You may vary both values to create different climatic effects or to create a constant environment for analysis of specific population questions.

Stocking

You can modify fish populations by stocking. Fish can be stocked by type and size (fry, fingerling, or catchable) by semi-season. The stocked fish are assumed to behave exactly like the same species and size of fish in the water at the time of the stocking. No difference in mortality or food competition is assumed.

Harvest Regulations

Length and numerical limits for sportfish species can be introduced to the fish populations included in RIOFISH. Length limits can be set as minimum, maximum, or slot limits.

Initial Fish Population Structure

You can introduce new estimates of total fish density in the reservoirs. When you change fish density, be aware that the estimates at the beginning of the scenario are not likely to be in equilibrium with the modeled environmental conditions at that time. Therefore, some period of adjustment may be needed to allow your initial population estimates to come into "equilibrium" with the modeled conditions. The length of equilibrium time needed depends on how close the initial population estimate was to equilibrium.

In fact, because conditions are continuously changing in the modeled habitat, there is no true equilibrium condition and there is no way one can be created without holding habitats and angler effects constant. You can create constant conditions if you wish to examine population behavior in response to changes in population parameters. Otherwise, the last years in a modeled sequence are most likely to reflect modeled conditions.

The fish populations that occur at the end of a model run may be introduced to a subsequent series of years. The entire 12-year period can be simulated by reintroducing fish populations after each run. If 5-year runs are used, the entire 12 years of the hydrological record can be simulated with two end-of-the run introductions.

Fish Population Parameters

The model user may change fish population parameters to check their effects on fish population dynamics or to create a more realistic fish population when improved data becomes available. You can also create your own species, one not presently in the model, by changing parameters of a fish species found in the model. For example, freshwater drum may be introduced to Caballo Lake by changing the parameters of rainbow trout or any other species not found in Caballo Lake, to fit the population parameters of freshwater drum. You must record the change in species because you cannot change the name of any species in the model. It is possible to create entirely new fish communities by this method.

Mortality rate. The natural mortality rate (non-fishing mortality) for fish older than age 0 may be changed by the user. The mortality rate is assumed to be constant over all age groups older than age 1.

Fish kill refuge. Some species of fish are killed by excessively high temperatures (trout, salmon) or excessively cold temperatures (threadfin shad) when there is no tolerable zone remaining in the modeled lake. Low oxygen precludes zone use by trout when temperatures are tolerable. You can influence the fraction of fish killed to simulate a partial kill.

P/B for larvae, juvenile and adults. The annual maximum production/biomass ratio distributes fish production among different age groups in a fish population according to a maximum expected growth rate. The P/B is higher for larval fish than for juveniles or older fish. The P/B decreases with age much as survival curves decrease. You may change the P/B as improved data becomes available or to analyze the effect on fish population dynamics.

Sex Ratio. The sex ratio of adult fish in RIOFISH is assumed to be 1:1. You may change the sex ratio.

Sexual maturity weight. The weight of female fish at sexual maturity is needed to estimate the reproductive potential. You may change the maturity weights now included in RIOFISH.

Water-level Fluctuation effect on egg mortality. The egg mortality of each species is related to intrinsic natural mortality in stable waters (the intercept value) and the degree that changed water levels expose eggs to lethal conditions. You can control natural egg mortality (line intercept) and waterlevel effect (line slope).

Larval growth rate. Fish larvae die of starvation in RIOFISH. If the larvae do not grow to juvenile size within a semi-season (six weeks), they die. The probability of death in RIOFISH is determined by production of zooplanktonic food available and the amount that larvae must grow to reach juvenile size within the semi-season. All larvae in the model reach juvenile stage at the same size. The initial size of the larvae upon yolk-sac absorption determines the growth needed to survive the six-week period. You can adjust both the initial size and the growth rate (the final larval size divided by initial larval size) of the larvae

Minimum juvenile survival weight. Juvenile fish have to reach a minimum weight to survive the winter of their first year of life. If they do not reach that size, they starve and increase the natural mortality. You can change the minimum size required to survive to Age 1.

Harvestability. A fish's harvestability or catchability determines the likelihood of fishing mortality. The harvestability value is determined by the intensity of fishing for the species, the ease of capture and the retention of the fish once caught. In practice, the harvestability is estimated by yield divided by catchable fish density. You can change the harvestability parameter. Doing so increases or decreases kept catch rate for the density of fish present.

Minimum catchable size. This is the smallest size normally caught by fishing. You can adjust the value.

Compensatory mortality. Past estimates of the effects of fishing on total mortality vary from totally compensatory (fishing ultimately replaces all natural mortality without adding to mortality) to completely additive (fishing mortality adds to natural mortality without compensation). RIOFISH assumes compensatory mortality until you adjust it. You can adjust the degree of compensation along a continuum from 1 to 0.

Spawning season. The seasons of fish spawning can be changed by the model user.

Fecundity. You can change the egg number/kg represented in RIOFISH.

Initial fish population lengths. You may adjust the mean length of each age class.

Fish length-weight relationship. The user can change the length-weight relationship for each population. The relationship is assumed to be the same for all ages of fish.

Competition coefficient. Fish in different age categories of different species may feed on the same foods. If the different fish groups are equally competitive, they would have equal competition coefficients and share the food in proportion to their biomasses and P/B ratios. When one group has a competitive advantage over another the competition is represented by a range from 0 (no competitive advantage) to 1 (most competitive). You can adjust the competition coefficients.

Biomass fraction. Fish species are distributed in different habitats of the lake in different patterns. In RIOFISH, for example, sunfish are restricted to the littoral zone. Other species occur in most zones but in different relative biomasses. You may adjust the proportions of each fish in the five reservoir habitats (littoral, sublittoral, profundal, limnetic and pelagic).

User-Controlled Economic Inputs

Recreation Site Characteristics

Reservoir volume. You can modify average summer volume (acre-feet).

Reservoir area. You can change average summer surface area (acres).

Accessibility. You can modify the percentage of a reservoir's shoreline that is accessible by either car or foot.

Number of concrete boat ramps. You can change the number of available concrete boat ramps on a reservoir.

Fishing quality. You can increase or decrease the fishing success rate per unit effort for sport fish (trout, bass, northern pike and walleye).

Angler Population Characteristics

County population. You can change county population and thus impact the number and distribution of angler visits across all sites.

Fraction of county population who are anglers. You can modify this parameter to again change the number of angler visits and their distribution.

Urban density of county. You can change the fraction of county population living in urban areas.

County population. You can change county population to alter the number and distribution of angler visits across all sites.

State population. You can change state population to alter the number of angler visits. The fraction of anglers will remain constant.

Factors Affecting the Cost of Fishing Trips

Site use fees. You can control user fees by imposing a new fee on a site, or you can raise or lower existing fees. When you impose a new fee or raise an existing fee, the number of visits to that site will decrease, but this will be partly offset by an increased number of visits to other sites. Anglers will receive less total benefits from all sites when a fee is imposed or increased at any site.

Travel cost. You can change travel cost per mile to affect visit rate and benefit. Travel cost includes a dollar value for travel time as well as the vehicular costs, gasoline and other operational costs and a fraction of the total travel cost.

Fishing Trip Data

You can see the number of per capita trips from a given county to a given site. Per capita trips are determined by 1) county-site proximity and 2) site quality. Per capita trips are sometimes negative because predicted model results are shown instead of observed values.

You can also see the number of per capita trips from a given county to all substitutes for a given site. This number represents the intensity of competition facing a given site.

SECTION V: MODEL USES

Main Uses

The main uses of RIOFISH include

- forecasting planning environment effects
- formulating realistic but challenging objectives
- expanding inventory estimates
- issue management
- operational planning budget allocation
- self-teaching
- sensitivity analysis.

RIOFISH is first a planning system model. Because of its capacity to track many simultaneous processes and their interactions, RIOFISH helps identify complementary and counteractive trends in proposed planning procedures. The model is best used as one of several planning aids. For most effective model use, the user should be familiar with contemporary planning principles. For any planning approach, objectives need to be formulated in terms of some measurable outcome that is compatible with planning goals.

Fishery management agencies use a variety of indices to evaluate their management impact on objective accomplishment. Some of the most commonly used are outputs of RIOFISH, including

- fish catch rate
- fish total yield
- angler recreational days

- catchable fish stocks
- fish forage production
- habitat potential for productivity
- angler economic benefit

Forecasting Planning Environment Effects

RIOFISH is sensitive to many of the environmental factors that determine fishing opportunity, angler participation, and angler distribution of effort. Among those factors included in RIOFISH are

- travel cost
- total human population
- fish catch rate
- total water surface area
- road access to fishery
- boat ramp access
- condition at substitute sites

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 has a dynamic planning environment, no one future can be predicted reliably. Based on past history, the probability of change can be estimated, thus 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.
- Per capita income could decrease as much as 0.5 percent per year or increase as much as 5 percent per year.
- Water surface area could be sustained at a maximum surface area near 120,000 acres or fall to as low as 25,000 acres.
- Real travel costs could remain low or increase as much as two times present costs.
- Certain reservoirs could be built, others could be drained or closed totally and certain waters could be diverted to decrease, maintain, or increase site surface areas.
- Certain roads could be built that would allow access to fishable waters; others could be closed.
- Catch rate could be lowered or increased based on certain water management decisions or natural events.

Certainly among the possible future events, four variables stand out as having major potential impacts:

- human population growth
- travel costs
- real income
- statewide water-surface area.

A simultaneous leveling of human population growth, decrease in water surface area, increase in travel cost, and decrease in real income would decrease angler participation and management revenue. Alternative combinations of events could increase angler participation and management revenue. RIOFISH can be used to evaluate any projected combination of events for factors that are included in the model.

Formulating Objectives

Objectives should be challenging but attainable. Unrealistic objectives guarantee failures. Objectives formulated for a planning environment that is greatly different from the future that emerges are not likely to be realistic. Therefore, planning objectives should be designed for any of the probable futures that may emerge. For example, the objective "increase 1988 angler days over five years to 50 percent greater when population growth is high" could be modified to a more appropriate scenario when low-growth conditions appear probable: "keep 1988 angler days from falling more than 20 percent when human population growth is slow."

An alternative 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, an average objective accomplishment can be identified for accomplishment over the planning horizon.

Expanding Inventory Estimates

State fishery resources inventories usually are estimated by sampling a small fraction of the entire state resource. RIOFISH enables estimates of over half of the New Mexico statewide fishery resource and habitat conditions in those fisheries. 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.

RIOFISH will improve as an inventory aid as estimates of resource densities and population parameters improve. Using field data from selected sites, the populations are calibrated for particular years throughout the fishery. Choice 2 in menu 4 is a summary output useful for general inventory information.

It provides information about the state of

- water levels
- water volumes
- water surface areas
- exchange rates
- organic loads
- forage production
- catchable fish stocks
- catch rates
- angler activity

Issue Management

RIOFISH is useful for analyzing the potential for issues to grow into more critical proportions. Recent examples of such real New Mexico issues have included the potential dewatering of Ute, Caballo, and Pecos River reservoirs; the role of striped bass in Elephant Butte Reservoir; a threadfin shad kill in Elephant Butte Reservoir, and a decreased kokanee salmon catch rate in Heron Reservoir. The model may be used to estimate how much angler activity and economic benefit are involved potentially, 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.

Operational Planning - Budget Allocation

RIOFISH provides economic benefit estimates that may be contrasted with proposed management strategy costs in order to evaluate the most cost-effective disbursement of moneys to operations that will obtain management objectives. In practice, strategic planning analysis (in which realistic objectives are formulated) and operational planning (in which the most cost effective budgets are developed) are integrated in a combined analysis.

Planning Sensitivity Analysis

The sensitivity of RIOFISH outputs to various changes made in the model is a useful tool for directing information gathering, ranging from routine 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. Planning results needing evaluation most critically usually are those with the least benefit-cost attached to them.

RIOFISH allows the benefits side of the equation to be estimated; the manager-user needs to estimate the management cost. Using planning sensitivity analysis, planning evaluation can be focused on those strategies judged to have the most impact.

The model also may be used to diagnose those parts of the model needing improvement most critically. This research sensitivity analysis enables identification of those statistically uncertain model values that have the greatest effect on model outputs.

Self-teaching

Fish population dynamics and their interactions with habitats and anglers are complex and difficult to visualize in field circumstances. Usually only the field result is recognized in the form of indices to fishery status. Many of these indices are the focus of routine fisheries inventory or original research. Such indices include:

- condition factor
- length-weight relationship
- growth rate
- relative weight
- proportional stock density
- sex ratio
- age ratio
- recruitment rate
- predator-prey ratio
- fecundity
- mortality rate
- morphoedaphic index
- Jenkin's production index

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 "meaning" of indices -- i.e., what they indicate (or do not indicate) in the modeled populations.

RIOFISH allows fishery managers to do things to the modeled fisheries that are impossible in real fisheries. For example, habitats and angler activity can be held absolutely stable (or done away with in the case of anglers), and population dynamics may be analyzed in such circumstances. Many fishery indices and techniques assume unrealistic stability of the planning environment.

RIOFISH can be used to test the affects of assumption violations on the value of fishery indices. Using the model as a tool, managers can learn limitations inherent in various indices and become more skilled in the application of indices.

Setting up the Reference

A minimum of two model runs are needed to make meaningful use of RIOFISH -- a reference run and a scenario run. 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 planning environment or the fishery. The user can rely on the references provided in RIOFISH, or create a reference of his or her own. It is not important that the reference represent an actual historical condition. In fact, it is impossible to recreate an actual historic condition; even with the best data, uncertainty will preclude that possibility. RIOFISH, like any model, is a simplified simulation of what is intended to be the most important elements of the fishery planning system.

The modelers have concentrated on making the responsiveness of the reference condition to model changes representative of the degree of change one might expect in the real world. To do this an "if--what" statement is defined. "If the modeled fishery has the modeled attributes, what will be the change in angler benefits when an attribute is changed by x amount?" This "if--what?" run should 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, a response curve can be developed and the most desirable combination of outputs can be used to determine which strategy is preferred. Although reality in the reference is not critical (and probably is impossible), the model user should attempt to make the model reference as realistic as possible by changing the modeled reference conditions to fit the prevailing perception of reality. It is important, however, to maintain the same reference state for all comparisons, once the reference has been altered.

Selecting the Contrasting Outputs

The selection of appropriate output is critical. If the model user wishes to maximize angler satisfaction, he or she needs to select outputs most representative of satisfaction, such as angler days of activity or economic benefit. Measures of catchable fish stocks represent fishing opportunity; that opportunity may not be used by anglers if there is no access to the fishery. Actual angler use and angler benefits arising from that use usually are the preferred measures of fishery objectives accomplishment. On the other hand, if the question relates to improved understanding of yield regulation (e.g., what is the effect of water-level stability on the morphoedaphic index to fish yield?), the fish yield is the output of interest.

An output value may be more meaningfully interpreted when a suite of outputs is provided, representing the general condition of the fishery. These general outputs are provided in choice 2 of menu 4 (the RESULTS menu) of RIOFISH. More specific outputs are available as well for in-depth heuristic or diagnostic purposes.

The outputs can be arranged in a table like that shown in Table 2, which analyzes differences in output generated by model changes made with respect to the reference.

Table 2. Examples of output values for last year, 1987, of a five-year run (1987) when Heron Reservoir is stocked at different rates than it actually was stocked (reference run).

	Stocking Rate				
	0.1x	0.5x	1x (reference)	2x	10x
Catchable Sportfish	44.0	59.0	70.0	78.0	83.0
Catch rate (no/hr)	0.54	0.99	1.11	1.21	1.82
Angler days	85,214	89,382	93,540	99,495	108,393
Angler benefits ($1000)	133,634	133,748	133,876	134,056	134,345
Estimated cost ($1)	23,000	115,000	230,000	460,000	2,300,000

Selecting Appropriate Dimensions

The time and space scales used in model runs is important to determine model output. Because fisheries are not independent either from year-to-year or from habitat-to-habitat, the model user may not make the best judgement of his or her management strategy impact by too restrictive a view of impact. For example, a stocking of fingerlings could have an impact on the fishery for several years and the full benefit of that stocking cannot be assessed without running all years affected by the stocking.

Also, if the stocking is made in one of a number of other angler substitute waters, the effects on the angler effort at the other waters cannot be assessed without taking a larger perspective. In fact, the effects of proposed management changes at a group of substitute sites are not necessarily independent in effect. It is up to the serious planner-model user to analyze the interaction of such effects through reiterative analysis. In this way the number of sites included as well as the duration of runs needed can be estimated.

Common Planning Concerns

Redistribution of stocking

Is an operational goal of management to redistribute stocked fish to increase statewide angler benefit? If so, RIOFISH can be used to estimate the most effective distribution of stocking for various water levels and angler population growth patterns. Another issue that can be addressed is the benefit of adding more total stocking capacity to the hatchery system.

Fish Introductions and Removals

Can sportfish production and angler benefit be increased by introducing new sport species or forage species? What are long-term benefits, if any? Are the long-term benefits enough to justify any risks that may be incurred (eg., endangering native species)? What effect would removal of certain fractions of the fish community have on benefits or opportunity? For example, would carp or shad removal by rotenone application increase opportunity or benefit, particularly in low-water years?

Watershed management practices

Although RIOFISH does not model watershed processes, it can be used to identify relevant questions about the effects of material loadings including

- total suspended solids
- total phosphorus
- total nitrogen
- total organic carbon

Estimates of how much each of these will be fractionally increased or decreased are valid concerns, and once obtained can be used to estimate impacts on downstream fisheries.

Managing access to fisheries

The effects of a proposed new road or new access fees can be evaluated with RIOFISH. If boats are to be banned, the effect may be evaluated indirectly by eliminating boat ramps. Expenditure of certain management funds dedicated to boat ramp construction can be analyzed for the best distribution of boat ramp installation.

Regulations

Fishing regulations usually are applied to increase sharing of fishery resources. Over-fishing may increase short-term angler/benefit but depresses long-term angler benefits. In under-fished waters, unnecessary regulations may reduce angler benefits. RIOFISH can be used to help develop the most useful regulations. It is assumed in RIOFISH that all regulations are obeyed.

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Water redistribution

Water is owned, bought, and sold in New Mexico. Laws require that water be stored in ways that protect the value of water for the water owners. Several such proposals have recently influenced New Mexico fishery management decisions and activities. RIOFISH can be used to assess the impact on fisheries of proposed water redistribution and the effect of alternative strategies useful for mitigating such impacts. RIOFISH also can be used to analyze for the best water storage strategies for fishery benefits within the range of storage options.

Coordinated planning

RIOFISH allows proposed fishery plans to be examined at the modeled sites over the plan duration. Variations of these plans can be analyzed to examine their effect on angler benefits.

Postscript

Much can be done with RIOFISH as it now stands, and more is planned for the future. However, RIOFISH has its limitations, and users should be aware of them.

All model results are affected by the data that were used for development and calibration. Some information is more accurate than other information. Research is continuing to refine the model structure and to improve the utility of the model for all major river basins in New Mexico and for watersheds with small tributaries and reservoirs.

Your comments about RIOFISH are welcome. As you use the model, you may identify limitations in accuracy and application. Comments forwarded to the address below will be used to help improve model performance.

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Fishery Management Model for New Mexico
Fishery Division
New Mexico Department of Game and Fish
State Capitol
Santa Fe, NM 87503

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