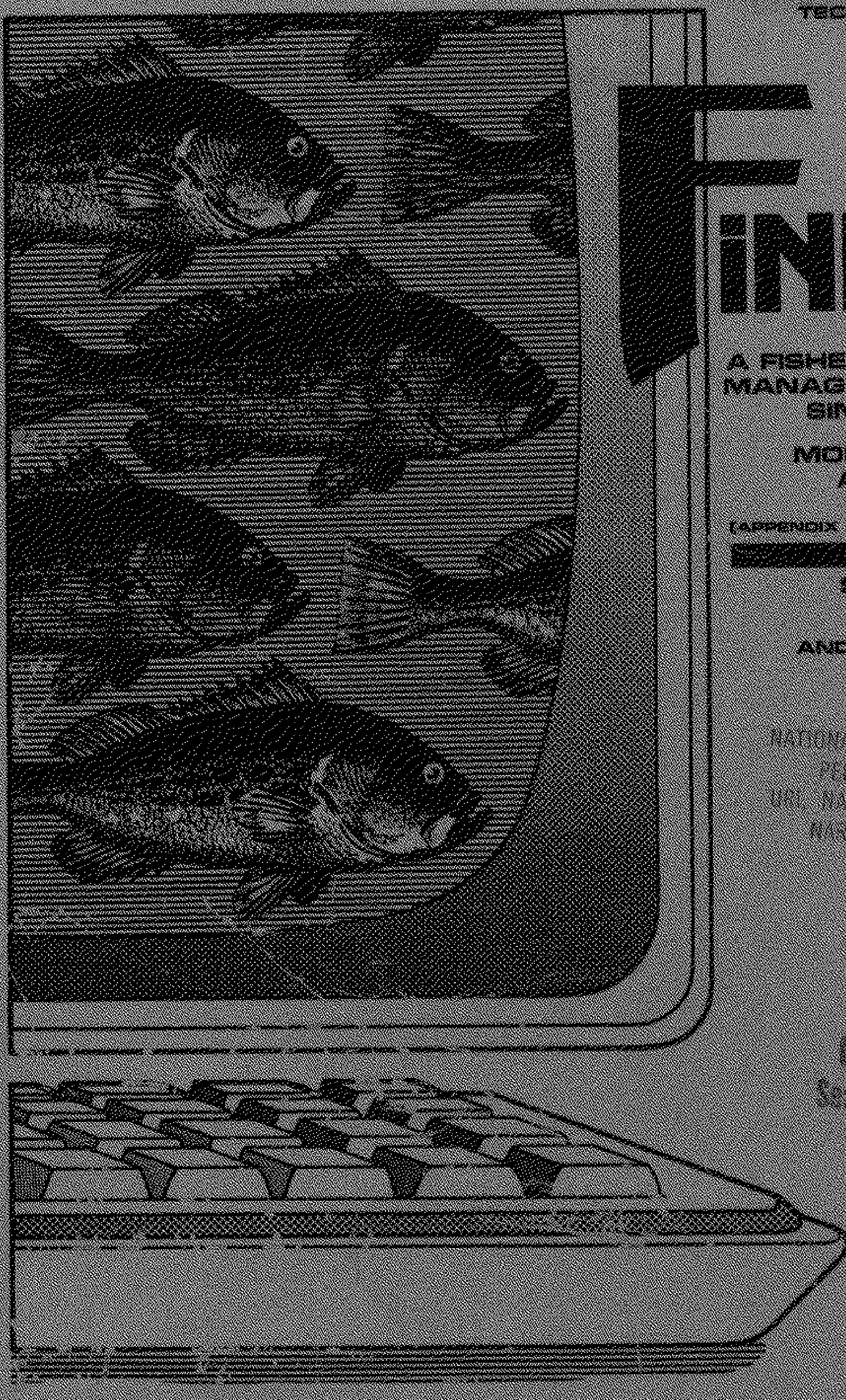
TECHNICAL PAPER #47-A



FINMAN

A FISHERIES INSTITUTION MANAGEMENT-TRAINING SIMULATION MODEL

MODEL DESCRIPTION AND OPERATIONS MANUAL

(APPENDIX TO TECHNICAL PAPER #47)

SEPTEMBER 1986

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SEA GRANT

FLORIDA SEA GRANT COLLEGE

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A Fisheries Institution Management-Training Simulation Model

MODEL DESCRIPTION AND OPERATIONS MANUAL

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ABSTRACT

FINMAN (Fishery INstitutional MANagement-Training Simulation Model) is a microcomputer-based program which simulates decision-making responses at three levels within the fishery management institution: (1) fishery management rules, (2) fishery agency general budget allocations, and (3) research budget allocations. The program also allows for a variety of fishery types, rule development structures, and levels of authority over the fishery. FINMAN serves as (1) an analysis program for investigating system responses, and (2) an educational program for demonstrating system responses under a variety of situations. The program is written in BASIC with versions available for the Apple IIe, Apple IIc and IBM-PC microcomputers.

1.0 Identification:

Program Name: **FINMAN** Verson 1.0*

Language: **BASIC**

Model description and operations manual for the University of Miami Fishery Institution Management-Training and Research Simulation Project: William W. Fox, Jr., Principal Investigator. By Jerald S. Ault and William W. Fox, Jr., CIMAS, Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, Florida. This work is a result of research sponsored by NOAA Office of Sea Grant, Department of Commerce, Florida Sea Grant College Program, under Grant No. E/C-8.

Designed for the **Apple IIe, IIc,** and the **IBM/PC** microcomputer systems. Program storage requirements are 128K in RAM (64K in ROM) and one disk drive; output is arranged for an 80-column display. Available versions are written in Applesoft BASIC (Apple computers) and Microsoft BASIC (IBM/PC's), and are user-interactive with specialized data base file manipulation features.

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*To obtain a copy of the program send one (1) blank two-sided 5 1/4" diskette or two (2) blank single-sided 5 1/4" diskettes, specifying the type of microcomputer you have, along with a prepaid return mailer, to the **authors** at Rosenstiel School of Marine and Atmospheric Science, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149.

2.0 Introduction

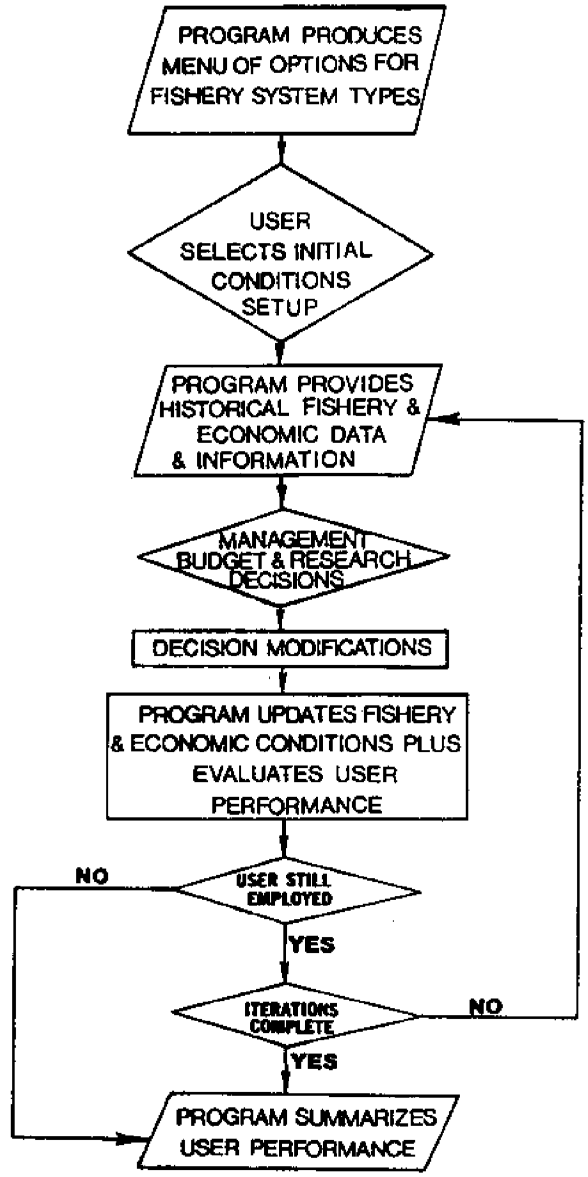
Fisheries worldwide are under increasing pressure for rigorous management policy due to competing uses for available oceanic resources from both commerical and recreational interests. Presently, with escalating resource usage, managers are increasingly pressured to make immediate decisions on the regulation and allocation of marine resources that have significant biological, economic and social impacts. Fishery management decisions are based on these complex variable systems. A successful fishery management institution builds resource-user confidence. Such "success" depends on the decisions made by fishery managers, fishery agency administrators and fishery research supervisors. Thus, managers, agency administrators, as well as research supervisors need to understand the complex relationships among these aforementioned impacts, and to anticipate situations which may arise.

An educational tool has been needed to assist students, professionals, and fishery management appointees in gaining experience making management and research program decisions. The objective of this work is to fill that need by presenting a numerical simulation model which allows examination of system responses to exploitation for a wide variety of aquatic life-history patterns while incorporating different management, social, and economic schemes. The simulation model examines the mechanisms involved in the evolution of a fishery system and can also be used to evaluate the expected transitional states from an annual fishery, as well as the expected equilibrium. It is also useful in that it demonstrates large-scale and often, counter-intuitive interactions.

Throughout the simulation sequence the user works interactively with the computer, selecting and modifying management plans, budgetary allocations and enforcement efforts in order to optimize the objective function, satisfy constituency expectations, and achieve appropriate biological and economic goals. These exercises provide the user: (1) clearer understanding of the inter-relationships between factors impinging on fisheries institutions, and (2) the impetus for considering the implications of effort strategies coupled with budgetary allocations in evaluating management alternatives. Thus, one can utilize the FINMAN model for planning, evaluating alternatives, and identifying sensitive areas of the system.

3.0 Model Flow Diagram and General Description

A flow chart of the age-structured simulation model is shown in Figure 3.0. The user's goal is to maximize the objective function through a utility function that allows comparisons of different manager's orientations and varying human attitudes, by preference orderings, towards management objectives. Survival of the user through all the iterations is based on probabilities influenced by the performance of the fishery and constituency "contentment". FINMAN allows the user to select among a series of options: (1) the species-type for management strategy simulation; (2) the management system type, (3) management scope or competence, (4) the fishing pressure pattern, (5) the level of recruitment variability, (6) the stock(s) existing condition, and (7) the extent of the fishery and economic information available. The program then generates the initial data and information set, including the situation the user is confronted with in terms of his continued employment, and queries the user on a series of budget and management decisions. To establish the constraints placed on management authority and abilities, a series of options are shown so that an initial conditions information base, used to make basic decisions regarding management measures and insitutional budget allocations, can be generated. These decisions include (1)



Flow Diagram of FINMAN

Figure 3.0: Flow Diagram of the Fisheries Institution Management - Training Computer Simulation Model FINMAN.

management measures to be implemented, (2) overall budget allocations among research, enforcement, and development, and (3) research budget allocations among data collection and analysis projects. The program then updates the history of the fishery management network. The precision and/or accuracy of the overall view of the state of the fishery is controlled in part by the budget allocations and particular management decisions. Since most processes have a stochastic element, the program uses chance variables in formulating each "annual" update. When the user's employment is terminated due to poor performance, or after a selected number of iterations is attained, FINMAN provides a summary of the user's performance.

4.0 Species-Type Modules for Management Strategy Simulation

The present version of FINMAN has six "Fish stock" life history types, each parameterized with economic, sociological and biological variable settings that typify fishery institution management frameworks for their respective fisheries. The available species-types for management strategy simulation strategy are (by section): Grouper (4.1), Tuna (4.2), Anchovy (4.3), Shrimp (4.4), Sciaenid (4.5), and Snapper (4.6).

The following narratives encapsulate the background information on these five species-types and set the stage for the management strategy simulation scenarios. The user has the ability to modify the life history and fishery specific information as necessary to gain a wider picture of the possible avenues of fishery response to exploitation and various management schemes.

One of the useful features of the FINMAN simulator is that it allows one to visualize approximate system response of a particular exploited stock, even when the fine details of the fishery system are not known. This situation is, of course, prevalent in developing countries and developing fisheries. For such situations, the user may approximate the unknown variables by "best guesses", transferring information from other similar but better understood fish stocks. In that way the investigator may study system responses to various parameter scalings to gain insight concerning system sensitivity; and to determine the envelope in which system responses are guaranteed to occur, and further disregard infeasible parameter and/or system space. In this regard, intuition may be gained with respect to developing or initiating prudent management alternatives for successful system evolution.

4.1 Gag Grouper, Mycteroperca microlepis

Groupers (Serranidae) form an ecologically and economically important component of reef fish communities. The term "reef fish" applies to a diverse category of co-occurring demersal and semi-pelagic fish often exploited as a multispecies complex. The gag grouper is an Atlantic province grouper which is recognized as an apex predator. It is a reef and continental slope dweller and is slightly migratory. In the United States Fisheries Conservation Zone both commercial and recreational fisheries are involved in their capture, and species associated with the continent suggest that these populations behave essentially as a unit stock. Gag Grouper have a relatively low natural mortality rate and are slow growers which reach a relatively large size (M/K = 1.639), with approximately 13 yearclasses in the fishable life span. Gag groupers are protogynous hermaphrodites, i.e., individuals mature as females but later transform to function as males. The FINMAN model explicitly considers the effects of either interspecific interaction or hermaphroditism and can be used to investigate the potential effect of protogyny on responses to exploitation and the population dynamics of groupers.

4.2 Yellowfin Tuna, *Thunnus albacares*

Yellowfin tuna (Scombridae) support extensive commercial fisheries in almost all the world's tropical and subtropical seas. The sex ratio of yellowfin is biased towards males at the older ages. The yellowfin tuna is considered an apex predator which inhabits the open ocean to nearshore pelagic waters. Yellowfin tuna have an intermediate natural mortality rate and are considered fast growers which reach a relatively large size (M/K = 1.333), with approximately 10 yearclasses involved in the fishable life span. The tunas are highly migratory, are esteemed for their flesh, and are pursued by many nation's fishing fleets thus making mangement of this species a complex task. Development of specialized fishing craft equipped with purse seines and large refrigeration systems for freezing and holding tuna aboard for long periods has permitted development of several distant-water fisheries. Both commercial and recreational fisheries involved in their capture.

4.3 Northern Anchovy, *Engraulis mordax*

Clupeoids, in general, are pelagic species which are known to concentrate in frontal and upwelling regions, areas which support a relatively large biomass of small pelagic fishes. These species often support major commercial reduction fisheries where the fishes are processed to provide fish meal and oil for other ancillary industries. Stock sizes fluctuate widely due to environmental factors, fishing activity, and competition among the species themselves during their early life history. Anchovies have a very high rate of natural mortality and can be considered intermediate growers which reach a relatively small size (M/K = 3.549). The sex ratio is biased slightly towards females. Seven year-classes are involved in the fishable life span. The anchovy is a primary predator, feeding extensively off dinoflagellate and micro-zooplankton blooms. The fishery is limited to the commercial sector.

4.4 Pandalid Shrimp

Shrimp have an intermediate natural mortality rate and are considered to have a low to intermediate growth rate, reaching a relatively small size (M/K = 1.997), with approximately 6 yearclasses involved in the fishable life span. Pandalid shrimps are protandric hermaphrodites -- i.e., individuals mature as males but later transform to function as females. Fertilization is accomplished through copulation, the females carry fertilized eggs 3-9 months until hatching, and they exhibit pronounced stepwise growth. The fishery for pandalid shrimps is limited to the commercial sector.

4.5 Sciaenid

Sciaenids form an ecologically important component of nearshore and estuarine fish communities throughout tropical and subtropical waters. The seatrout is a tertiary level predator feeding extensively on shrimps and small fishes. The seatrout is a coastal Atlantic and Gulf of Mexico coast fish that, in conjunction with others in the Sciaenid complex, comprises and important component of the commercial and recreational catch in the U.S. FCZ. The seatrout has a low to intermediate rate for both natural mortality and growth (M/K = 1.163), reaching a intermediate size spread over 12 year-classes in the fishable life span.

4.6 Snapper

Snappers form an important component of shallow reef, slopes, and nearshore communities in tropical to subtropical waters worldwide. Snappers are upper level carnivores consumming small fishes, shrimps, crabs and various molluscs. The snapper studied here has an intermediate natural mortality rate and an attendant low growth rate (M/K = 2.485), reaching a relatively small size in the 8 years of the fishable life span. Snappers have a sex ratio biased towards males at young ages, and then biased towards females at the older ages. Snapper fisheries typically support recreational and small commercial fisheries.

5.0 FINMAN Initial Conditions

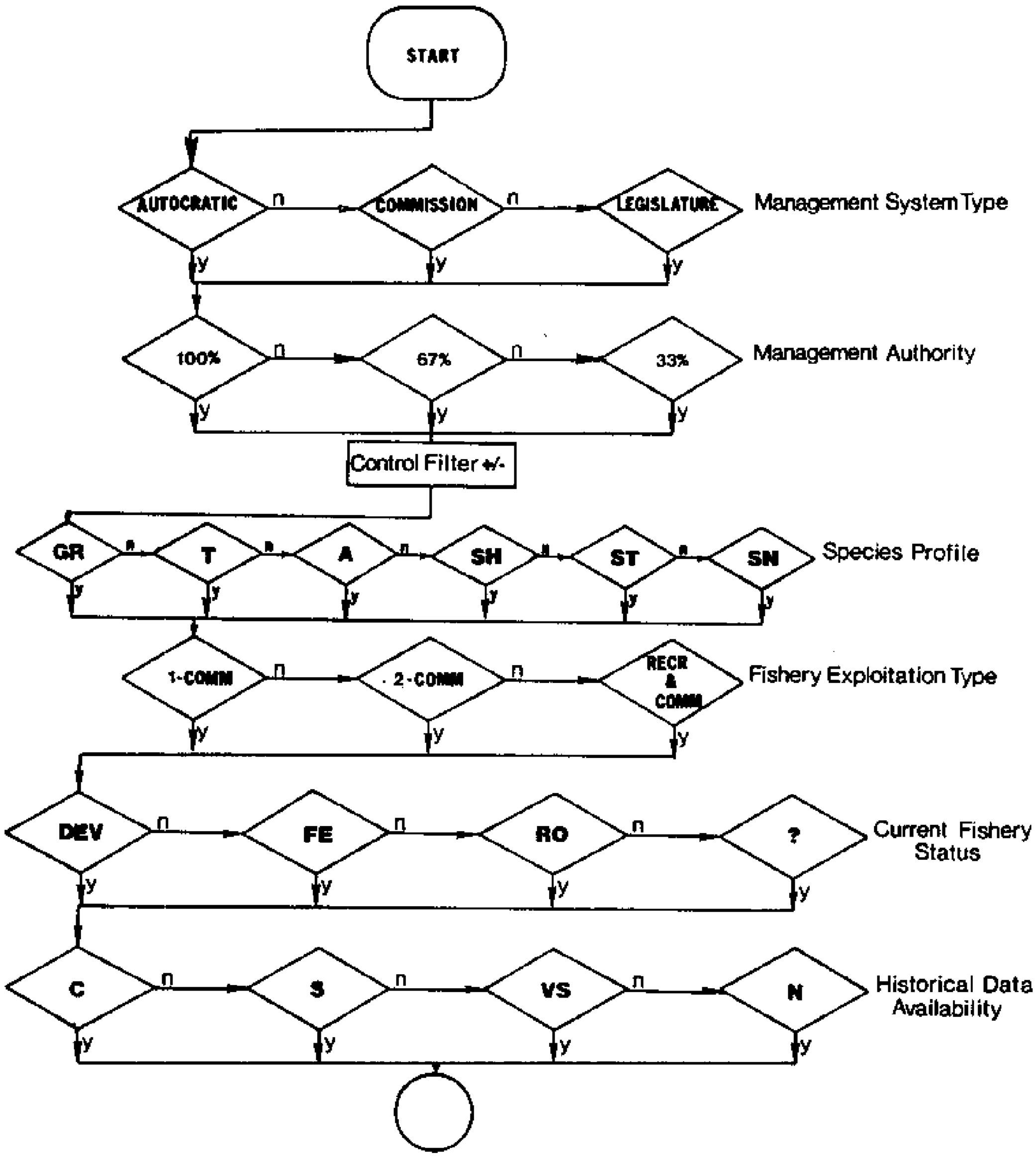
5.1 Starting Conditons and Option Selections for Management Scenário

FINMAN is characterized by several levels of complexity or difficulty for each of six different program elements. As the director of this management system you are able to select the degree of your ability to exert control over the actual implementation of management measures as you deem appropriate, both in terms of the political system through which management measures are enacted, and the degree of control exerted over the stock. To establish the constraints to be placed on your management authority and abilities within a particular fishery, you will be shown a series of options so that an initial conditions information base can be generated. The information base is used to guide basic decision processes regarding management measures and institutional budget allocations (Figure 5.2).

5.2 Options Sequence

5.2.1 Management System Type

This option allows you to choose 1 of among 3 types of fishery management structures. The management system types are ordered in ascending levels of complexity and difficulty for achieving optimum fishery management policy.



FINMAN Initial Conditions Setup

Figure 5.2: Flow Diagram of FINMAN Model Initial Conditions Selection Setup. GR = Grouper, T = Tuna, A = Anchovy, SH = Shrimp, ST = Seatrout, SN = Snapper, DEV = Developing, FE = Fully Exploited, RO = Recruitment Overfished, C = Complete, S = Sketchy, VS = Very Sketchy, N = None.

5.2.1.1 Autocratic

In this category your decisions for managing the fishery are 100% implemented. You hold independent and unlimited powers of government decision-making. However, these decisions are additionally filtered by other budget and policy decisions made by the user and their relationship to optimum.

5.2.1.2. Commission

You are a member of a body of persons authoritatively charged with stewardship of a fishery. You make recommendations on fishery institution management decisions. Your policy implementing power is limited to having one vote on a commission member board of seven individuals. Again, your recommendations are filtered by other policy and budget decisions.

5.2.1.3. Legislature

You are empowered to serve on a managing body who exercise the function of making or enacting laws; however, under this selection you strictly make recommendations, and implementation of your recommendation(s) is based on the strength of your constituency support, which dictates the controlling factor on the amount of policy recommendations that actually are implemented.

5.2.2 Scope of Management Authority Over Stock

This option allows you to set the level of your control of the unit stock of interest.

5.2.2.1. 100% Authority

This fishery is essentially a unilateral fishery management institution, i.e. one policy body for the stock management.

5.2.2.2. 67% Authority

This unit stock is shared with one other management entity where you have complete control of 67% of the stock. This is the case of the bilateral policy on a stock with overlapping distributional boundaries. The remaining 33% control is computed as a stochastic variable each iteration to determine your overall level of control.

5.2.2.3. 33% Authority

This unit stock is shared with two other management entities and you have control of only 33% of the stock. This is the multilateral policy case.

5.2.3 Fishery Exploitation Type

Your control over the type of fishery to be managed includes an array of choices ranging from:

5.2.3.1 Commercial (1 Gear Type)

One-gear fishery with constant selectivity properties for all ages past t_c.

5.2.3.2 Commercial (2 Gear Types)

Sequential competition (i.e., one segment of the fishery operates on a younger portion of the stock than another).

5.2.3.3 Commercial and Recreational In Sequence

The most difficult level where nonconsumptive (recreational) interests also compete with consumptive (commercial) interests or values.

If the user selects either of the two-gear functions (i.e. Fishery Type = 2 or 3), then following either of these selections in the major prompt, the user must decide whether he would like to select the targeted ages exploited by the two gear types. Otherwise default conditions will be applied. The choice allows for simulating the effects of overlapping gear selectivity patterns. Default conditions cause the ffect of (1) discrete non-overlapping selection of gears for Fishery Type 2 (2-commercial gears), and (2) slightly overlapping selection of gears for Fishery Type 3 (recreational and commercial). If the user chooses to set ages of selection then he must (1) enter the **maximum age** to be fished by Fleet 1 which then has the gear fishing from ages 1 to the 1st choice (= maximum age) , and (2) enter the **minimum age** fishes by Fleet 2 which then runs from the 2nd choice (= minimum age) to the oldest age. Ages of overlap receive summed effects.

5.2.4 Current Fishery Status

5.2.4.1 Developing

A developing fishery where the fish stock is in essentially the virgin state.

5.2.4.2 Fully Exploited

A fully exploited condition that has the fishery at roughly maximum sustainable yield (MSY).

5.2.4.3 Recruitment Overfished

The fishery is well past MSY and the spawning stock has been severely reduced.

5.2.4.4 Unknown

The program generates a prompt which asks the user to enter an integer number of any size. Upon entry of the integer, the program selects randomly either a developing, fully exploited, or recruitment overfished condition of the fishery.

5.2.5. Historical Data Availability

5.2.5.1 Complete

Program provides all data and great analyses.

5.2.5.2 Sketchy

Program provides catch and effort statistics, some economic data, and a production model estimate.

5.2.5.3 Very Sketchy

Program provides imprecise catch and effort statistics and a production model estimate.

5.2.5.4 None

No data available.

5.3.0 Decisions Sequence

5.3.0.1 Management Measures To Be Implemented

The program displays the scope of your management authority over the stock and then begins the management meaures sequence. Four major groupings of fishery management measures are available, (1) effort limits, (2) size limits, (3) season limits, and (4) catch limits and allocations (Figure 5.3.0).

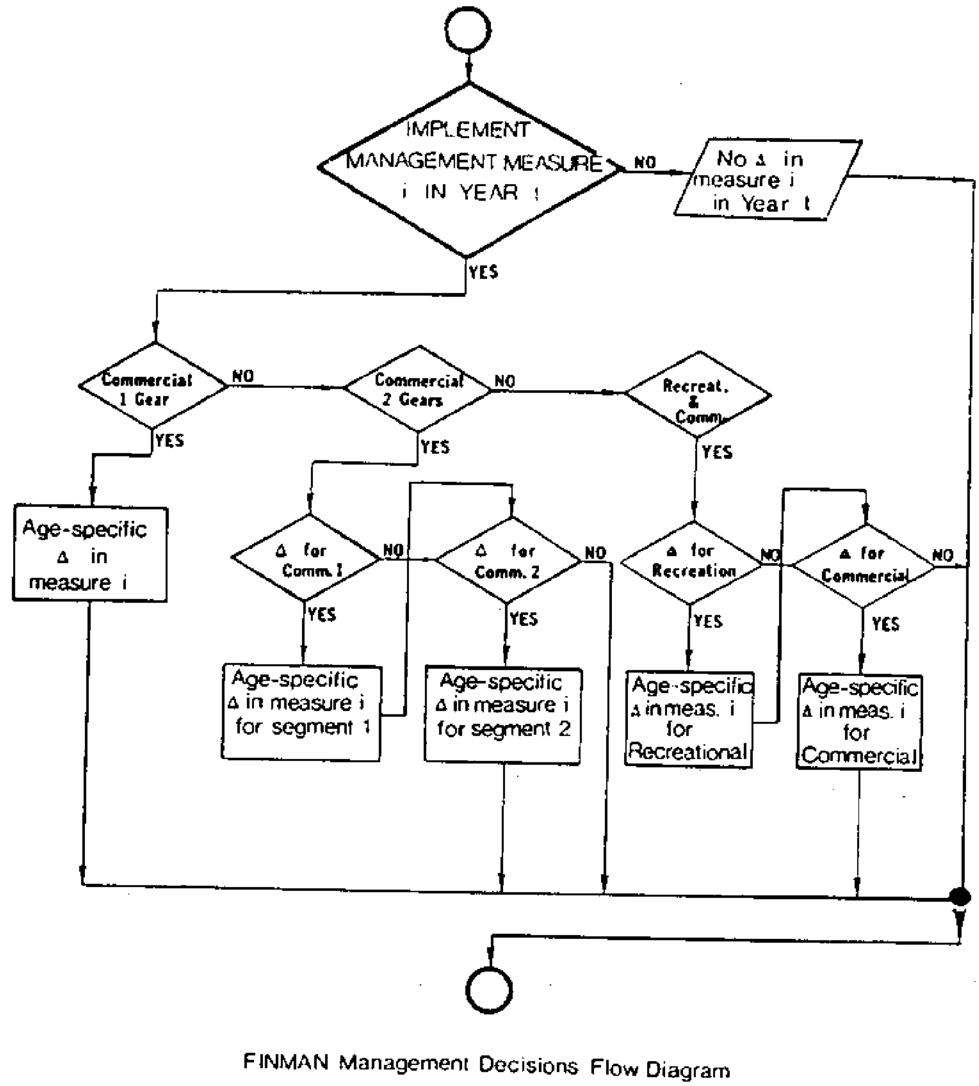


Figure 5.3.0: Flow Diagram of Generalized FINMAN Model Management Decisions Process.

5.3.1 Fishing Effort Strategy

Presently the user defines the fishing mortality rate, and this is modified to units of gear effort by the appropriate operation of the catchability coefficient. All mortality rates are age-specific and constant across ages in the single gear fishery, although age-specific mortality rates can be made variable if so desired. It will be remembered that for a given relative distribution of fish and fishing in a specified area the value of instantaneous fishing mortality, F, is proportional to the total fishing effort, measured in standardized units.

The user must decide whether he would like to alter the fishing effort strategy for the present year of simulation. If the decision is YES, the input constant value represents potential fishing mortality which is the instantaneous fishing mortality coefficient of a fully available age group in a given year.

If two fleets have previously been selected for by the user (i.e., Fishery Type = 2 or 3), then the user must decide whether he wants to regulate the fishing effort strategy in the present year for the two fleet groups separately. Your potential choices are in the present year (iteration) are: (1) no regulated change in F for both fleets, (2) change in regulated F for fleet 1 and no change for fleet 2, (3) no change in F for fleet 1 and change in regulated F for fleet 2, and (4) change in regulated F for both fleets.

If the decision is YES for either or both fleet 1 and fleet 2, then a prompt will appear asking you to input the value of F recommended for the respective fleet. The input value of F will then be applied against the segment of the age distribution choosen in the initial options sequence.

5.3.2 Size and Age of Capture

The user selects the age at first capture (= age and/or size of 100% vulnerability) to be used by the particular gear-type operating. Like fishing effort strategy, this decision is obviously tempered by what the manager feels is optimum, and can also be affected by the various management filters in place. The age of capture is set as a minimum size available to the fleet(s) as a whole. This decision then sets the minimum age (size) at vulnerability which may be altered depending on the filters operating during the present decision loop.

5.3.3 Seasonal Closures

Closed seasons (specific months of the year) can be selected to achieve specific mortality rates, and to protect the stock during critical events like spawning and recruitment. Closures are set for the fleet(s) as a whole.

Closures are operable from day one of the starting month to day one of the ending month. That is, a closure that runs from March (=3) to June (=6) would run from March 1 to June 1, a total of 3 months.

5.3.4 Catch Limits and Allocations

Catch quotas, by individual fleets, can be instituted in order to adjust the age-specific instantaneous fishing mortality rates upwards or downwards to acheive yields or catch rates within a particular tolerance.

The tolerance for the catch quota set by default is 0.5% over the recommended upper limit for catch in the present year of simulation. The type of catch quota available to the user is dependent upon the selection of the fishery type. Specific options are:

5.3.4.1. Overall Catch Limit (Fishery Type 1)

Catch quota set for the single gear-type fishery. The user sets the catch limit for the single fleet in weight, which is entered in terms of the units of W_∞ (i.e., ultimate weight from the von Bertalanffy formulation).

5.3.4.2. Catch Limit Subdivided by Fleets (Fishery Type 2)

Catch quota sequence set for the two commercial gear-types fishery. The catch limits can be set for either or both fleets in the same year, the program will solve the exact solution of the catch equation, even when the gears have overlapping selective properties. Quotas for both fleets are set in weight (in units of W_{∞}) allowable for the respective fleets with a 0.5% tolerance at solution considered acceptable.

5.3.4.3. Boat Quotas and/or Bag Limits (Fishery Type 3)

This is the sequence of catch restrictions for commercial and recreational fleets operating jointly. Catch limits for the commercial fleet are set in terms of weight of the catch, while catch limits for the recreational fleet are set in terms of maximum number of fish per angler allowable (i.e., bag limit). If the recommended bag limit is not exceeded the program provides a solution to the catch equation on the first iteration; however, if the bag limit is exceeded by virtue of the present level of fishing effort, then the program minimizes the catch equation, within the specified constraints, to achieve the recommended number of fish per angler for the entire recreational segment available to capture.

Reduction of catch by setting a limit to the total catch that may be taken in a given year is an indirect method of controlling fishing effort. It is indirect because the catch obtained in a particular year by the expenditure of a given effort is influenced to a greater or lesser extent by biological factors, of which fluctuations in recruitment and especially for migratory fish, the distribution of fish, are the most important.

5.4.0 Overall Budget Allocations Among Enforcement, Research and Influence with Constituents

You will have an initial total resource management budget of one million dollars for the first year of management simulation. This budget can increase or decrease in subsequent years based on the level of constituency satisfaction. Each simulation year the general budget must be distributed as allocations among the following three (3) agencies and subgroups (Figure 5.4.1).

5.4.1 Assessment and Monitoring

Sets the overall budget available to five (5) component research and monitoring groups.

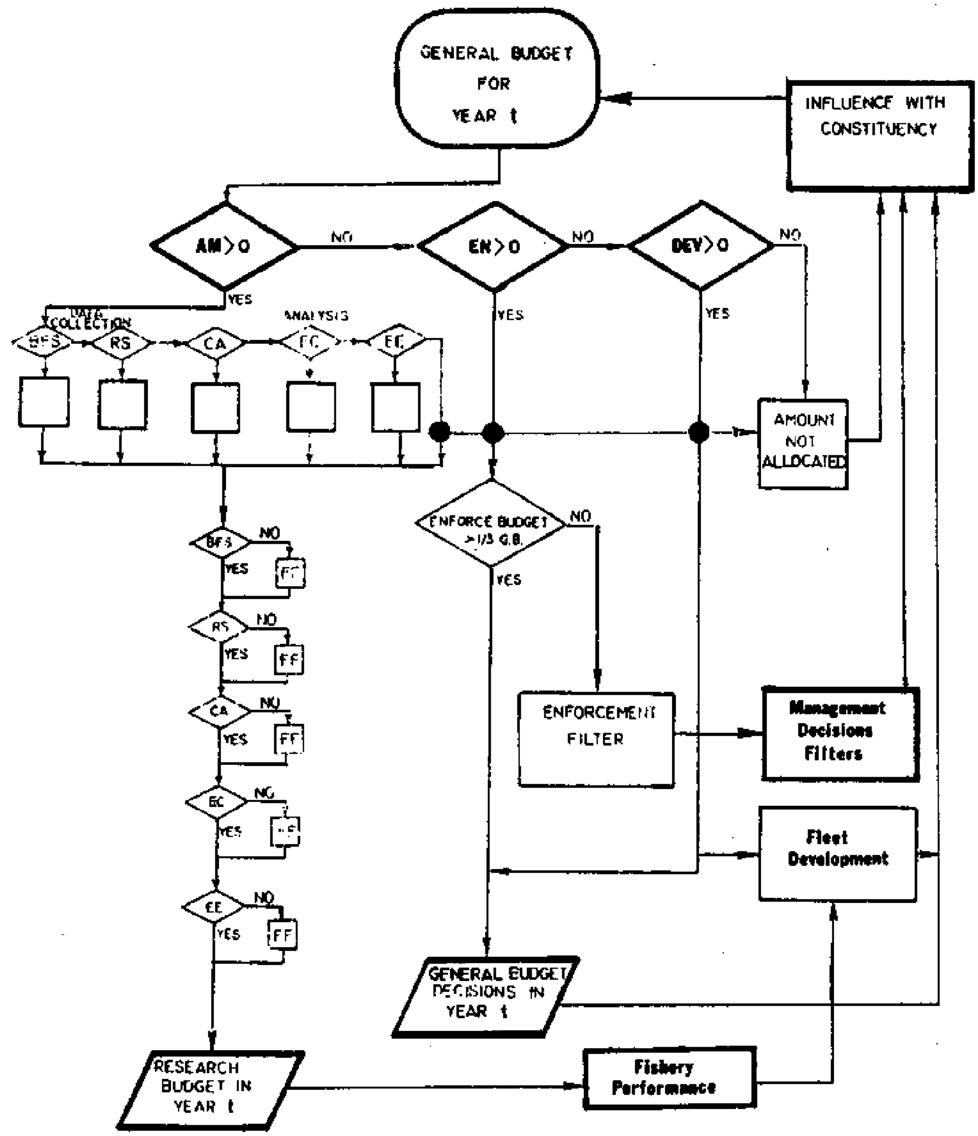
5.4.2 Enforcement

Generates the dollars for the necessary police action to maintain imposed regulations within their recommended levels.

5.4.3 Development

Allows the development of the fishery from an economic and effort prespective, and also feeds into the constituency function.

The dollar amounts allocated to each of the above agencies dictates the level of accuracy and precision you will observe in the external output the degree of compliance with your recommended management measures, the rate of fishery development and the level of constituency satisfaction. After responding to the general budget prompts with allocations, you will be shown a screen with a summary of your decisions. The amount in the "unallocated" cell is considered fiscal surplus which feeds back in the "Influence with Constituency" function, and proportionalizes potential budget increases for the next program iteration.



FINMAN Budget Decisions Flow Diagram

Figure 5.4.1: Flow Diagram of FINMAN Budget Decisions. AM = Assessment and Monitoring, EN = Enforcement, DEV = Development, BFS = Basic Fishery Statistic, RS = Resource Surveys, CA = Catch Analyses, EC = Economics, EE = Environmental Effects.

5.5 Research Budget Allocations Among Data Collection and Analysis Projects

From the total dollar amount allocated to Assessment and Monitoring activities you must then allocate funds to the following component research endeavors. Once again, the dollar amount allocated to each of the following component data collection and research activities dictates the level of accuracy and precision you will observe on the external output, tempered by the initial conditions selections and the internal modifying functions. The specific component variables for each of these five assessment and monitoring group allocations are completely delineated in sections 11.4.1 and 11.4.2 of this manual for one- and two-gear fisheries, respectively.

5.5.1 Compilation of Basic Fishery Statistics

5.5.2 Catch Analysis

5.5.3 Resource Surveys

5.5.4 Economic Analysis

5.5.5 Environmental Trends and Effects on Fishing Activities

After you have allocated the assessment and monitoring budget, a screen with a summary of your allocations will appear. The amount in the unallocated cell is considered "misallocated" and as such has a negative impact on your "influence" on the constituency.

5.6 Review of Input Parameterization

The review consists of the input parameters for the biological portion of the model. This screen aids the model builder and is not available in the final "General User" version. It constitutes the module REVIEW.DATA (RVDT) explained in Section 13.11 of this manual.

5.7 Calculation of a Simulation Sequence

Upon completion of all management, budget, and decisions input and bypassing the review sequence, FINMAN will then compute the present year's simulation. The program first passes through a decisions modification loop which adjusts the input decision values according to the present budget decisions; this influences the precision and/or accuracy of the output. After adjustments are made, if any, the program then calculates statistics for the present loop. This entire calculation process takes approximately fifteen seconds.

If the user has chosen to implement a catch quota, the above calculations will undoubtedly take longer than fifteen seconds. Computation time for the catch quota loop is a function of: (1) the complexity of the fishing pattern (i.e. two gears more complex than a single gear), and (2) the segment of the yield curve on which the desired quota value lies. When the desired quota value is attained, the prompt "**Quota within tolerance**" will appear on the screen.

5.8 Timing and Accounting

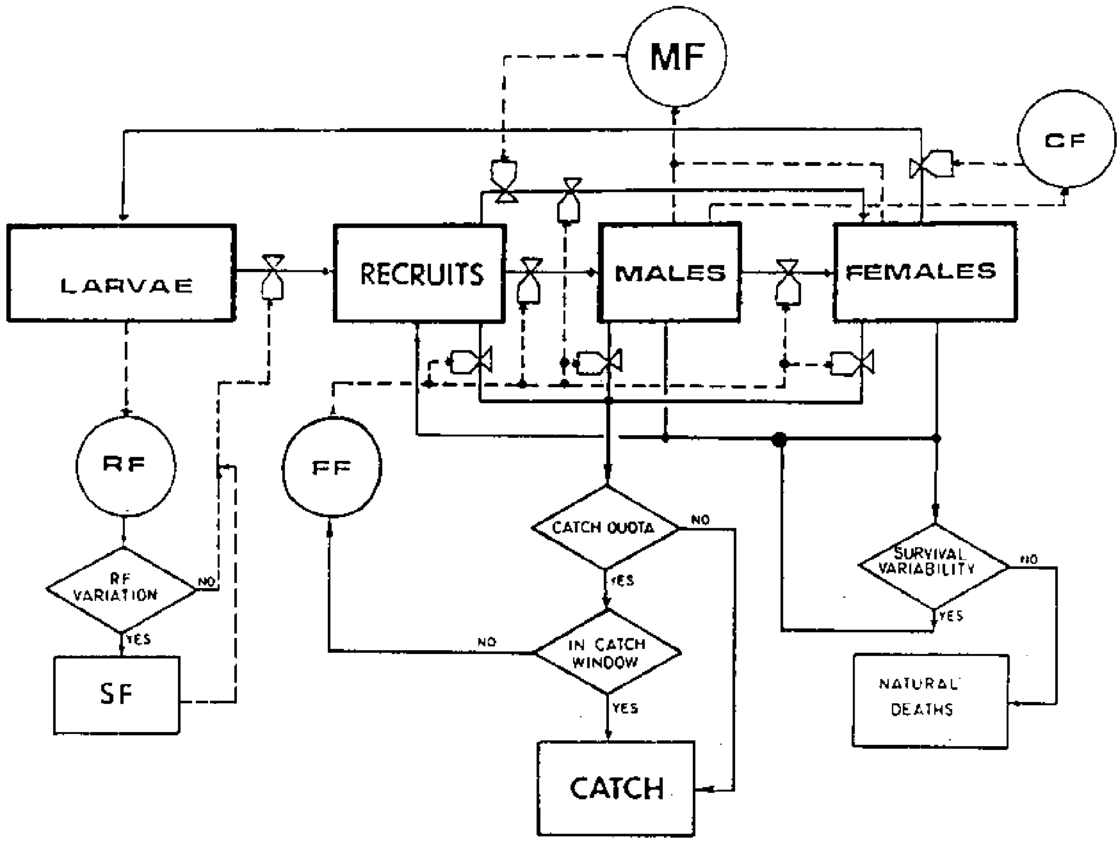
The ordinal numbering system is used throughout FINMAN. This means that Yearclass 1 are the young of the year (0's), and Yearclass 2 are individuals in their second year of life (1's), etc. The unit length of time is the reproductive cycle, commonly a year in subtropical and temperate species. Computations are conducted once during each time unit, thus it represents a year for the species considered. Time unit (1,1) is either (1) the **time of spawning** for viable fertilized ova which hatch in less than one-half month or for specific life histories where the ova are cast freely into the environment (i.e., most marine fishes), or (2) the **time of hatching** for eggs which hatch after periods greater than one-half months incubation and during this period are carried by one of the parents (i.e., most crustaceans). All accumulated statistics are carried on a fiscal basis. P(1,1) is either the number of viable fertilized ova cast under case (1), or the number of larvae hatched under case (2). P(4,1) is the number of individuals in their fourth year of life at the start of the first month.

5.9 Destination for FINMAN Output

After completion of a simulation sequence, a prompt is shown which asks: (1) Do you want the results sent to the printer?, or (2) Do you want the results to be displayed on the monitor screen? If the results are to be sent to the printer, then the output contains all the present loops' statistics, plus complete time series information for the years of simulation to date, including the number of years of historical data originally provided. If the results are displayed on the monitor screen, then the information presented includes all data available from the present loop, plus time series data equivalent to the last t years in the fishery.

6.0 Biological Model Structure

A flow chart of FINMAN indicating the optional fishery types and life history sectors of the model are presented in Section 5.0 (see Figure 6.0). Each sector is described by the equations below. The basic time period for calculations in FINMAN is annual with all processes summed on an annual basis. Output is age-specific and summed for all ages and fishery types operating. In the following sections continuous time expressions are denoted as C(x,y) while their discrete time analog formulations are represented as $C_{x,y}$.



FINMAN Fishery Sector Flow Diagram

Figure 6.0: Flow Diagram of FINMAN Biological and Fishery Sector. MF = Sex-specific Maturation Function, CF = Copulation Function, FF = Fishing Mortality Function, SF = Stochastic Function, RF = Recruitment Function.

6.1 Mortality

Mortality is age-specific and is assumed to be representable by an exponential decline:

$$N(x,t+1) = N(x,t)e^{-Z(x,t)} \qquad (6.1.01)$$

$$\text{with} \quad Z(x,t) = M(x,t) + A(x,t)*F(x,t) \qquad (6.1.02)$$

where,

$N(x,t)$ = number of animals belonging to the x^{th} yearclass at the beginning of year t.

$M(x,t)$ = instantaneous rate of natural mortality for yearclass x in year t.

$F(x,t)$ = instantaneous rate of fishing mortality of a fully available yearclass, $x = 1,...,t_\lambda$, in year t.

$A(x,t)$ = availability multiplier for yearclass x in year t.

The generalized stating of natural and fishing mortality allows the model to simulate catch limits and allocations, effort limits, size limits, season limits and the effects of seasonal mortality patterns.

6.1.1 Stochastic Natural Mortality

The stochastic version of the simulation model allows natural mortality (M) to become a random variable with a known mean and variance. This procedure is explained more fully in Section 6.4.3.1.

6.1.2 Average Number Alive

The average number of yearclass x during year t is given by

$$\bar{N}(x,t) = N_{x,t}(1 - e^{Zx,t})/Z_{x,t} \qquad (6.1.2)$$

6.2 Growth

The growth in weight of the fish can be represented by at least two alternative formulations:

6.2.1 von Bertalanffy Formulation

$$W(x,t) = W_{\infty}(1 - e^{-K_{x,t}(x-t_0)})^3 \qquad (6.2.1)$$

where,

$W(x,t)$ = average weight of an individual in yearclass x at the beginning of the interval t.

W_{∞}, K, t_0 are parameters of the von Bertalanffy growth equation.

6.2.2 Linear Segmental Formulation

$$Wij = a + b\Delta t \qquad (6.2.2)$$

where,

$$a = wi, j\text{-}1$$

$$b = (Wij - Wi, j\text{-}1)$$

$$\Delta t = 1$$

6.3 Maturation

A maturity schedule of the sexes is computed. This is accomplished in the simulator with two vectors of age-specific values, one denoting the average fraction of males in each yearclass curing the breeding season, ϕ_{mx}, and the other denoting the female fractions, ϕ_{fx}.

6.3.1 Average Number of Males

The mean number of males, $\bar{N}_m$, during year t at spawning is:

$$\bar{N}_m(t) = \sum_{x=1}^{\lambda} \phi_{mx} N_{x,t}(1 - e^{-Z_{x,t}})/Z_{x,t} \qquad (6.3.1)$$

6.3.2 Average Number of Females

The mean number of mature females, $\bar{N}_f$, during year t at spawning is:

$$\bar{N}_f(t) = \sum_{x=1}^{t_\lambda} \phi_{fx} N_{x,t}(1 - e^{-Z_{x,t}})/Z_{x,t} \qquad (6.3.2)$$

6.3.3. Sex Ratio

$$\bar{S}(t) = \bar{N}_m(t)/\bar{N}_f(t) \qquad (6.3.3)$$

where S(t) = mean sex ratio for time interval t.

6.4 Recruitment

The computation of the number of recruits entering the population takes the following forms:

6.4.1 Beverton and Holt Dynamics

$$R(t+\zeta) = \frac{1}{\alpha + \beta/S_{x,t}} \qquad (6.4.1)$$

6.4.2 Ricker Dynamics

$$R_{(t+\zeta)} = S_{x,t}\alpha e^{-\beta S_{x,t}} \qquad (6.4.2)$$

where, α and β are parameters of the models, and

$S_{x,t}$ = total production of gametes by the stock in year t.

Note that recruitment is defined as the joining of the progeny to the population and not necessarily to the fishable population (i.e., that portion vulnerable to the fishing gear).

6.4.3 Stochastic Recruitment Variability

This life history option allows the user to set the level of recruitment variability he would like to have operating in the population of interest. If recruitment variability is choosen, then the desired percentage variability around present mean recruitment level must be entered. The +/- percentage is computed as a stochastic variable around the mean of the density-dependent stock-recruitment relationship.

6.4.3.1 Random Uniform Distributions (R.U.D.)

The R.U.D. is simulated by introducing the parameters of the cumulative density function, i.e.,

$$F(x) = \int_{L}^{U} f(x)dx \qquad Pr\left\{ X \leq x \right\}$$

$$E[x] = \int_{L}^{U} xf(x)dx = X \tag{6.4.3.1.01}$$

$$Var(x) = \int_{L}^{U} f(x)(x - E[x])^2 dx = \sigma_X^2 \tag{6.4.3.1.02}$$

U = Upper Bound

L = Lower Bound

Passing these parameters to the uniform distribution where there is equal probability of selection anywhere along the density function:

$$a = E[x] - (3 * Var(x))^{0.5} \tag{6.4.3.1.03}$$

$$b = 2E[x] - a \tag{6.4.3.1.04}$$

r = uniform random variable between 0 and 1

$$r = F(x) = (x - a)/(b - a)$$

$$x = a + (b - a) * r \tag{6.4.3.1.05}$$

The stochastic version of the simulation model allows annual recruitment, **R**; natural mortality, **M**: availability, **A**; and several other budget and management decision variables to become random variables, each with a known mean and variance.

6.4.3.2 Autocorrelated Sine Wave Periodicy for Recruitment

To simulate the autocorrelated time trend of environmental variation with that of recruitment to the fishery, an autocorrelated sine wave with variable period is incorporated into the recruitment function. This function can be activated with a preselected period. For example, the southern oscillation (i.e., El Nino event) is suggested to have a phase of seven (7) years. The input value is then the cycle phase (period) in years.

The general formulations utilized are:

$$Y(t) = \theta \sin (at + b) \qquad (6.4.3.2.01)$$

where t = year of simulation

θ = amplitude = fixed % of maximum recruitment.

Period = $2\pi/a$

Frequency = $\frac{1}{\text{Period}} = a/2\pi$

To maintain recruitment in the positive domain therefore, recruitment in year t is:

$$R(t) = P(1,JJ\%) + Y(t) \qquad (6.4.3.2.02)$$

6.4.4 Spawning Stock

MY = year of life during which reproductive maturity begins.

SS(t) = spawning stock in numbers at the beginning of year t.

$$SS(t) = \sum_{x=MY}^{t_\lambda} N_{x,t} \qquad (6.4.4)$$

6.4.5 Number of Larvae

$E_{x,t}$ = number of viable ova per individual female age x.

NL(t) = number of larvae in year t.

$$NL(t) = \sum_{x=my}^{t_\lambda} \phi_{fx} N_{x,t} E_{x,t} \ (1 - e^{-Zx,t})/Z_{x,t} \qquad (6.4.5)$$

Where, $N_{x,t}$ = population abundance at the beginning of the year t for fish aged x reference years old.

6.5 Yield

Yield from the population is computed both in numbers and weight for each yearclass x under the von Bertalanffy growth model. The total annual yield from population is the sum of the yields from each of its constituent year-classes during one year of life.

$$Yn(x,t) = A_{x,t}F_{x,t}N_{x,t}(1 - e^{-Z_{x,t}})/Z_{x,t} \qquad (6.5.01)$$

where, $N_{x,t}$ = population abundance at the beginning of the year t for fish aged x reference years old.

and $Yn(x,t)$ = the yield of fish in numbers and which is complementary in form to Baranov's catch equation.

Thus, the yield in numbers from the entire population in year t is equivalent to:

$$Yn(t) = \sum_{x=1}^{t_\lambda} Yn_{x,t} \qquad (6.5.02)$$

Under the von Bertalanffy growth model, the yield in weight, $Yw(x,t)$, is computed as:

$$Yw(x,t) = A_{x,t}F_{x,t}N_{x,t}W_\infty \sum_{n=0}^{3} \frac{U_n e^{-K_{x,t}(x-t_0)}}{Z_{x,t}+nK_{x,t}}\left[1 - e^{-(Z_{x,t} + nK_{x,t})}\right]$$

where $U_n = 1,-3,3,-1$, respectively. (6.5.03)

Therefore the yield obtained in weight from the population throughout its fishable life span, i.e. between ages $t_{\rho'}$ and t_λ is obtained as:

$$Yw(t) = \sum_{x=t_{\rho'}}^{t_\lambda} Yw_{x,t} \qquad (6.5.04)$$

It has been assumed that the recruitment of a year-class to the exploited area and its entry to the exploited phase takes place instantaneously at ages t_ρ and $t_{\rho'}$, respectively.

6.5.1 Fishable Average Population

$$\bar{N}(x,t)_{fishable} = N_{x,t}(1 - e^{-(M_{x,t} + A_{x,t} * F_{x,t})}) / (M_{x,t} + A_{x,t} * F_{x,t}) \qquad (6.5.1)$$

where, $A_{x,t} > 0$

6.6 Other Characteristics of the Catch and Population

In a study of an exploited fish population there are several quantities, besides the annual yield in weight, that will require assessment. From an economic perspective it is necessary to know the catch per unit effort and the mean weight of fish in the catch, while the analysis of situations in which factors such as natural mortality and growth vary with the population density requires expressions giving numbers and biomass of the population. Finally, when the behavior of population models comes to be tested by observation or experiment, or they are used as an adjunct to fishery management, it is of help to obtain from the models predicted values of certain quantities such as the mean length and mean age of fish in the catch, which are directly estimated from samples.

6.6.1 Mean Length and Weight of Fish in the Catch

$$TL(t) = F_{x,t} \sum_{x=t_{\rho'}}^{t_\lambda} N_{x,t} L_{x,t} \qquad (6.6.1.01)$$

where $L_{x,t}$ = mean length of a fish aged x in year t.

t_ρ ' = age at 100% vulnerability to the gear.

t_λ = oldest age of fish in the catch.

TL(t) = total length of all fish caught in year t.

Yn(x,t) = total number of fish caught aged x in year t.

$$= F \int_{t_{\rho'}}^{t_\lambda} N_x dx \qquad (6.6.1.02)$$

$$\cong F_{x,t} \sum_{x=t_{\rho'}}^{t_\lambda} N_{x,t} \qquad (6.6.1.03)$$

$\bar{L}(t)$ = mean length of fish in the annual catch in year t .

$$\bar{L}(t) = F_{x,t} * \sum_{x=t_{\rho'}}^{t_\lambda} N_{x,t} L_{x,t} / \left[F_{x,t} * \sum_{x=t_{\rho'}}^{t_\lambda} N_{x,t} \right] \qquad (6.6.1.04)$$

$\bar{W}(t)$ = mean weight of fish in the annual catch in year t.

$$\bar{W}(t) = Yw_t / Y_{N_t} = F_{x,t} * \sum_{x=t_{\rho'}}^{t_\lambda} Y_{W_{x,t}} / \left[F_{x,t} \sum_{x=t_{\rho'}}^{t_\lambda} Nx,t \right] \qquad (6.6.1.05)$$

6.6.2 Age Distribution

$u_{x,t}$ = age-specific mortality rate.

$B_{x,t}$ = birth rate per individual as a function of aged x in year t.

$C_{x,t}$ = fraction of population in age class x.

$$\int_0^\infty C(x,t)dx = 1 \qquad (6.6.2.01)$$

$$b = \int_0^\infty C(x,t)B(x,t)dx \quad \text{and} \quad u = \int_0^\infty C(x,t)u(x,t)dx$$

The relationship between survivorship and mortality schedules are:

$$l(x,t) = e^{-\int_0^\infty u(y)dy} \qquad (6.6.2.02)$$

The fraction of the population in age class x at time t for a stable population can be calculated as:

$$C(x,t) = N(x,t)/N(t) = e^{-rx} l(x) / \int_0^\infty e^{-ry} l(y)dy \qquad (6.6.2.03)$$

in discrete form:

$$C_{x,t} = (\lambda^{-x}) l_x / (\lambda^{-k}) l_k$$

$$= (e^r)^{-x} \, l_x / \sum_{k:t_{\rho'}}^{t_\lambda} (e^r)^{-k} \, l_k \qquad (6.6.2.04)$$

where, $\lambda = e^r$

and $r = b - u$

6.6.3 Mean Age of Fish in the Population and Catch

The mean age of fish in the population is;

$$\bar{T} = \sum_{x=t_\rho}^{t_\lambda} t * N_{x,t} / \sum_{x=t_\rho}^{t_\lambda} N_{x,t} \qquad (6.6.3.1)$$

Similarly, the mean age of the fish in the annual catch is:

$$\bar{T}_y = \frac{1}{F+M} + \frac{t_\ell' - t_\lambda e^{-(F+M)\lambda}}{1 - e^{-(F+M)\lambda}} = \sum_{x=t_\ell'}^{t_\lambda} t * N_{x,t} / \sum_{x=t_\ell'}^{t_\lambda} N_{x,t} \qquad (6.6.3.2)$$

It can be shown that the latter statement remains true irrespective of the occurrence of fluctuations in the annual number of recruits.

6.6.4 Equilibrium Yield Per Recruit

The concept of equilibrium (or steady-state) is intimately tied to the yield per recruit approach. Yield per recruit models examine the balance of growth and mortality assuming a constant level of reproduction. The yield per recruitment is simply the total annual yield from a given number of recruits computed from the sum of the yield from all age classes available to the fishery -- or the yield from one yearclass throughout its life in the fishery, since the calculations are for a population at equilibrium.

$$Yw(t) = \int_{t_\ell'}^{t_\lambda} F(t)N(t)W(t)dt \qquad (6.6.4.1)$$

where, $Yw(t)$ = the total yield per recruitment in weight.

$F(t)$ = instantaneous coefficient of fishing mortality.

$N(t)$ = numbers of recruits, R, surviving to time t.

$W(t)$ = mean weight of an individual at time t.

t_ℓ' = age of 100% vulnerability to the fishing gear.

t_λ = maximum age attained in the fishery.

A simple and reasonable expression of equation 6.6.4.1 due to Beverton and Holt is:

$$Yw/Rc = FW_\infty \sum_{n=0}^{3} \frac{U_n e^{-nK(t_\ell' - t_0)}}{F + M + nK} * (1 - e^{-(F+M+nK)(t_\lambda - t_\ell')}) \qquad (6.6.4.2)$$

where, Un = 1,-3,3,-1 respectively.

Rc = number of recruits surviving to t_{ρ}'.

M = instantaneous coefficient of natural mortality.

W_{∞}, K, t_0 = parameters of the von Bertalanffy growth equation.

The result of these calculations gives the yield per recruit as a function of two independent variables, which are in principle controllable by suitable management action - the fishing mortality, F, and the age at first capture t_c. These results are best presented in a two-dimensional diagram (or three-dimensional graphic representation, see Sections 15.1 - 15.6), in which the yield from any combination of F and t_c can be easily read off.

6.7.0 Stock Size

$N_{x,t}$ = number of animals aged x at the beginning of year t.

S(t) = total fish stock size at the beginning of year t.

$$S(t) = \sum_{x=1}^{\lambda} N_{x,t} \qquad (6.7.0)$$

6.8.0 Selection

The selection curves can have any desired shape. The default settings of the present model assumes knife-edged selection (100%) begins at the age of t_c (=t_{ρ}') and remains constant for all older age groups.

6.8.1 Non-stochastic Availability

Selection is accomplished by the modifying the coefficient $A_{x,t}$ in

$$Z(x,t) = M(x,t) + A(x,t)*F(x,t) \qquad (6.8.1)$$

so,

$$A(x,t) \begin{cases} 0.0 < t_c \\ 1.0 \geq tc \end{cases}$$

An infinite number of selection patterns are potentially simulated by this generalization.

6.8.1.1 Stochastic Availability

The stochastic version of the simulation model allows availability to become a random variable with a known mean and variance (see Section 6.4.3.1.).

6.8.2 Season Closures

The entire fishery may be closed for any (or every) month of the year. In this case no vessels may land anything until the closure is lifted.

Seasonal closures are accomplished in the annual simulation by modifying the availability coefficient through a proportionality constant that indicates the span of the year in which fishing shall take place.

MW(t) = month of year in which closure begins.

ME(t) = month of year in which closure ends.

The closure is instituted and ends on the first days of the months selected. That is, a closure beginning in March (MS=3) and running through June (MS=6) will be of three months total duration and is calculated as:

MC(t) = months of closure in year t.

MC(t) = ME(t) - MW(t)

The availability coefficient, $A_{x,t}$, is modified accordingly as:

$$A(x,t) = (12\text{-}MC(t)/12) * A(x,t) \qquad \text{For } x = 1 \text{ to } t_\lambda$$

7.0 Catch Quota

$Y_1W(t)$ = total catch in weight in year t.

$$Y_1W(t) = \sum_{x=t_{\rho'}}^{t_\lambda} Yw_{x,t} \qquad (7.0)$$

CL(t) = proposed catch quota in year t.

TOL(t) = tolerance for catch quota in year t.

CBL(t) = lower bound for catch limit in year t.

CUB(t) = upper bound for catch limit in year t.

7.1 Overall Catch Quota

Quotas, as a tool of management, rank highly in terms of flexibility and implementation. To the extent that the state of the biological stock can be determined before the season, pertubations in the level of population can be allowed for in the quota. Quotas may be a satisfactory tool to maximize yield from the fishery, but in of themselves are not sufficient to obtain the maximum economic yield.

7.1.1 Single Fleet or Two Fleets in Sequence

$$CBL(t) = CL(t) - (CL(t) * TOL(t)) \qquad (7.1.1.01)$$

$$CUB(t) = CL(t) + (CL(t) * TOL(t)) \qquad (7.1.1.02)$$

if $Y_1W(t) > CUB_{(t)}$ then $F_{x,t}$ downwards

if $Y_1W(t) < CLB_{(t)}$ then $F_{x,t}$ upwards

if $CLB(t) \leq Y_1W(t) \leq CUB(t)$ then $Y_1W(t) = \sum_{x=t_\rho}^{t_\lambda} Yw_{x,t}$

7.2 Catch Limit Subdivided by Fleets

O4CQ(t) = proposed catch quota for fleet 1 in year t.

05CQ(t) = proposed catch quota for fleet 2 in year t.

QL(t) = lower bound for catch limit in year t for fleet 1.

QH(t) = upper bound for catch limit in year t for fleet 1.

KL(t) = lower bound for catch limit for fleet 2 in year t.

KH(t) = upper bound for catch limit for fleet 2 in year t.

Y5W(t) = yield for fleet 1 segment (1 to SE1) of age structure in year t.

Y6W(t) = yield for fleet 2 segment (S2 to N1YC) of age structure in year t.

Q = Q1 = 1 when catch quota on; Q = Q1 = Ø when catch quota not on for both fleets.

Fleet 1	if $Y5W(t) > QH(t)$	$F_{x,t}$ downwards
	if $Y5W(t) < QL(t)$	$F_{x,t}$ upwards x = 1 to SE1
	if $QL(t) \leq Y5W(t) \leq QH(t)$	then $Y5W(t) = \sum_{t=1}^{SE1} Yw_{x,t}$
Fleet 2	if $Y6W(t) > KH(t)$	$F_{x,t}$ downwards
	if $Y6W(t) < KL(t)$	$F_{x,t}$ upwards x = S2 to N1YC
	if $KL(t) \leq Y6W(t) \leq KH(t)$	then $Y6W(t) = \sum_{t=S2}^{N1YC} Y_{w_{x,t}}$

7.3 Bag Limit

Purpose is to set an upper limit restriction on the number of fish taken per angler or the recreational fishing effort unit. Program will solve a catch vector equivalent to the recommended level per angler for every angler if the initial bag per angler exceeds the recommended value.

7.4 Seasonal Closures

In principal the quota on catch is a simple and direct regulation. It operates through limitation of fishing time in any one year. The quota then is equivalent to the closed season. The date when the season is to be opened is determined in advance together with the total allowable catch (TAC - the quota); when this catch has been taken the season is closed until the following year.

7.5 Management Systems

Three types of management system structures for designing fishery management rules are available in the **FINMAN** model. System types are ordered in ascending levels of difficulty in achieving the 100% probability for incorporating management decisions in the present loop.

7.5.1 Autocratic Body

Your decisions for managing are fully implemented.

7.5.2 Commission Body

CD(t) = proportion of total budget allocated to research in year t.

CR(t) = random number generated from CD(t) allocated in year t.

p = probability of measures being implemented.

$$p(t) = \text{probability of compliance} = \alpha + \beta[(AM/t)/BVD(PZ)] \qquad (7.5.2)$$

$$\alpha = 0, \ \beta = 1$$

$$\text{if } CD(t) \begin{cases} 1.0 & p = CD(t) \\ 0\text{–}.999\ldots & p = CD(t) \\ & 1-p = \text{probability of vetoing policy} \end{cases}$$

7.5.3 Legislative Body

LD(t) = proportion of total budget allocated to research in year t.

LF(t) = proportion of total budget allocated to development in year t.

CD(t) = probability of measures being implemented in year t.

$WT_i(t)$ = weighting function for proportion i in year t.

$$CD(t) = (WT_i(t) + LD(t)) + (WT_i(t) * LF(t)) \qquad (7.5.3)$$

$LD(t) = (AM/t)/BUD(t))^{1.5}$

$LF(t) = DEV(t)/BUD(t)$

If policies vetoed in year t, then regulations in effect in year t-1 will supercede the present policy recommendations.

8.0 Economics (Costs & Returns)

The economic aspects of the FINMAN model have intimate interaction with the other major components of the model. In general, profits realized by each fishing effort unit and the distribution of fishing effort determines catch, which determines profits. We are implicitly assuming that the distribution of effort has been determined, and this effort is applied to the respective fishery for a simulated year to generate the yields by cohorts of the species by each gear type. Vessel profits for the year are then calculated. Fishing effort can be readjusted to better exploit profit potential. At year's end, vessels may enter or leave the fishing fleet based upon historical profits or losses and other factors (see Section 10.0).

8.1 Fishing Effort (Units)

q(t) = catchability coefficient in year t.

F(x,t) = instantaneous rate of fishing mortality of a fully available (vulnerable) year-class x in year t.

f(t) = effective fishing effort in year t where we assume that the fishing intensity is unity in all areas. The gross stock of vessels of class K targeting on species S can be calculated by:

8.1.1 Single Fleet

$NV_K(t)$ = total effective effort units of class K in year t

if, $F(x,t) = q(t) * f(t)$

then $f(t) = F(x,t)/q(t) = NV_K(t)$

8.1.2 Multiple Fleets

$q_1(t)$ = catchability coefficient for Fleet 1 in year t.

$q_2(t)$ = catchability coefficient for Fleet 2 in year.

$U_1(t)$ = number of fishing effort units in Fleet 1.

$U_2(t)$ = number of fishing effort units in Fleet 2.

so,

$$U_1(t) = F(x,t)/q_1(t) \quad \text{and}$$

$$U_2(t) = F(x,t)/q_2(t)$$

where x is an aged x member of the population under a knife-edge selectivity pattern for fleet K (K= 1,2).

8.2 Unit Costs

Vessel costs can be either fixed costs (slip fees, insurance, etc.) or variable costs (costs that may vary with effort, i.e. fuel, gear repair, etc.). The conditions in a specific fishery are simulated by the appropriate assignment of cost coefficients.

8.2.1 Single Fleet

$OC_i(t)$ = operating costs for vessel i in year t.

$VC(t)$ = total vessel costs in year t.

$$VC(t) = f(t) * \sum_{i=1}^{NV_K} OC_i(t) \qquad K=1 \qquad (8.2.1)$$

8.2.2 Two Fleets

$OC_1(t)$ = operating costs for a fleet 1 vessel in year t.

$OC_2(t)$ = operating costs for a fleet 2 vessel in year t.

V1C(t) = vessel costs for fleet 1 in year t.

V2C(t) = vessel costs for fleet 2 in year t.

$$V1C(t) = \sum_{i=1}^{v_1} OC_{1i}(t) \quad (8.2.2.01)$$

$$V2C(t) = \sum_{i=1}^{v_2} OC_{2i}(t) \quad (8.2.2.02)$$

8.3 Gross Revenue

The ex-vessel price being established for a particular species by unit weight, we are now in a position to calculate the revenues collected by each vessel. All vessels of a given fleet are assumed to behave similarly, hence each will generate the same catch and profits and calculations based on a per-boat basis can be easily extrapolated to fleet totals.

8.3.1 Single Fleet

V(x,t) = value per unit of catch aged x in year t.

NU(t) = gross revenue for fishery in for fishery year t.

$$NU(t) = \sum_{x=1}^{t_\lambda} (Yw(x,t) * V(x,t)) \quad (8.3.1)$$

8.3.2 Two Fleets

V3G(t) = gross revenue for fleet 1 in year t.

V4G(t) = gross revenue for fleet 2 in year t.

$$V3G(t) = \sum_{x=A_1}^{A_2} Yw(x,t) * V(x,t) \quad (8.3.2.01)$$

$$V4G(t) = \sum_{x=A_3}^{A_4} Yw(x,t) * V(x,t) \quad (8.3.2.02)$$

$$NU(t) = V3G(t) + V4G(t) \quad (8.3.2.03)$$

8.4 Net Returns

The vessel profits are calculated for each vessel type under each species scenario. In addition to their obvious role in determining the economic survival of the fishery, profits can influence vessel and constituency behavior in that; (1) vessels may choose to target on a more profitable species, and (2) vessels may enter or exit the fishery as a result of potential profits or real losses.

8.4.1 Single Fleet

RG(t) = net returns to the fishery in year t.

$$RG(t) = NU(t) - VC(t) \quad (8.4.1)$$

8.4.2 Two Fleets

R2G(t) = net returns to fleet 1 in year t.

R3G(t) = net returns to fleet 2 in year t.

$$R2G(t) = V3G(t) - V1C(t) \quad (8.4.2.01)$$

$$R3G(t) = V4G(t) - V2C(t) \quad (8.4.2.02)$$

$$RG(t) = R2G(t) + R3G(t) \quad (8.4.2.03)$$

8.5 Rate of Profit

RP(t) = rate of profit in year t.

$$RP(t) = RG(t)/VC(t) \quad (8.5.01)$$

While vessels may fish or lay idle, the actual fleet size does not change throughout a simulated year. At year's end, however, vessels may enter or exit the fishery based upon the expected return available in the fishery relative to the rest of the economy. To facilitate the computations, a profit stack is kept for each vessel class, wherein the annual profits realized for each of the four previous years are stored. The expected profits for the coming year are calculated as a weighted sum of the previous profits, i.e.

$$EP_K(t) = \sum_{L=1}^{4} PW_L * RP_{KL} \qquad (8.5.02)$$

$EP_K(t)$ = expected annual profits for one vessel of class K in year t.

RP_{KL} = rate of profit realized by vessel of class K in Lth previous year (L=1 the year just completed).

PW_L = weights dependent on time.

8.6 Budget Factors

The budget appropriation for the t+1 iteration is a function of three factors computed in iteration t. These appropriations can be increasing, decreasing, or stable as outlined in Table 8.6.

8.6.1 Budget Activities

PD(t) = development fraction in year t.

PX(t) = research fraction in year t.

PP(t) = enforcement fraction in year t.

BUDFAC(t) = budget activities factor in year t.

$WT_i(t)$ = weighting factor for activity in year t.

$$PD(t) = (DEV(t)/BUD(t))^{1.5} \qquad (8.6.1.01)$$

$$PX(t) = (AM(t)/BUD(t))^{1.5} \qquad (8.6.1.02)$$

$$PP(t) = -((EN(t)/BUD(t)^{1.5}) \qquad (8.6.1.03)$$

$$BUDFAC(t) = (WT_i(t) * PD(t)) + (WT_i(t) * PX(t)) + (WT_i(t) * PP(t)) \qquad (8.6.1.04)$$

Table 8.6: **Summary of Budget Factors in Iteration t and their Effect on Budget Appropriations in Iteration t+1.**

Budget Increments

		Positive	Stable	Negative
BUDGET FACTORS	**Budget Activities**	1. $ to Development 2. $ to Research		1. $ to Enforcement
	Profit Activities	Decreasing Profits	Stable Profits	Increasing Profits
	Population Activity	Decreasing Population	Steady Pop'n	Increasing Pop'n

8.6.2 Profit Activities

RP(t) = Rate of profit for fleets in year t.

PROFAC(t) = Profit factor in year t.

$$\text{If } RP(t) \begin{cases} < \emptyset & PROFAC(t) = -(RP(t)^{1.5}) \\ \emptyset & PROFAC(t) = \emptyset \\ > \emptyset & PROFAC(t) = -(RP(t)^{1.5}) \end{cases}$$

8.6.3 Population Activity

PJ(t) = Population size in year t.

DEL(t) = Percentage change in population size in year t.

POPFAC(t) = Population Factor in year t.

DEL(t) = (PJ(t) - PJ(t-1))/PJ(t-1)

$$\text{If } DEL(t) \begin{cases} < \emptyset & PROFAC(t) = -(DEL(t)^{1.5}) \\ \emptyset & PROFAC(t) = \emptyset \\ > \emptyset & PROFAC(t) = -(DEL(t)^{1.5}) \end{cases}$$

8.6.4 Budget Appropriation

$$BUDAPRO(t) = (WT_i(t) * BUDFAC(t)) + (WT_i(t) * PROFAC(t)) + (WT_i(t) * POPFAC(t))$$

$$BUDGET(t+1) = BUDGET(t) = (BUDAPRO(t) * BUDGET(t))$$

$$\text{If } BUDGET(t+1) \begin{cases} \leq \emptyset & BUDGET(t+1) = \$100K \\ > \emptyset & BUDGET(t+1) \end{cases}$$

9.0 Enforcement Budget Decision Filters

When the user under-allocates with respect to the optimal enforcement allocation required, the program then reverts to the enforcement decision filters.

These filters deleteriously affect the major components of the management regulation framework as follows:

BUD(t) = total budget in year t.

EF(t) = optimal enforcement budget in year t.

EN(t) = amount allocated to enforcement budget in year t.

OA(t) = percent allocation of optimal enforcement budget in year t.

$OA(t) = EN(t)/EF(t)$

if, $OA(t) < 1.0$ then go to filters (9.1 -9.4)

$OA(t) \geq 1$ then bypass filters

9.1 Fishing Mortality Exceeding Recommended

$FIL(t) = OA(t)^{1.5}$ for $FIL(t) < 3$

if, $FIL(t) \geq 3$ then $FIL(t) = 3$

and,

$$F(x,t) = F(x,t) + (F(x,t) * FIL(t)) \qquad (9.1)$$

9.2 Age of 100% Vulnerability Below Recommended

TC(t) = age of 100% vulnerability to gear in year t.

$$FIL(t) = -(OA(t)^{1.5}) \qquad (9.2)$$

if, $FIL(t) \geq 3$ then $FIL(t) = 3$ for $TC(t) = 1,2,3,...,t_\lambda$

$TC(t) = TC(t) + FIL(t)$

if, $TC(t) \leq 2$ then $TC(t) = 2$

$$A_{x,t} \begin{cases} 0.0 \text{ for } < TC(t) & x = 1,..., (TC(t)-1) \\ 1.0 \text{ for } \geq TC(t) & x = (TC(t)-1) \text{ to } t_\lambda \end{cases}$$

9.3 Season Closures Less than Recommended

$$A(x,t) = \left[(12\text{-}MC(t)/12) * A(x,t)\right] * FIL(t)$$

which modifies the availability coefficient accordingly.

9.4 Catch Quota Exceeding Recommended

$CL(t)$ = recommended catch quota in year t.

$$FIL(t) = OA(t)^{2.0} \quad (9.4.01)$$

if, $FIL(t) > 1.0$ then $FIL(t) = 1.0$

$$CL(t) = CL(t) + (CL(t) * FIL(t)) \quad (9.4.02)$$

10.0 Effort Development Decision Filters

This set of filters allows for the potential maximum rate of development of fishing effort (without regulation) with an optimal choice or allocation to development. In this regard, a weighted evaluation by the utility function is made at each iteration to determine if the manager is to be removed from his position. The more money allocated to development increases the probability that the manager will stay in position by adding positive weighting to the utility function, and thus an overall favorable view of this action by the constituency.

$RG_K(t)$ = net profits from fleet type K in year t.

$VC_K(t)$ = total vessel costs of fleet type K in year t.

$RP_K(t)$ = rate of profit for fleet type K in year t.

FDI_K = factor of effort increase for fleet type k in year t+1.

DEV (t) = development budget allocation in year t.

OPTDEV(t) = optimal budget allocation to development in year t.

DEVFAC (t) = ratio of development budget to optimal developmental. budget in year t.

WX(t) = development budget factor in year t+1.

$F2MULT_K$ = fishing mortality multiplier for year t+1.

$$WX(t) = \begin{cases} DEV(t)/OPTDEV(t) & \text{when } DEVFAC(t) \leq 1.0 \text{ and } RP \geq 0 \\ 1.0 & DEVFAC(t) > 1.0 \text{ and } RP(t) \geq 0 \\ 0.5 & DEVFAC(t) \geq 1.0 \text{ and } RP(t) < 0.0 \\ 1.0 & DEVFAC(t) < 1.0 \text{ and } RP(t) < 0.0 \end{cases}$$

The flow of effort units into and out of the fishery follows approximately the pattern outlined in Table 10.0.

Table 10.0: **Rates of effort flow into and out of fishery based on rate of profit and budget levels**

		RATE OF PROFIT (RP)	
		Negative	**Positive**
Development Budget (DEV)	**Low**	High F Departure	Low F Entry
	High	Low F Departure	High F Entry

10.1 Commercial, 1 Gear Type (K=1)

The factor of potential effort increase is calculated as:

$$FDI_K(t+1) = (RG_K(t)/VC_K(t))^{0.5} = (RP_K(t))^{0.5} \quad \text{when } RP \geq 0.0$$

$$FDI_K(t+1) = -((ABS(RP))^{1.5} \quad 0.0 > RP(t) \geq -1.0$$

$$FDI_K(t+1) = -1.0 \quad -1.0 > RP$$

So,

$$F2MULT_K(t) = FDI_K(t) * WX(t) \qquad (10.0.01)$$

then the fishing mortality development calculation without regulation is:

$$F_K(t+1) = F_K(t) = F_K(t)\ F2MULT_K(t) \qquad K = 1 \qquad (10.1.02)$$

10.2 Commercial, 2 Gear Type in Sequence

Factor of potential effort increase for 2-gear types (K=2) is calculated as:

$$FDI_K(t+1) = (R2G_K(t)/V1C_K(t))^{0.5} \quad K=1 \quad \text{when } RP_K \geq 0.0$$

$$FDI_K(t+1) = (R3G_K(t)/V2C_K(t))^{0.5} \quad K=2$$

$$FDI_K(t+1) = -((ABS(RP_K))^{1.5}) \quad K=1,2 \quad 0.0 > RP_K(t) \geq -1.0$$

$$FDI_K(t+1) = -1.0 \quad -1.0 > RP_K$$

$$F2MULT_K(t+1) = FI_K(t+1) * WX(t) \quad K=1,2 \qquad (10.2)$$

10.3 Commercial 1-Gear Type and Recreational Fishery

10.3.1 Commercial Sector

The factor of potential effort increase for the commercial gear sector of the fishery is calculated as:

$$FDI_C(t+1) = (RG_C(t)/VC_C(t)) \quad \text{when } RP_C \geq 0.0$$

$$FDI_C(t+1) = ((ABS(RP_C))^{1.5}) \quad 0.0 > RP_C(t) \geq -1.0$$

$$FDI_C(t+1) = -1.0 \quad -1.0 > RP_C(t)$$

$$F2MULT_C(t+1) = FI_C(t+1) * WX(t) \qquad (10.3)$$

10.3.2 Recreational Sector

The factor of potential effort increase for the recreational fishery sector is the product of three multipliers:

10.3.2.1 Virgin Population Criterion

MX(t) = virgin population size in numbers in year t.

PJ(t) = population size in numbers in year t.

VPC(t) = % of virgin population present in year t.

PMSY = population size at maximum sustainable yield.

$$VPC(t) = PJ(t)/MX(t) \tag{10.3.2.1}$$

if, $PJ(t) \geq PMSY$ then $FI_{VPC}(t+1) = (VPC(t))^{1.5} \geq 1.0$

$PJ(t) < PMSY$ then $FI_{VPC}(t+1) = 1.0$

10.3.2.2 Human Population Density Effect

Longterm growth of recreational fishing intensity is proportional to the growth of the human population density in the urban area near the fishery. Thus, if the quality of the stock is high (i.e., VPC(t) = 1) then this fact indicates good recreational fishery action and a high potential change in recreational fishing effort.

HP(t) = human population density increase in year t.

R = intrinsic rate of human population growth.

HP(t+1) = factor of effort increase due to human population growth in year t+1.

$$HP(t+1) = HP(t) * EXP(R) \tag{10.3.2.2.01}$$

$$HI(t+1) = (1+R) \tag{10.3.2.2.02}$$

10.3.2.3 No Growth

If PJ(t)   PMSY population then there will be no direct growth in fishing intensity from a recreational fishery standpoint, thus $FI_R(t+1) = 1$ and $DEVFAC(t) = 1$.

10.3.2.4 Availability

Recreational fishing intensity is ultimately controlled by pure availability.

10.3.2.5 Factor of Recreational Effort Increase

$$FI_R(t+1) = FI_{VPC}(t+1) * HI(t+1) \quad (10.3.2.5.01)$$

and

$$F2MULT(t+1) = FI_R(t+1) * WX(t) \quad (10.3.2.5.02)$$

11.0 Assessment and Monitoring Filters

Of the dollars for research and analysis projects allocated for Assessment and Monitoring purposes, there are 5 destination groups for these funds. Suboptimal budget decisions for the various groups causes variations in the reported values of particular levels. Deviations are group specific.

11.1 Decision Variables

FINMAN utilizes decision variables to set stochastic variation tolerance for output in the following respective categories.

OMA = Optimum Management Allocations in Dollars.

OLMA = 50% Level of OMA.

BFS = Basic Fishery Statistics Allocation.

RS = Resources Survey Allocation.

CT = Catch Analysis Allocation.

EC = Economic Analysis Allocation.

EE = Environmental Trends Allocation.

R = Random Variable.

VAR = Variable.

11.2 Standard Decision Loop

A standard decision loop for the respective output categories is computed as follows:

M1 = BFS/OMA = % of Optimum Allocation.

IF = (BFS $\geq$ OMA) then Bypass Filter.

IF = (OLMA $\leq$ BFS) and (BFS $<$ OMA) then 1

IF = (BFS $<$ OLMA) then 2

1. AO = 0.6 + (0.4 * M1) : Go to 3 (11.2.01)

2. AO = 1.6 * M1 : Go to 3 (11.2.02)

3. AR = VAR - (VAR * (1-AO)) (11.2.03)

   BR = VAR + (VAR * (1-AO)) (11.2.04)

   VAR = AR + (BR-AR) * R (11.2.05)

11.3 Sampling Curve

The sampling curves for the Assessment filters for one and two fleet output, computed as the +/- stochastic oscillation around the mean response are formulated by the following linear equations.

Sampling Segment A:

Y = 0.6 + 0.4x (Budget Allocation $\geq$ 50% of Optimum) (11.3.01)

Sampling Segment B:

Y = 1.6x (Budget Allocation $<$ 50% of Optimum) (11.3.02)

11.4 Effect on Simulation Output

The following four modular segments listed are functional transformation routines in the module **ASSESS.FILTER.** These modular routines alter the original variables according to the segment of the sampling curve the value lies. Relative variation in sampling survey precision is due to allocations in the major headings of the assessment and monitoring budgetings.

BFS = Basic Fishery Statistics.

CT = Catch Analysis.

EC = Economic Analysis.

RS = Resource Surveys.

Following then are listings of the original variabiles names (OV), the name of that when transformed (TV), the modification routines (AMR), and the storage variable name of the time series variable (TSV). These are listed for (1) single gear output (Section 11.4.1), and (2) multiple gear output (Section 11.4.2).

11.4.1 Single Gear Type Output Modification

		Original Variable (OV)	Transformed Variable (TV)	Asses.Filter Modification Routine (AMR)	Time Series Variable (TSV)
11.4.1.1	**Quota and Catch**				
11.4.1.1.1	Proposed Catch Quota	OQC			
11.4.1.1.2	Actual Total Catch	Y1W	"	EC	Y2W(T)
11.4.1.1.3	Total Number in Catch	YZN	"	EC	
11.4.1.1.4	Average Weight in the Catch	WA	"	BFS	WBAR(T)
11.4.1.1.5	Average Length in the Catch	AL	"	BFS	LBAR(T)
11.4.1.2	**Cost and Returns**				
11.4.1.2.1	Total Effort (# of Units)	NV	"	BFS	Z6(T)
11.4.1.2.2	Vessel (Unit) Cost	VC	"	EC	EC(T)
11.4.1.2.3	Gross Revenue from Fishery	NU	"	EC	HV(T)
11.4.1.2.4	Net Returns to Fishery	RG	"	EC	NET(T)
11.4.1.2.5	Rate of Profit	RP	"	EC	EYPR(T)
11.4.1.2.6	Yield in Weight by Age class	YW(I,1)	"	EC	
11.4.1.2.7	Yield in Numbers by Age class	YN(I,1)	"	EC	
11.4.1.3	**Catch Analyses**				
11.4.1.3.1	Age-specific Fishing Mort.	F(I)	FC(I)	CT	F6(T)
11.4.1.3.2	Age-specific Natural Mort.	XM(I)	XØ(I)	BFS	
11.4.1.3.3	**Von Bertalanffy Parameters**				
11.4.1.3.3.1	Ultimate Weight(W_∞)	WINF	G1	CT	
11.4.1.3.3.2	Ultimate Length (L_∞)	LINF			
11.4.1.3.3.3	Growth Coefficient	XAKV	G2	CT	
11.4.1.3.3.4	T-Zero (to)	TØ	G3	CT	
11.4.1.3.3	Sex Ratio	S1XRS	"	BFS	

		(OV)	(TV)	(AMR)	(TSV)
11.4.1.3.4	Population Size @ Year's Start by Age-class	P(I,1)	P∅(I,1)	CT	
11.4.1.3.5	Average Population Size by Age-class	RN(I,1)	"	CT	
11.4.1.3.6	Fishable Average Population	FP(I,1)	"	CT	
11.4.1.4	**Stock & Recruitment Trends**				
11.4.1.4.1	Stock Size @ Years' Start	PJ	P∅	CT	FS(T)
11.4.1.4.2	Spawning Stock @ Year's Start	SP	"	RS	ST(T)
11.4.1.4.3	Numbers of Larvae RS	P(1,1) NL(T)	LY		
11.4.1.4.4	Recruitment	P(1,JJ%)	REC	RS	RC(T)
11.4.1.5	**Yield Per Recruit Analysis**	YA(I,J)			
11.4.1.6	**Fishery Economic History**				
11.4.1.6.1	Number of Effort Units	NV	"	BFS	Z6(T)
11.4.1.6.2	Gross Revenue	NU	"	EC	HV(T)
11.4.1.6.3	Effort Costs	VC	"	EC	EC(T)
11.4.1.6.4	Net Returns	RG	"	EC	NET(T)
11.4.1.6.5	Rate of Profit	RP	"	EC	EYPR(T)
11.4.1.7	**Fishery Catch & Effort Record**				
11.4.1.7.1	Catch	Y1W	"	BFS	Y2W(T)
11.4.1.7.2	Fishing Mortality Rate	F(I)	FC(I)	BFS	F6(T)
11.4.1.7.3	Average Weight in the Catch	WA	"	BFS	WBAR(T)
11.4.1.7.4	Average Length in the Catch	AL	"	CT	LBAR(T)
11.4.1.7.5	Age @ 100% Selection	TC	"	-	TC(T)
11.4.1.8	**Point Awards for Loop**				
11.4.1.8.1	Newness Allocation	AN			
11.4.1.8.2	Conservation Ethic	CE			

		(OV)	(TV)	(AMR)	(TSV)
11.4.1.8.3	Commercial Ethic	CM			
11.4.1.8.4	Budget Management	BM			
11.4.1.8.5	Management Measures Perception	PAP			
11.4.1.8.6	Total Award	UT(PZ-1)			PTS
11.4.1.9	**Historical Budget Allocation Decisions**				
11.4.1.9.1	Assessment & Monitoring	AM			AM(T)
11.4.1.9.2	Enforcement	EN			EN(T)
11.4.1.9.3	Development	DEV			DEV(T)
11.4.1.9.4	Not Allocated	LEFT			NA(T)
11.4.1.9.5	Total Budget	BUD(PZ)			BDG(T)
11.4.1.10	**Historical Assessment & Monitoring Decisions**				
11.4.1.10.1	**Data Collection**				
11.4.1.10.1.1	Basic Fishery Statistics	BFS			BFS(T)
11.4.1.10.1.2	Resource Surveys	RS			RS(T)
11.4.1.10.2	**Analysis**				
11.4.1.10.2.1	Catch Analysis	CT			CT(T)
11.4.1.10.2.2	Economics	EC			E3(T)
11.4.1.10.2.3	Environmental Trends	EE			EE(T)
11.4.1.10.5	Not Allocated	ML			ML(T)
11.4.2 Multiple Gear Type Output Modification					
11.4.2.1	**Quota and Catch**				
11.4.2.1.1	**Proposed Quota**				
11.4.2.1.1.1	**Numbers**				
11.4.2.1.1.1.1	Fleet 1	∅			
11.4.2.1.1.1.2	Fleet 2	QN			

		(OV)	(TV)	(AMR)	(TSV)
11.4.2.1.1.1.3	Both Fleets Combined	∅			
11.4.2.1.1.2	**Weight**				
11.4.2.1.1.2.1	Fleet 1	04CQ			
11.4.2.1.1.2.2	Fleet 2	05CQ			
11.4.2.1.1.2.3	Both Fleets Combined	(04CQ + 05CQ)			
11.4.2.1.2	**Actual Catch**				
11.4.2.1.2.1	**Numbers**				
11.4.2.1.2.1.1	Fleet 1	Y3N	"	EC	
11.4.2.1.3.1.2	Fleet 2	Y4N	"	EC	
11.4.2.1.2.1.3	Both Fleets Combined	YZN	"	EC	
11.4.2.1.2.2	**Weight**				
11.4.2.1.2.2.1	Fleet 1	Y5W	"	EC	
11.4.2.1.2.2.2	Fleet 2	Y6W	"	EC	
11.4.2.1.2.2.3	Both Fleets Combined	Y1W	"	EC	
11.4.2.2	**Average Size in the Catch**				
11.4.2.2.1	**Average Weight**				
11.4.2.2.1.1	Fleet 1	A7W	"	BFS	
11.4.2.2.1.2	Fleet 2	A8W	"	BFS	
11.4.2.2.1.3	Both Fleets Combined	WA	"	BFS	
11.4.2.2.2	**Average Length**				
11.4.2.2.2.1	Fleet 1	L1A	"	BFS	
11.4.2.2.2.2	Fleet 2	L2A	"	BFS	
11.4.2.2.2.3	Both Fleets Combined	AL	"	BFS	
11.4.2.3	**Economics (Costs & Returns)**				
11.4.2.3.1	Effort (# of Units)				

		(OV)	(TV)	(AMR)	(TSV)
11.4.2.3.1.1	Fleet 1	U1	"	BFS	
11.4.2.3.1.2	Fleet 2	U2	"	BFS	
11.4.2.3.1.3	Both Fleets Combined	(U1 +U2)	"		
11.4.2.3.2	**Vessel Costs**				
11.4.2.3.2.1	Fleet 1	V1C	"	EC	
11.4.2.3.2.2	Fleet 2	V2C	"	EC	
11.4.2.3.2.3	Both Fleets Combined	VC	"	EC	
11.4.2.3.3	**Gross Revenue**				
11.4.2.3.3.1	Fleet 1	V3G	"	EC	
11.4.2.3.3.2	Fleet 2	V4G	"	EC	
11.4.2.3.3.3	Both Fleets Combined	NU	"	EC	
11.4.2.3.4	**Net Returns**				
11.4.2.3.4.1	Fleet 1	R2G	"	EC	
11.4.2.3.4.2	Fleet 2	R3G	"	EC	
11.4.2.3.4.3	Both Fleets Combined	RG	"	EC	
11.4.2.3.5	Yield in Weight by Age-class	YW(I,1)	"	EC	
11.4.2.3.6	Yield in Number by Age-class	YN(I,1)	"	EC	
11.4.2.4	**Catch Analysis**				
11.4.2.4.1	Age-specific Instantaneous Fishing Mortality Rate	F(I)	FC(I)	CT	
11.4.2.4.2	Age-specific Instantaneous Natural Mortality Rate	XM(I)	XØ(I)	BFS	
11.4.2.4.3	**Von Bertalanffy Growth Equation Parameters**				
11.4.2.4.3.1	Ultimate Weight (W_∞)	WINF	G1	CT	
11.4.2.4.3.2	Ultimate Length (L_∞)	LINF		CT	
11.4.2.4.3.3	Growth Coefficient (K)	XAKV	G2	CT	
11.4.2.4.3.4	T-zero (t_0)	TØ	G3	CT	

		(OV)	(TV)	(AMR)	(TSV)
11.4.2.4.4	Sex Ratio	S1XRS	"	BFS	
11.4.2.4.5	Population Size @ Year's by Age-class	P(I,1)	P∅(I,1)	CT	
11.4.2.4.6	Average Population Size by Age-class	RN(I,1)	"	CT	
11.4.2.4.7	Fishable Average Population by Age-class	FP(I)	"	CT	
11.4.2.5	**Stock & Recruitment Trends**				
11.4.2.5.1	Stock Size @ Year's Start	PJ	P∅	CT	FS(T)
11.4.2.5.2	Spawning Stock @ Year's Start	SP	"	CT	ST(T)
11.4.2.5.3	Number of Larvae	P(1,1)	LY	RS	NL(T)
11.4.2.5.4	Recruitment	P(1,JJ%)	REC	RS	RC(T)
11.4.2.6	**Yield-Per-Recruit**	YA(I,J)			
11.4.2.7	**Fishery Economic History**				
11.4.2.7.1	**Gross Revenue**				
11.4.2.7.1.1	Fleet 1	V3G	"	EC	Z7(T)
11.4.2.7.1.2	Fleet 2	V4G	"	EC	HV(T)
11.4.2.7.2	**Effort Costs**				
11.4.2.7.2.1	Fleet 1	V1C	"	EC	E4(T)
11.4.2.7.2.2	Fleet 2	V2C	"	EC	NET(T)
11.4.2.7.3	**Net Returns**				
11.4.2.7.3.1	Fleet 1	R2G	"	EC	EYPR(T)
11.4.2.7.3.1	Fleet 2	R3G	"	EC	R3G(T)
11.4.2.8	**Fishery Catch & Effort Record**				
11.4.2.8.1	**Number of Effort Units**				
11.4.2.8.1.1	Fleet 1	U1	"	BFS	U1(T)
11.4.2.8.1.2	Fleet 2	U2	"	BFS	U2(T)

		(OV)	(TV)	(AMR)	(TSV)
11.4.2.8.2	**Catch in Weight**				
11.4.2.8.2.1	Fleet 1	Y5W	"	EC	U3(T)
11.4.2.8.2.2	Fleet 2	Y6W	"	EC	U4(T)
11.4.2.8.3	**Catch Per Unit Effort**				
11.4.2.8.3.1	Fleet 1	I1			U5(T)
11.4.2.8.3.2	Fleet 2	I2			U6(T)
11.4.2.8.4	**Average Weight in Catch**				
11.4.2.8.4.1	Fleet 1	A7W	"	BFS	C1(T)
11.4.2.8.4.2	Fleet 2	A8W	"	BFS	C2(T)
11.4.2.8.4.3	Both Fleets	WA	"	BFS	C3(T)
11.4.2.8.5	**Average Length in Catch**				
11.4.2.8.5.1	Fleet 1	L1A	"	BFS	C4(T)
11.4.2.8.5.2	Fleet 2	L2A	"	BFS	C5(T)
11.4.2.8.5.3	Both Fleets	AL	"	BFS	C6(T)
11.4.2.9	**Point Awards for Loop**				
11.4.2.9.1	Newness Allocation	AN			
11.4.3.9.2	Conservation Ethic	CE			
11.4.2.9.3	Commercial Ethic	CM			
11.4.2.9.4	Budget Management	BM			
11.4.2.9.5	Management Measures Perception	PAP			
11.4.2.9.6	Total Award	UT(PZ-1)			PTS
11.4.2.10	**Historical Budget Allocations**				
11.4.2.10.1	Assessment & Monitoring	AM			AM(T)
11.4.2.10.2	Enforcement	EN			EN(T)
11.4.2.10.3	Development	DEV			DEV(T)

		(OV)	(TV)	(AMR)	(TSV)
11.4.2.10.4	Not Allocated	LEFT			NA(T)
11.4.2.10.5	Total Budget	BUD(PZ)			BDG(T)
11.4.2.11	**Historical Assessment & Monitoring Allocations**				
11.4.2.11.1	**Data Collection**				
11.4.2.11.1.1	Basic Fishery Statistics	BFS			BFS(T)
11.4.2.11.1.2	Resource Surveys	RS			RS(T)
11.4.2.11.2	**Analysis**				
11.4.2.11.2.1	**Catch Analysis**	CT			CT(T)
11.4.2.11.2.2	Economics	EC			E3(T)
11.4.2.11.2.3	Environmental Trends	EE			EE(T)
11.4.2.11.3	Not Allocated	ML			ML(T)

12.0 Point Allocations and Development of Utility Equation Parameters

Rational management of a fishery by a public agency requires optimization of an objective function which reflects benefits to the users. The decision maker must specify certain measures of effectiveness, and then continues to develops a utility function governing explicit measures or attributes. Given such a utility function, the decision-maker would prefer the alternative with the greatest expected utility. Such a utility function is an expression of preference. The categories of utility function evaluation are defined by the following five attributes for the management of the fishery:

$\vec{x}_1$ = AN(t) = point award for relative **newness** of manager in year t.

$\vec{x}_2$ = CE(t) = point award by people interested in stock **conservation** and not necessarily economics in year t.

$\vec{x}_3$ = CM(t) = point award by **commercial** sector based on economic input in year t.

$\vec{x}_4$ = BM(t) = point award for relative amount of money to development (buying favor) in year t.

$\vec{x}_5$ = PER(t) = point award relative to the number of management measures enacted in year t.

The utility function describes the preference orderings of a hypothetical decision maker, such as the Director of an International Fishery Management Commission. The utility is used in the simulation-optimization model in which (1) performance above a threshold level in a particular year, and (2) maximization of the sum of utility over years, is the objective.

12.1 Newness Allocation

User allocated maximum points in year 1, with an exponential decay from the period t to t + 1. We are assuming a discount rate here (b_1) such that after 5 years the utility is about 10% of the original value.

PZ = year of management simulation.

AN(t) = award for newness in year t.

MAX = maximum intial point award for newness.

$$AN(t) = MAX * e^{-0.45(PZ)} = x_1 \qquad (12.1.01)$$

$$u_1(x_1) = x_1^{b_1}$$

$$u_1(x_1) = 0.5\left[u_1(x_1*)\right] + 0.5\left[u_1(x_1^o)\right] \qquad (12.1.02)$$

$$b_1 = \frac{\ln(0.5)}{\ln(x_1)}$$

$$x_1 = 0.6666667$$

$$b_1 = 1.7095113$$

Since $\vec{x}_1$ is time as defined here, and $\vec{x}_1$ is multiplicative with the other attributes, then the utility of this function represents an assumed discount rate and the risk behavior asociated with it.

12.2 Conservation Ethic

Point award based on constituency expectations by people interested in conservation, and not strictly economic benefits. For certain, the value of recreational fishing is a legitimate part of the economic yield from the fishery. Most recreational fishermen see value in the fishing activity and not just the catch. In this case the higher the percent present population of virgin population (i.e. no fishery) the greater the reward because of the assumed higher catch rates per angler for the recreational angler, and presumably more bigger fish available.

MX_o = virgin fish population size in numbers = $\sum_{x=1}^{t_\lambda} N_{x,t}$ $\qquad t=0$

$PJ(t)$ = population size in year t = $\sum_{x=1}^{t_\lambda} N_{x,t}$

$$x_2 = PJ(t)/MX_o$$

$$= 0.5\left[u_2(x_2*)\right] + 0.5\left[u_2(x_2^o)\right] = 0.5 \qquad (12.2.01)$$

$b_2 = \ln(x_2)$ (12.2.02)

$x_2 = 0.15$

$b_2 = 0.3653681$

CPP(t) = fraction of present population to virgin in year t = $PJ(t)/MX_o$

CE(t) = conservation ethic award.

$CE(t) = -100 + (200 \times CPP(t)) = x_2$

12.3 Commercial Ethic

Point award based on the economics of the commercial sector, i.e., the rate of growth of the within year investment (see section 8.0).

CO(t) = cost of 1 vessel operating in year t.

NV(t) = number of vessels operating in year t.

VC(t) = total vessel costs in year t.

NU(t) = gross revenue in year t.

RG(t) = NU(t) - VC(t) = profit for year t.

PF(t) = profit per unit capital outlay in year t.

$PF(t) = RG(t)/VC(t)$ (12.3.01)

CM(t) = commercial ethic point award in year t.

$CM(t) = PF(t)/MZ = x_3$ (12.3.02)

MZ = maximum possible rate of profit = Cmax

$u_3(x_3) = CM(t)/Cmax$

$u_3(x_3) = x_3^{b_3}$

$b_3 = \frac{\ln(0.5)}{\ln(x_3)}$

$x_3 = .25$

$b_3 = 0.5$

12.4 Budget Management

Point award for the relative amount of money to development, i.e., buying favor. The fisheries manager is allocated dollars to meet certain goals. If he returns the money without achieving the goals, then he is doing a poor job.

BUD(t) = total research and management budget level in year t.

LEFT(t) = total dollars unspent in year t.

DEV(t) = total dollars allocated to development in year t.

$$BM(t) = DEV(t)/BUD(t) = x_4 \qquad (12.4.01)$$

$u_4(x_4) = x_4$

$x_4 = .40$

$b_4 = 0.7774211$

$$PM(t) = LEFT(t)/BUD(t) \qquad (12.4.02)$$

BM(t) = budget management point award in year t.

$$BM(t) = MAX \times PM(t)^{1.5} \qquad (12.4.03)$$

12.5 Perceptions

Constituencies view of the manager's use of potential regulation schemes.

In general, fewer regulations are better than more.

MAXREGS(t) = maximum number of possible regulatory measures in year t.

REGS(t) = number of management measures enacted in year t. (12.5)

PAP(t) = point award for perceptions in year t.

$$PAP(t) = (MAXREGS(t) - REGS(t)) / MAXREGS(t) = x_5 \qquad (12.5)$$

$u_5(x_5) = x_5^{b_5}$

$x_5 = 0.95$

$b_5 = 13.513407$

12.6 Multiattribute Function Development and Parameterization

Given five attributes which contribute to our "quality of fishery management" criterion, we desire to construct a utility function $u(x_1, x_2, x_3, x_4, x_5) = u(x)$, reflecting all of these measures.

$$u(x) = f\left[u_1(x_1),u_2(x_2),u_3(x_3),u_4(x_4),u_5(x_5)\right] \quad (12.6.1)$$

where, $u_i(x_i)$ is a utility function over attribute x_i.

Let, x_i^o = least preferred outcome of x_i.

x_i^* = most preferred outcome of x_i.

then, $u_i(x_i^o) = 0$ and $u_i(x_i^*) = 1$

so, $u(x_1^o,x_2^o,x_3^o,x_4^o,x_5^o) = 0$

$u(x_1^*,x_2^*,x_3^*,x_4^*,x_5^*) = 1$

As mentioned previously, $k_i = (x_i^*,x_{i-}^o)$. Therefore, each k_i could be evaluated by finding the probability p at which the decision-maker was indifferent to $u(x_i^*,x_{i-})$ for certain and a lottery offering $u(x^*)$ with a probability p, or $u(x^o)$ with a probability 1-p. This result yields

$$u(x_i^*,x_{i-}) = p\left[u(x^*)\right] + (1-p)\left[u(x^o)\right] \quad (12.6.2)$$

since $(x^*) = 1$ and $(x^o) = 0$, then (12.6.2) reduces to

$$(x_i^*,x_{i-}^o) = p \quad (12.6.3)$$

If $\Sigma k_i=1$, and $K=\emptyset$ then the model is linear. If $\Sigma k_i \neq 1$, then $K \neq \emptyset$ and must be evaluated.

$$1+ Ku(x) = \prod_{i=1}^{5} 1+Kk_iu_i(x_i) \quad (12.6.4)$$

$$1+Ku(x) = (1+Kk_1u_1(x_1))(1+Kk_2u_2(x_2))(1+Kk_3u_3(x_3))(1+Kk_4u_4(x_4))(1+Kk_5u_5(x_5)) =$$

$$u(x) = \left[(1+Kk_1u_1(x_1))(1+Kk_2u_2(x_2))(1+Kk_3u_3(x_3))(1+Kk_4u_4(x_4))(1+Kk_5u_5(x_5)) -1\right]/K$$

where the k_i are scaling factors ($0<k_i<1$) and K is another scaling factor ($-1<K$). The scaling factor K may be found numerically by solving

$$1+K = \prod_{i=1}^{5}(1+Kk_i) \qquad (12.6.5)$$

Equation (12.6.5) is derived from (12.6.4) when all attributes are offered at their most preferred amounts; i.e $x=x^*$. If $\Sigma k_i > 1$, then $-1<K<0$, and if $\Sigma k_i < 1$, then $K > 0$. Thus (12.6.5) may be solved by trial and error (see Powers, J.E. 1976. Virginia J. Sci. 27(4):191-198.). The scaling factor k_i is equal to p, i.e.:

$$u\left[u_1(\text{new in position}),u_{1\_}(0)\right] = k_1 = 0.8$$
$$u\left[u_2(\text{maximum pop'n size}),u_{2\_}(0)\right] = k_2 = 0.45$$
$$u\left[u_3(\text{max.rate of profit}),u_{3\_}(0)\right] = k_3 = 0.4$$
$$u\left[u_4(\text{max.\$ to development}),u_{4\_}(0)\right] = k_4 = 0.6$$
$$u\left[u_5(\text{minimum regulations}),u_{5\_}(0)\right] = k_5 = 0.8$$
$$K \doteq -0.995$$

A utility function represents the decision-maker's personal preference, and there is no "right" or "wrong" associated with it. However, by the very nature of his position a decision-maker employed by a public agency is required to make value judgements about benefits to the public whom the agency serves. In all likelihood, preference orderings by the users will not be consistent. Even if they were, it is unlikely that the decision-maker's utility responses would completely coincide with those of the public. Therefore, by definition the decision-maker must decide on the utility responses himself. However, the decision-maker may have no a priori judgements of marginal utilities and tradeoffs which will affect public benefits. In such a case public input may be desireable.

Table 12.6.0 Utility Attributes and Their Ranges

Attribute:	Least Desirable Amount	Most Desirable Amount
1) Newness (years)	30	0
x_1:scaled	0	1
2) Conservation	0	Pmax
x_2:scaled	0	1
3) Economic Revenue to Commercial Sector	Zero and Negative Profits	Max. Profit
x_3:scaled	0	1
4) Dollars to fleet development	0	1/3 Total Budget
x_4:scaled	0	1
5) Number of Management Measures	All possible	None
x_5:scaled	0	1

Table 12.6.1: Example Utility derived for outcomes of x_1 (newness), x_2(conservation), x_3 (commercial), x_4 (budget), and x_5 (regulation) using parameter values given in Sections 12.1-12.5.

$u_5(x_5)$	$u_4(x_4)$	$u_3(x_3)$	$u_2(x_2)$	$u_1(x_1)$	x_i
3.0×10^{-14}	.167	.316	.431	.020	.1
3.5×10^{-10}	.286	.447	.555	.064	.2
8.5×10^{-8}	.392	.548	.644	.120	.3
4.2×10^{-6}	.490	.632	.715	.209	.4
8.6×10^{-5}	.583	.707	.776	.306	.5
1.0×10^{3}	.672	.755	.830	.418	.6
8×10^{-3}	.758	.837	.878	.543	.7
.049	.840	.894	.922	.683	.8
.24	.921	.949	.962	.835	.9
1.0	1.0	1.0	1.0	1.0	1.0

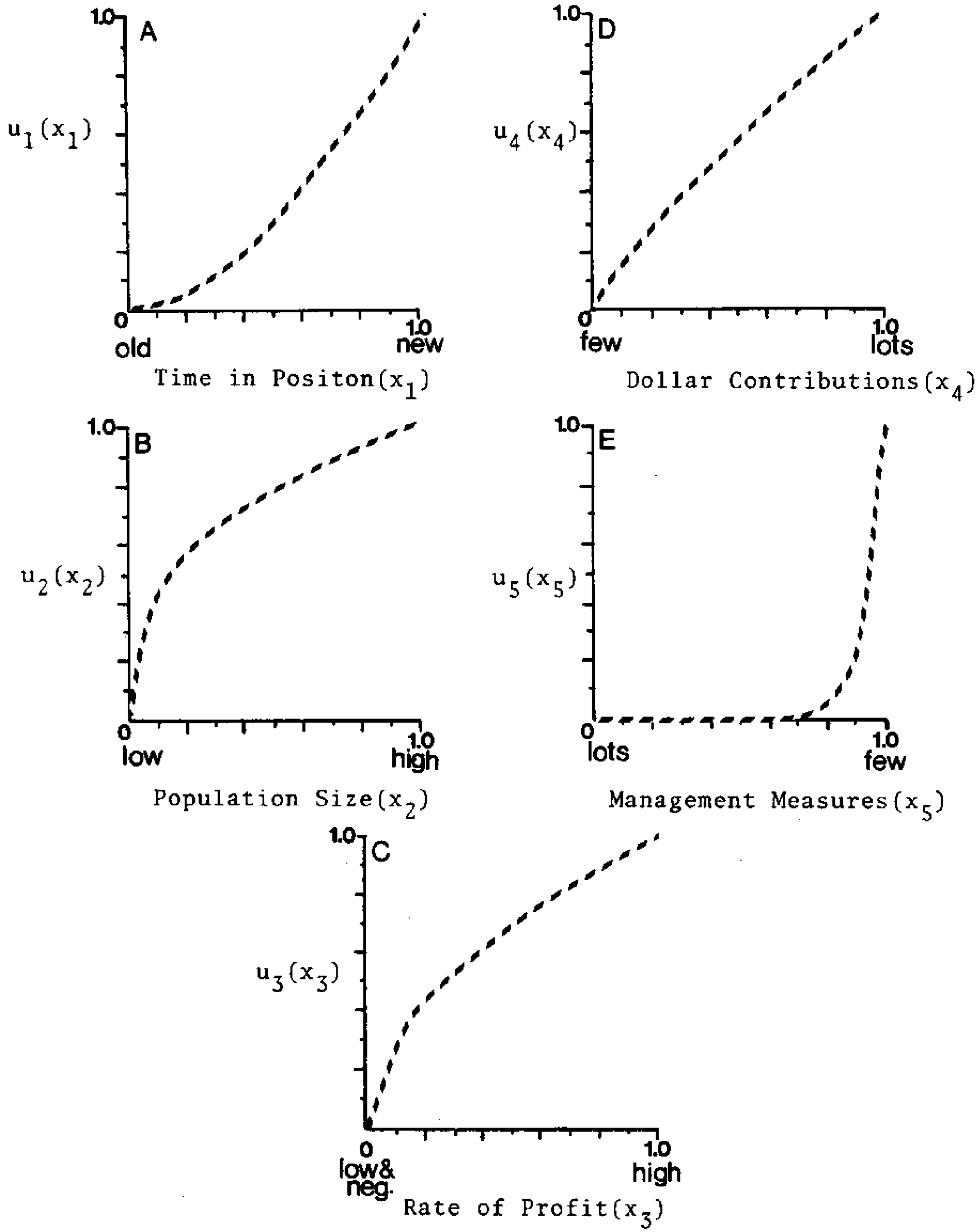


Figure 12.6.0: Utility Derived Outcomes of A) x_1(newness), B) x_2(conservation), C) x_3(commercial), D) x_4(budget), and E) x_5(regulation).

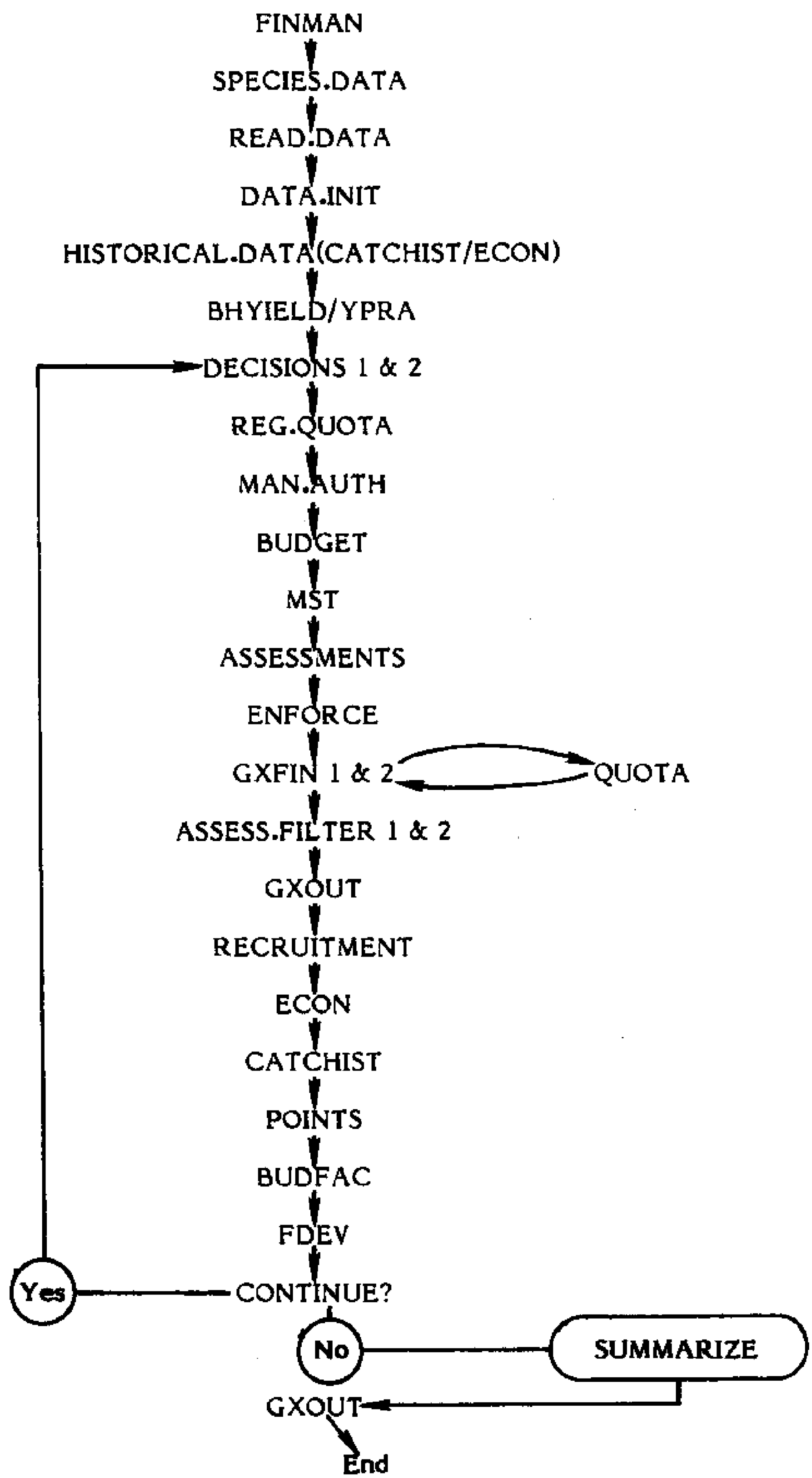
13.0 FINMAN Computer Program Module Descriptions

13.0.1 Generalized Program Flow

The FINMAN program flow for a typical single-gear type fishery arrangement is diagrammed in Figure 13.0.1. Modules for both single- and multiple-gear fisheries are executed in sequence to control the computational and decisions flow network, variables are continuously entered and retained for the entire simulation exercise. Modular routines and their general functions for the Apple (and IBM) microcomputers are listed below:

	Module Name	Function
13.1	FINMAN.MAIN (FMAN)	Allows selection of the species profile and sets controls for the management system type, management authority, species life history strategy, fishery exploitation type, current fishery status, and historical data availability.
13.2	"SPECIES"	Loads to random access memory (RAM) the 'SPECIES' life history and management system profiles as RAM text data modules.
13.3	READ.DATA (RDAT)	Loads to active working memory the user selected subsets of management and species profiles.
13.4	DATA.INIT (DTIN)	Initializes historical data with predetermined precision bounds.

Figure 13.0.1: Simplified modular flow diagram for computer program FINMAN module execution for a 1-gear type fishery.



13.5	BHYIELD (BHYLD)	Calculates Equilibrium Yield per Recruit surface.
13.6	CATCHIST (CTHS)	Calculates and displays the fishery specific historical catch information for a single-gear type fishery.
13.7	DECISIONS 1 & 2 (DEC & DEC2)	Sets management decisions strategy for fishing mortality and age of capture for the current iteration.
13.8	BUDGET (BDGT)	Sets research, enforcement, and development budgets for current iteration.
13.9	ASSESSMENTS (ASMT)	Sets basic fishery statistics, resource survey, catch analyses, economic, and environmental monitoring budget decisions for the current iteration.
13.10	ENFORCE (ENFOR)	Modifies management decision strategy based on enforcement allocations for the present iteration.
13.11	REVIEW.DATA (RVDT)	Allows review of the life history and management settings prior to computation of the current iteration.
13.12	GXFIN 1 & 2 (GXFIN & GXF2)	Calculates age- and sex-specific fishery effects for the current loop including larvae, recruitment, growth,

		yearclass sizes, spawning sex ratio, fertilized female ratio, yields and associated economic conditions for the current iteration.
13.13	QUOTA (QUOTA)	Calculates quota-tolerances, catch quotas, and bag limits for the current iteration.
13.14	ASSESS.FILTER 1 & 2 (ASFL & ASFL2)	Modifies all output catagories based on assessment and monitoring budget allocations for the current iteration.
13.15	GXOUT (GXO)	Single-gear type complete fishery and economic analyses output for the current iteration.
13.16	GXOUT2 (GX02)	Multiple-gear type complete fishery and economic analyses output for the current iteration.
13.17	RECRUITMENT (RECT)	Displays historical stock and recruitment trends.
13.18	YPRA (YPRA)	Displays in tabular form the equilibrium yield per recruit analysis surface, and the fishing mortality and age of capture estimations for year t-1, and the selections by management in year t.
13.19	ECON (ECON)	Displays historical fishery economic analyses for a single gear type.

13.20 POINTS (POINT) — Calculates and displays utility function solution and evaluates user performance for the current iteration.

13.21 CEFF2 & CEFF2.1 (CFF & CEFF2) — Calculates and displays the fishery specific historical catch and effort information for a multiple-gear fishery.

13.22 FISHECON2 (ECON2) — Calculates historical fishery economic analyses for a multiple-gear fishery.

13.23 BUDGET.HIST (BDGH) — Calculates and displays the historical, research, enforcement and development budget decisions.

13.24 ASSESS.HIST (ASHT) — Calculates and displays the historical data collection and analysis budget decisions.

13.25 FDEV (FDEV) — Calculates the rate of fishing effort development expected without regulation.

13.26 BUDFAC (BFAC) — Calculates budget factor and expected level of budget change in year t+1.

13.27 MST (MST) — Calculates the decisions sequence implementation probabilities for a commission or legislature-based policy body.

13.28 MAN.AUTH (MNAT) — Calculates the level of management decision compliance under a multi-lateral fishery management structure.

13.29 REG.QUOTA (RGQUO) — Sets catch quota and bag limit policy for single- and multiple-gear fisheries for the current iteration.

14.0 Loading and Creating Random Access Text Modules

The control program(s) GROUPER, TUNA, ANCHOVY, SHRIMP, SEATROUT and SNAPPER each, when executed create a series of random access text files which contain the starting condition input parameters necessary for execution of the FINMAN module series. Upon execution of one of the six aforementioned control programs, random access (Apple computers) or sequential access (IBM computers) memory data modules are created.

14.1 Editing the Text Files

14.1.0.1 Apple Computers (Applesoft BASIC)

The general syntax for editing and subsequent interpretation of each field variable takes the following form for the Apple IIe and IIc versions of Applesoft BASIC:

```
D$ = CHR$(4): REM CONTROL-D
```

To create a file directory and the associated subdirectory to a RAM or Disk location:

```
PRINT D$; "OPEN/RAM OR DISK/FINFILE/FILENAME, L"
```

To READ or WRITE to the subdirectory file of specified length L:

```
PRINT D$; "WRITE OR READ/RAM OR DISK/FINFILE/FILENAME, R"
```

Print statement for writing to a text file → Value of field variable → Colon indicates end of field

[...PRINT (INPUT) VARIABLE:...]

To CLOSE the specific directory and subdirectory:

PRINT D$; "CLOSE/RAM OR DISK/FINFILE/FILENAME"

L = File length in bytes

R = Text file record number

14.1.0.2 IBM Personal Computers (Microsoft BASIC)

The general syntax appropriate for creating, editing and subsequent interpretation of each field variable takes the following form in Microsoft BASIC:

To create a file directory and the associated subdirectory to Disk Drive A:

OPEN "A:/Directory/FILENAME" for output(input) as #1

To write or read to the subdirectory file:

Write statement for Writing to a text file → Value of field Variable #1

[WRITE(INPUT) #1, VARIABLE(1), ...VARIABLE (N)]

To close the directory and subdirectory:

CLOSE #1

The specific line numbers that require editing are referred to under each data text file heading.

14.1.1 INPUT

o Line #180

Reads in the successive values of NY, LI, LF, ROG, NRE, NAFMT, NPCF, N1YC, MY, MSB, MASE, MFR, ABREV, SE1, S2, ED, XH.

1. NY = Number of years that each F2MULT value is to be repeated. Input controls the number of years of simulation duration. Must equal 1.
2. LI = Numerical designation of initial yearclass to be printed on the output. Suggest 1.
3. LF = Numerical designation of final yearclass to be printed on the output. Suggest t_λ = N1YC.
4. ROG = Growth option. Growth in weight represented by one of the options:
   0) von Bertalanffy Formulation.
   1) Linear Segmental Growth Formulation.
5. NRE = Stock and recruitment model option.
   0) Beverton & Holt function.
   1) Ricker function.
6. NAFMT = Number of F-multipliers. Must equal 1.
7. NPCF = Random mating model option (Suggest 1).
   0) Retain.
   1) Delete.
8. N1YC = Oldest age of the fish stock (t_λ).
9. MY = Year of life during which reproductive maturity beings.
   Range: 1 to NIYC.

10. MSB = Month of year when spawning (or breeding) begins. Must equal 1.

11. MASE = Month of year when spawning ends. Must equal 1.

12. MFR = Month of year during which recruitment occurrs. Must equal 2.

13. ABREV = Output control specification. Must equal 2.

14. SE1 = Upper bound of age selected by gear type 1 in two-gear type fishery.

15. S2 = Lower bound of age selected by gear type 2 in two-gear type fishery.

16. ED = Effort Development filter (Ø-OFF, 1-ON).

17. XH = Budget calculation for year t+1 filter (Ø-OFF, 1-ON).

14.1.2 POPN"X_i"

o Line #'s 220, 260, 340.

Initial population age structure file (P(I,1)) where I = 1 to N1YC. The initial age structure should be input as the numbers in each yearclass at the start of month 1. Note: The input value for yearclass 1 should be zero; the program will automatically compute recruitment in year 1, month 1 = P(1,1), based on the selected stock-recruitment relationship.

X_i = input selection for the current condition of the fishery.

14.1.3 PARAPOPN

o Line #380.

Reads in the successive values XKC, PCF, A1, A2, RVL, VP, GA, PER, FV, THR.

The copulation coefficient may be thought of as consisting of two multipliers:

1. XKC = The instantaneous coefficient of males contacting females at random, i.e., rate of contact. Range: 0 to 1. (Suggest 1).
2. PCF = Fraction of the XKC encounters that result in copulations, i.e., copulated female fraction. Range: 0 to 1. (Suggest 1).

Input parameters of the mean stock-recruitment function relationship.

3. A1 = magnitude of the relationship (= α).
4. A2 = asymptotic rate parameter of the relationship (= β).
5. RVL = Level of recruitment variability about mean (1-mean/2-variable percentage).
6. VP = Percentage variability for recruitment (i.e., 90% variability = 0.9).
7. GA = Inclusion of autocorrelated recruitment waves (1-on/Øoff).
8. PER = Period for autocorrelated recruitment wave (entered in integer years).
9. FV = Fraction of maximum recruitment used as scalar for autocorrelated recruitment wave.
10. THR = Minimum threshold for recruitment if actual value is less than zero.

14.1.4 NATMORT

o Line #420.

Reads in the instantaneous natural mortality coefficient (XM(I)). May be input as constant or variable from yearclass to yearclass. One value for each yearclass.

14.1.5 AVAIL. "Filename"

o Line #'s 455-470, 505-520, 555-570.

Starting values for the coefficients of availability or catchability (A(I)). May be input as constant or variable from yearclass to yearclass to simulate different selection patterns. One value per yearclass.

14.1.6 FISHMORT. "X_1"

o Line #'s 610, 650, 690.

Reads in the starting values for the instantaneous fishing mortality coefficients (F(I)). May be input as constant or variable from yearclass to yearclass. One value per yearclass.

X_1 = selection for the current condition of the fishery (CCF).

14.1.7 FECUND

o Line #730.

Reads in the successive values of the number of viable ova produced per individual female for the respective yearclasses (E(I)). One value per yearclass.

14.1.8 FMULT

o Line #770.

Inputs the year specific F2MULT values which range from 1 to NAFMT. Suggest one F2MULT which is equal to 1.0.

14.1.9 MATUR

o Line #850.

Inputs two age specific vectors of percent maturity at age for males and females.

1. Fraction of males reproductively mature for the respective yearclasses (FM(I)). One value per yearclass. Range: 0 to 1.

o Line #860.

2. Fraction of females reproductively mature for the respective yearclasses (F1MF(I)). One value per yearclass. Range: 0 to 1.

14.1.10 VONBERT "X_1"

o Line #810.

Inputs the parameters of the Von Bertalanffy growth formulation.

WINF = ultimate weight.

XAKV = growth coefficient.

TØ = time at which the weight/length of the species was equal to zero.

LINF = ultimate length.

14.1.11 ECONOMICS

o Line #900.

Record 1: Inputs the optimal allocation amount (in dollars) for control of the assessment filters:

OMA(1) = Basic fishery statistics allocation.

OMA(2) = Resource surveys allocation.

OMA(3) = Catch analyses allocation.

OMA(4) = Economics allocation.

OMA(5) = Environmental effects allocation.

o Line #920.

Record 2: Fishing effort unit (vessel) costs for the various gear types.

CO(1) = unit cost for single gear type.

CO(2) = unit cost for commercial gear 1.

CO(3) = unit cost for commercial gear 2.

CO(4) = unit cost for commercial gear competing with recreational gear.

CO(5) = unit cost for recreational gear competing with commercial gear.

o Line #940.

Record 3: Value of catch per unit weight by ageclass (VA(I)). One value per yearclass dictated by unit weight in WINF.

o Line #960.

Record 4: Catchability coefficients for the various gear types.

Q(1) = catchability for single gear type.

Q(2) = catchability for commercial gear 1.

Q(3) = catchability for commercial gear 2.

Q(4) = catchability for commercial gear competing with recreational gear.

Q(5) = catchability for recreational gear competing with commercial gear.

o Line #980.

Record 5: Scaling parameters.

MX = Virgin population size at start of year for utility function calculation.

MZ = Optimum rate of profit for utility function calculation.

BUD(1) = Management budget in dollars for first year of simulation.

OPTP = Optimum population corresponding to MSY population size.

RM = Number of management measures possibly enacted.

YMAX(I) = Estimated maximum equilibrium yield for fishery condition type i.

MF(I) = Estimated optimum fishing effort for fishery condition type i.

14.1.12 CHIST

o Line # is 1000-1960.

These files produce catch and economic data histories corresponding to the Current Fishery Status (CCF) and the Historical Data Availability (HDI) requested by the user. In particular these create the files necessary when the user selects CCF = 2 or 3, and HDI = 1 or 2, and the respective files based on selection are outlined in Table 14.1.12.

Table 14.1.12: Data files accessed upon user selection of the subcategories of the Current Fishery Status (CCF) and the Historical Data Availability (HDI).

		CURRENT FISHERY STATUS	
		Fully Exploited	**Recruitment Overfished**
HISTORICAL DATA AVAILABILITY	Complete	CHISTMSYF MEYF	CHISTROF ECROF
	Sketchy	CHISTMSYS MEYS	CHISTROS ECROS

File 1: Catch History

Record 1: Y1W = Last year of fishery total catch in weight.

Y2W(T) = Fishery total catch in weight data for years t.

Record 2: FC(1) = Instantaneous fishing mortality for last year of fishery.

F6(T) = Instantaneous fishing mortality for years t.

Record 3: WA = Average weight of fish in the catch for last year of fishery

WBAR(T) = Average weight of fish in the catch for years t.

Record 4: AL = Average length of fish in the catch for last year of fishery.

LBAR(T) = Average length of fish in the catch for years t.

Record 5: TX = Age at 100% vulnerability for last year of fishery.

TC(T) = Age at 100% vulnerability for years t.

File 2: Economic History

Record 1: NV = Number of vessels participating in last year of fishery.

Z6(T) = Number of vessels in years t.

Record 2: NU = Gross revenue from last year of the fishery.

HV(T) = Gross revenue from fishery in years t.

Record 3: VC = Total vessel costs for participating fleet in last year of fishery.

EC(T) = Total vessel costs in year t.

Record 4: RG = Net returns from fishery in the last year.

NET(T) = Net returns in year t.

Record 5: RP = Rate of profit from last year of the fishery.

EYPR(T) = Rate of profit in year t.

15.0 Life History Modular Contents

All subsequent life history descriptions follow the flow of this description for life history modular contents. This initial section presents an overview, and then each life history description presents the specific parameter values used for the individual species simulations.

15.0.1 Mortality Parameters

All mortality rates are age specific. Natural mortality is estimated at $M_{x,t}$. The user specifies the potential fishing mortality, $F_{x,t}$, which is the instantaneous fishing mortality coefficient of a fully available age group x in a given year t. Fishing mortality is the product of three multipliers; (1) availability, $A_{x,t}$, represents the fraction of an age-class that is available to the fishery in a given year, (2) potential fishing mortality, $F_{x,t}$, is the instantaneous fishing mortality coefficient of a fully available age group in a given year, and (3) the fishing mortality growth multiplier, F2MULT, is used to adjust F from year to year, depending on development budget, economic, and constituency input. The total instantaneous mortality coefficient, $Z_{x,t}$, for age group x in year t of the simulation sequence is then:

$$Z_{x,t} = A_{x,t} * F_{x,t} * F2MULT + M_{x,t}$$

15.0.2 Growth Parameters

The growth in length and weight of the population of interest is represented by the von Bertalanffy growth equation. The von Bertalanffy formulation is:

$$W_{x,t} = W_{\infty}(1 - e^{-k(x - t_0)})^3$$

where, $W_{x,t}$ is the average weight of an individual in yearclass x at the beginning of year t,

and, W_∞, k, t_0 are parameters of the von Bertalanffy growth equation.

15.0.3 Maturation Parameters

Maturation coefficients are effected by sex- and age-specific multipliers representing the fractions of males and females reproductively mature of each age class at spawning time. This feature allows investigation of variable sex ratios at age, and hermaphroditism or sex reversal in populations like Grouper.

15.0.4 Reproduction Parameters

The production of prodgeny (larvae) is calculated as the summation over all reproductive age-classes of the numbers in each age class at spawning time multiplied by (1) the age-specific female fraction mature, (2) the number of vaible ova produced per individual female at age x, and (3) the fraction of females (or eggs) being fertilized during the spawning season. The latter is computed from the number of males present during spawning and selection of the random mating model.

15.0.5 Recruitment Parameters

The computation of the number of recruits entering the population follows the dynamics of the Beverton and Holt function, where A1 = α, and A2 = β, are parameters of the model. Note that recruitment is defined as the joining of the young to the population and not necessarily the "fishable" population (that portion vulnerable to the fishing gear).

15.0.6 Economic Characteristics

Costs and prices used in FINMAN have been adopted from among those estimated for the various fisheries. While these values may not always be exact, or may be dated; they still serve to illustrate the applications with respect to the fishery of concern.

15.0.7. Yield per Recruit Surface

For each species profile three dimensional surface plots are shown utilizing "best" life history data and the equations specified in Section 6.6.4.

15.1 Gag Grouper, Mycteroperca microlepis

15.1.1 Natural Mortality

Age specific natural mortality is estimated to be age-constant at M=0.2 in the model.

15.1.2 Growth Parameters

Growth in length and weight of the Grouper is represented by the von Bertalanffy equation with the following parameters:

W_∞ = 25.032719

L_∞ = 1290.0 mm

k = .122

t_o = -1.127

15.1.3 Maturation Parameters

The fractions of females and males reproductively mature by age-class at spawning time are:

Maturity Fractions

Age	Female	Male
1	1.0	0.0
2	1.0	0.0
3	1.0	0.0
4	1.0	0.0
5	.98	.09
6	.85	.15
7	.70	.30
8	.50	.50
9	.40	.60
10	.25	.75
11	.10	.90
12	.05	.95
13	0.0	1.0

15.1.4 Reproduction Parameters

The fecundity coefficients for Grouper are as follows:

Age	Fecundity
1-4	0.0
5	300,000
6	400,000
7	526,396
8	1,457,120
9	3,457,120

10	5,035,240
11	6,035,240
12	7,035,240
13	7,535,240

15.1.5 Recruitment Parameters

Number of Year Classes = 13

Age (in months) at First Recruitment = $t_r + 1 = 2$

Month Spawning Begins = $t_s = 1$

Month Spawning Ends = $t'_s = 1$

Year of First Maturity = $t_m = 5$

Rate of Contact = $k_c = 1$

Recruitment Function Parameters: A1 = 1.0E-06, A2 = 70,000

15.1.6. Economic Characteristics

15.1.6.1 Optimal Assessment Allocations

Basic fishery statistics = OMA(1) = 50,000

Resource surveys = OMA(2) = 50,000

Catch analyses = OMA(3) = 50,000

Economics = OMA(4) = 50,000

Environmental effects = OMA(5) = 50,000

15.1.6.2 Fishing Effort Unit Costs

Single gear = CO(1) = 1,000

Commercial gear 1 = CO(2) = 400

Commercial gear 2 = CO(2) = 500

Commercial gear competing with recreational = CO(4) = 500

Recreational = CO(5) = 25

15.1.6.3 Ex-Vessel Value of Catch per Unit Weight

Value of catch = VA(I) = 4.4 , I = 1 TO N1YC

15.1.6.4 Catchability Coefficients

Single gear = Q(1) = .0001

Commercial gear 1 = Q(2) = .0001

Commercial gear 2 = Q(3) = .0001

Commercial gear competing with recreational = Q(4) = .0001

Recreational = Q(5) = .00001

15.1.6.5 Scaling Parameters

Virgin population size = MX = 3,925,147

Optimum rate of profit = MZ = 5.0

Starting management budget = BUD(1) = 1.OE+06

Optimum poulation size = OPTP = 3,145,635

Maximum equilibrium yield: YMAX(2) = 1,311,012 ; YMAX(3) = 1,418,503

Optimum fishing effort: MF(2) = 5,420 ; MF(3) = 3,050

Default selection settings for two fleets:

1. Maximum age fished by fleet-type 1 = SE1 = 7.
2. Minimum age fished by fleet-type 2 = S2 = 8.

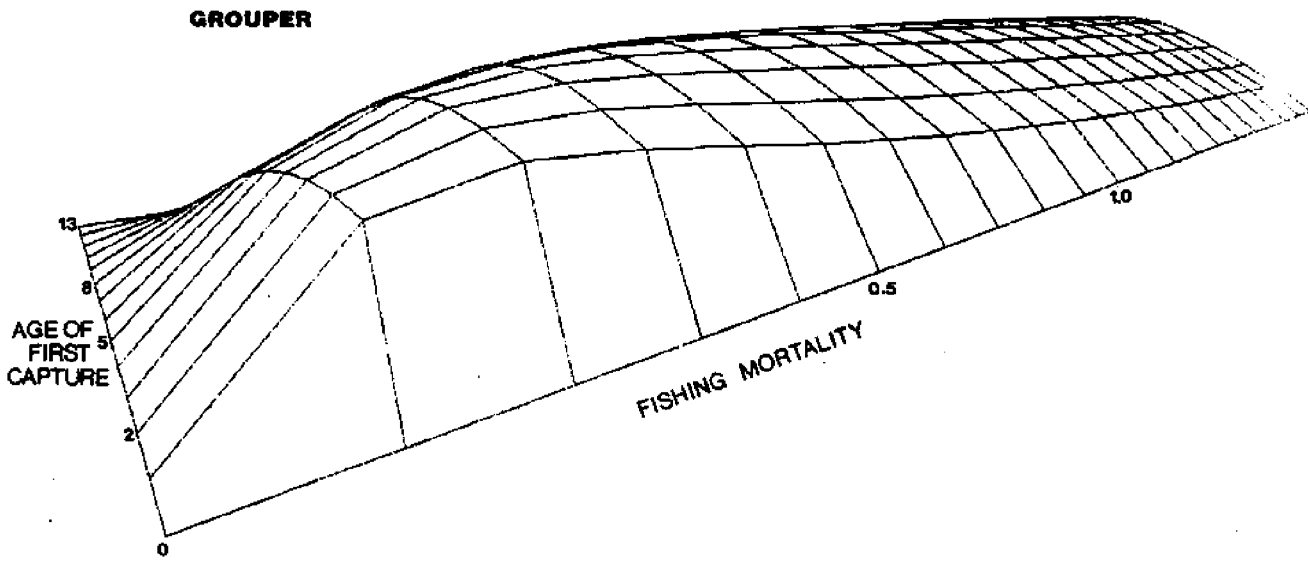


Figure 15.1.7: Equilibrium Yield Surfaces for Simulated Grouper Population.

15.2 Yellowfin Tuna, Thunnus albacares

15.2.1 Age Specific Natural and Fishing Mortality

Natural mortality is estimated to be M = 0.8 in the model. The user specifies the potential fishing mortality, $F_{x,t}$.

15.2.2 Growth Parameters

The growth in length and weight of the Yellowfin Tuna is represented by the von Bertalanffy growth equation with the following parameters.

W_∞ = 99.1272728 kilograms

L_∞ = 169.0 cm

k = 0.6

t_o = 0.83333333

15.2.3 Maturation Parameters

The fractions of females and males reproductively mature by age-class at spawning age:

Maturity Fractions

Age	Female	Male
1	.60	.40
2	.52	.48
3	.50	.50
4	.45	.65
5	.22	.78
6	.15	.85
7	.12	.88
8	.11	.89

(continued) **Maturity Fractions**

Age	Female	Male
9	.11	.89
10	.11	.89

15.2.4. Reproduction Parameters

The fecundity coefficients for Yellowfin Tuna are as follows:

Age	Fecundity
1	0.0
2	515,913
3	3,025,577
4	5,755,732
5	7,603,643
6	8,324,747
7	8,714,025
8	8,919,719
9	9,027,242
10	9,083,140

15.2.5 Recruitment Parameters

Number of Year Classes = $t_\lambda = 10$

Age (in months) at First Recruitment = $t_r + 1 = 2 = 0.1666667$ years

Month Spawning Begins = $t_s = 1$

Month Spawning Ends = $t^1{}_s = 1$

Age of First Maturity = $t_m = 2$ years

Rate of Contact = k_c = 1

Recruitment Function Parameters: A1 = 1.0E-07, A2 = 7E+05

Level of Recruitment Variability about Mean = RVL = 2

Percentage Variabilty for Recruitment = VP = 0.50

Inclusion of Autocorrelated Recruitment Wave = GA = 1

Period for Autocorrelated Recruitment Wave = PER = 4 Years

Fraction of maximum recruitment used as a scalar for autocorrelated wave=FV=0.30

Minimum threshold for recruitment = THR = 1.0 E+05

15.2.6 Economic Characteristics

Exvessel value = $0.40/lb. = $800.00/metric tons

15.2.6.1 Optimal Assessment Allocations

Basic fishery statistics = OMA(1) = 50,000

Resource surveys = OMA(2) = 50,000

Catch analyses = OMA(3) = 50,000

Economics = OMA(4) = 50,000

Environmental effects = OMA(5) = 50,000

15.2.6.2 Fishing Effort Unit Costs

Single gear = CO(1) = 30,000

Commercial gear 1 = CO(2) = 12,00

Commercial gear 2 = CO(2) = 15,000

Commercial gear competing with recreational = CO(4) = 12,000

Recreational = CO(5) = 150

15.2.6.3 Ex-Vessel Value of Catch per Unit Weight

Value of catch = VA(I) = 0.727 , I = 1 TO N1YC

15.2.6.4 Catchability Coefficients

Single gear = Q(1) = .01

Commercial gear 1 = Q(2) = .01

Commercial gear 2 = Q(3) = .01

Commercial gear competing with recreational = Q(4) = .01

Recreational = Q(5) = .00001

15.2.6.5 Scaling Parameters

Virgin population size = MX = 4,110,246

Optiumum rate of profit = MZ = 14.0

Starting management budget = BUD(1) = 1.OE+06

Optimum population size = OPTP = 1,792,162

Maximum equilibrium yield: YMAX(2) = 8,138,510 ; YMAX(3) = 8,138,510

Optimum fishing effort: MF(2) = 45 ; MF(3) = 45

Default selection settings for two fleets:

1. Maximum age fished by fleet-type 1 = SE1 = 4.
2. Minimum age fished by fleet-type 2 = S2 = 5.

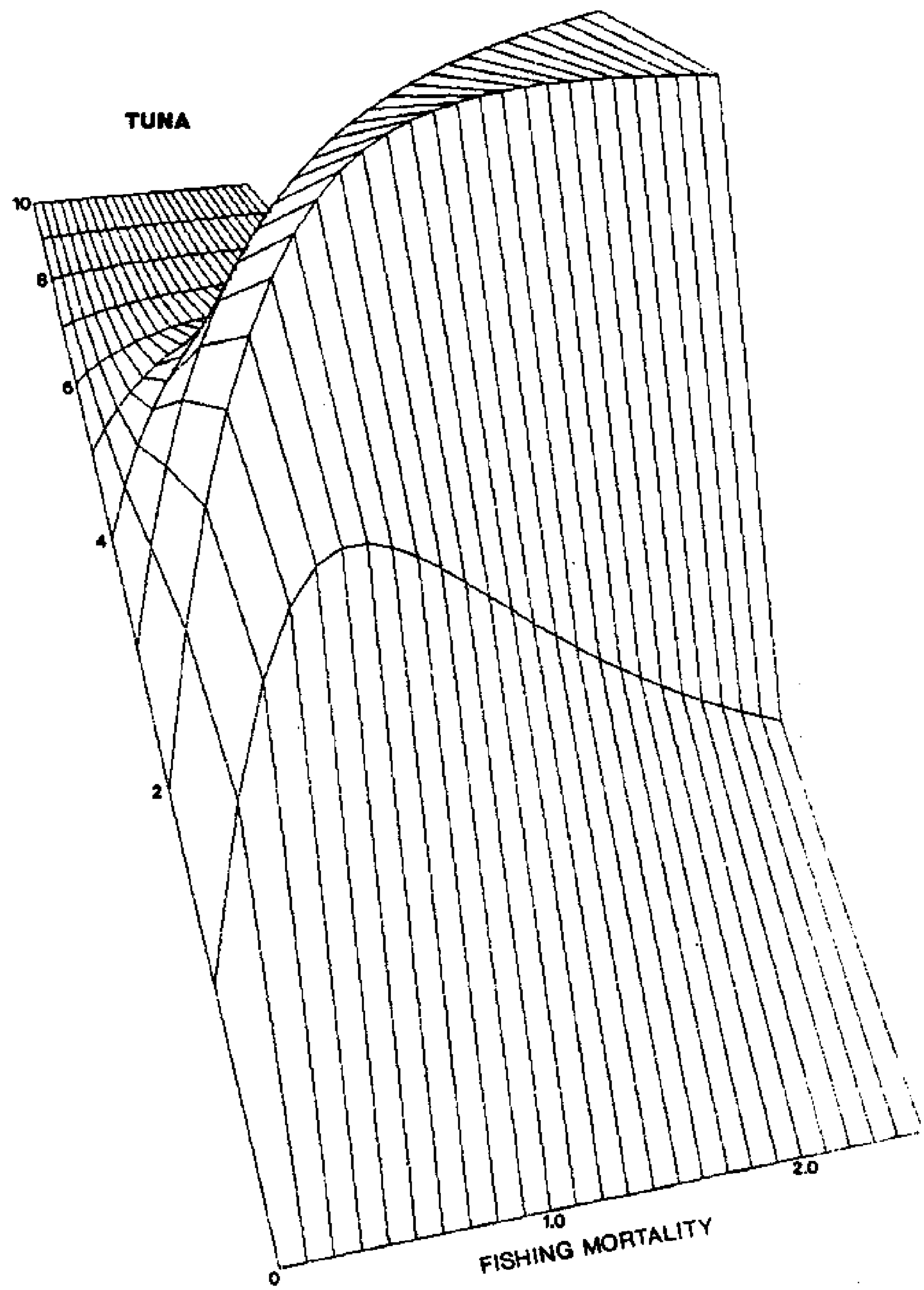


Figure 15.2.7: Equilibrium Yield Surfaces for Simulated Tuna Population.

15.3 Northern Anchovy, *Engraulis mordax*

15.3.1 Age-Specific Natural Mortality

Age-specific natural mortality is estimated to be age-constant at M = 1.06 in the model.

15.3.2 Growth Parameters

The growth in length and weight of the northern Anchovy is represented by the von Bertalanffy growth equation with the following parameters.

W_∞ = 4.682576E-05 metric tons

L_∞ = 159.1 mm

k = 0.32

t_0 = -2.08 years

15.3.3 Maturation Parameters

The fractions of females and males reproductively mature by age-class at spawning age:

Maturity Fractions

Age	Female	Male
1	.60	.40
2	.60	.40
3	.60	.40
4	.60	.40
5	.60	.40
6	.60	.40
7	.60	.40

15.3.4. Reproduction Parameters

The fecundity at age coefficients for northern Anchovy are as follows:

Age	Fecundity	% Mature
1	4,278	.1
2	8,255	.4
3	12,546	.8
4	16,617	.95
5	20,191	1.0
6	23,174	1.0
7	25,581	1.0

15.3.5 Recruitment Parameters

Number of Year Classes = 7

Age (in months) at First Recruitment = $t_r + 1 = 2$

Month Spawning Begins = $t_s = 1$

Month Spawning Ends = $t^1{}_s = 1$

Age of First Maturity = $t_m = 1$ year

Rate of Contact ± $k_c = 1$

Recruitment Function Parameters: A1 = $2.3809524 \times 10^{-12}$, A2 = 10001.0

Level of Recruitment Variability about Mean = RVL = 2

Percentage Variability for Recruitment = VP = 0.75

Inclusion of Autocorrelated Recruitment Wave = GA = 1

Period for Autocorrelated Recruitment Wave = PER = 20 years

Fraction of Maximum Recruitment used as Scalar for Autocorrelated

Recruitment Wave = FV = 0.5

Minimum Threshhold for Recruitment = THR = 1.0E+07

15.2.6.5 Scaling Parameters

Virgin population size = MX = 2.60E+11

Optiumum rate of profit = MZ = 10.0

Starting management budget = BUD(1) = 1.OE+06

Optimum population size = OPTP = 5.32803162 E+10

Maximum equilibrium yield: YMAX(2) = -- ; YMAX(3) = --

Optimum fishing effort: MF(2) = -- ; MF(3) = --

Default selection settings for two fleets:

1. Maximum age fished by fleet-type 1 = SE1 = 3.
2. Minimum age fished by fleet-type 2 = S2 = 4.

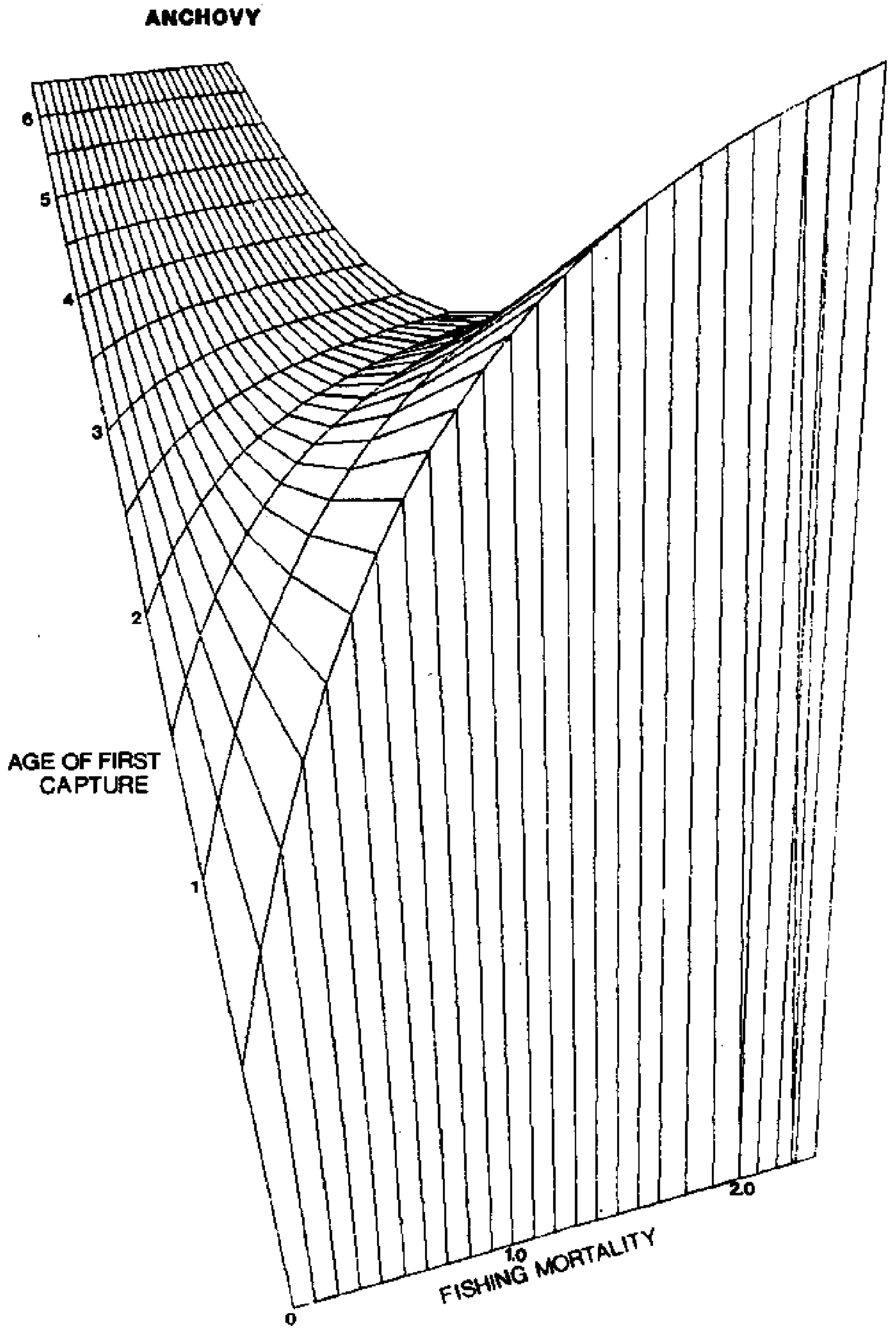


Figure 15.3.7: Equilibrium Yield Surfaces for Simulated Anchovy Population.

15.3.6 Economic Characteristics

15.3.6.1 Optimal Assessment Allocations

Basic fishery statistics = OMA(1) = 50,000

Resource surveys = OMA(2) = 50,000

Catch analyses = OMA(3) = 50,000

Economics = OMA(4) = 50,000

Environmental effects = OMA(5) = 50,000

15.3.6.2 Fishing Effort Unit Costs

Single gear = CO(1) = 145,805

Commercial gear 1 = CO(2) = 145,805

Commercial gear 2 = CO(2) = 145,805

Commercial gear competing with recreational = CO(4) = N/A

Recreational = CO(5) = N/A

15.3.6.3 Ex-Vessel Value of Catch per Unit Weight

Value of catch = VA(I) = 25.0 , I = 1 TO N1YC

15.3.6.4 Catchability Coefficients

Single gear = Q(1) = 0.0082167

Commercial gear 1 = Q(2) = 0.0082167

Commercial gear 2 = Q(3) = 0.0082167

Commercial gear competing with recreational = Q(4) = N/A

Recreational = Q(5) = N/A

15.4 Pandalid Shrimp, Pandalus borealis

15.4.1 Natural Mortality

Age-specific natural mortality is estimated to be age-constant at M = 0.72 in the model.

15.4.2. Growth Parameters

The growth in length and weight of the shrimp is represented by the von Bertalanffy growth equation with the following parameters.

W_∞ = 1.05419346E-05 metric tons

L_∞ = 25.90 mm

k = 0.3606

t_o = -.39675 years

15.4.3 Maturation Parameters

The fractions of females and males reproductively mature by age-class at spawning age:

Maturity Fractions

Age	Female	Male
1	0.0	0.0
2	0.0	0.0
3	0.5	0.5
4	0.5	0.5
5	0.5	0.5
6	0.5	0.5

15.4.4. Reproduction Parameters

The fecundity coefficients for shrimp are as follows:

Age	Fecundity
1	0
2	0
3	810
4	1,314
5	1,679
6	1,997

15.4.5 Recruitment Parameters

Number of Year Classes = 6

Age (in months) at First Recruitment = $t_r + 1 = 2$

Month Spawning Begins = $t_s = 1$

Month Spawning Ends = $t^1_s = 1$

Age of First Maturity = $t_m = 3$

Rate of Contact = $k_c = 1$

Recruitment Function Parameters: A1 = 3.2851×10^{-11} , A2 = 1.01

Level of Recruitment Variability about Mean = RVL = 2

Percentage Variability for Recruitment = VP = 0.50

15.4.6 Economic Characteristics

15.4.6.1 Optimal Assessment Allocations

Basic fishery statistics = OMA(1) = 50,000

Resource surveys = OMA(2) = 50,000

Catch analyses = OMA(3) = 50,000

Economics = OMA(4) = 50,000

Environmental effects = OMA(5) = 50,000

15.4.6.2 Fishing Effort Unit Costs

Single gear = CO(1) = 8,000

Commercial gear 1 = CO(2) = 3,000

Commercial gear 2 = CO(2) = 15,000

Commercial gear competing with recreational = CO(4) = N/A

Recreational = CO(5) = N/A

15.4.6.3 Ex-Vessel Value of Catch per Unit Weight

Value of catch = VA(I) = 750.0 , I = 1 TO N1YC

15.4.6.4 Catchability Coefficients

Single gear = Q(1) = .001

Commercial gear 1 = Q(2) = .001

Commercial gear 2 = Q(3) = .001

Commercial gear competing with recreational = Q(4) = N/A

Recreational = Q(5) = N/A

15.4.6.5 Scaling Parameters

Virgin population size = MX = 3.50E + 10

Optiumum rate of profit = MZ = 10.0

Starting management budget = BUD(1) = 1.OE+06

Optimum population size = OPTP = 2.37796873 E + 10

Maximum equilibrium yield: YMAX(2) = -- ; YMAX(3) = --

Optimum fishing effort: MF(2) = -- ; MF(3) = --

Default selection settings for two fleets:

1. Maximum age fished by fleet-type 1 = SE1 = 3.
2. Minimum age fished by fleet-type 2 = S2 = 4.

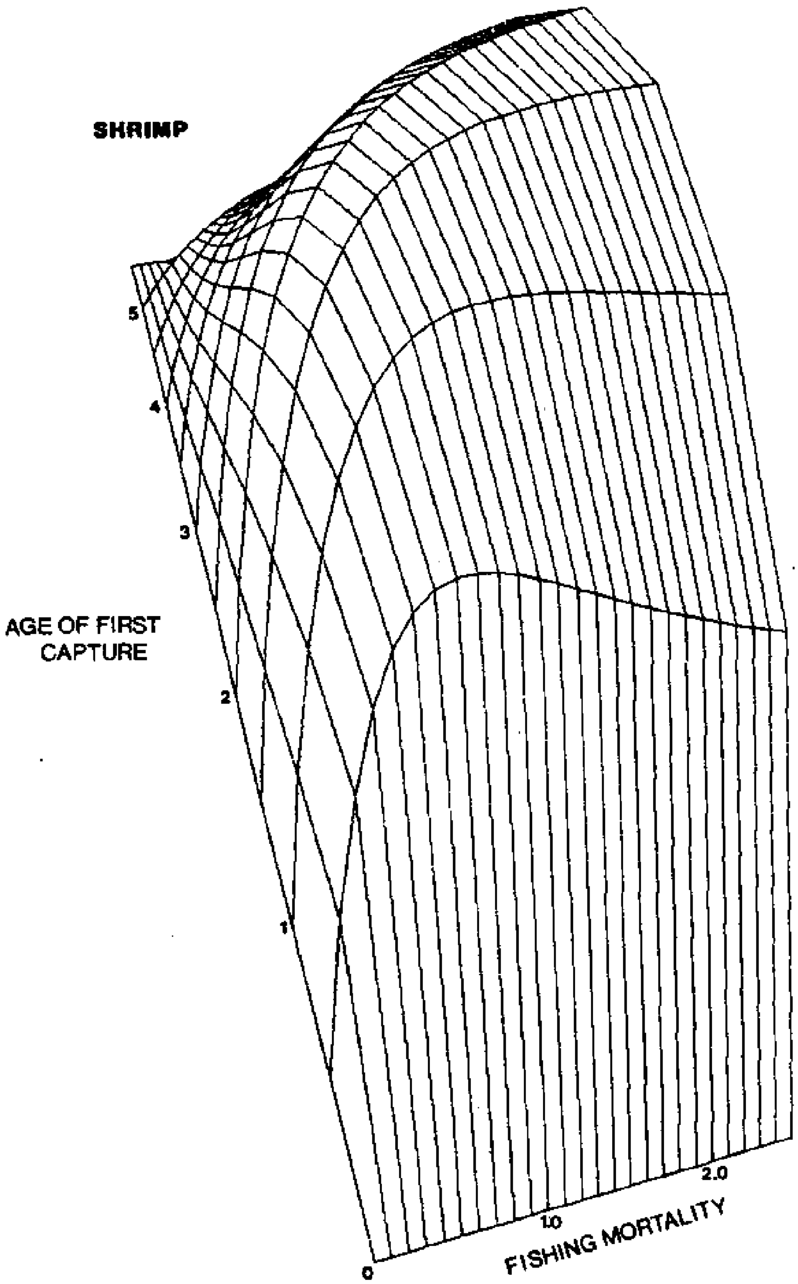


Figure 15.4.7: Equilibrium Yield Surfaces for Simulated Shrimp Population.

15.5 Speckled Seatrout, Cynoscion nebulosus

15.5.1 Natural Mortality

Age specific natural mortality is estimated to be age-constant at M = 0.35 in the model.

15.5.2 Growth Paramaters

Growth in length and weight of the Seatrout is represented by the Bertalanffy equation. The equation parameters are:

W_∞ = 15.830324 kg

L_∞ = 51.84 cm

k = .301

t_o = -.433

15.5.3 Maturation Parameters

The fractions of females and males reproductively mature by age-class at spawning time are:

Maturity Fractions

Age	Female	Male
1	.5	.5
2	.5	.5
3	.5	.5
4	.5	.5
5	.5	.5
6	.5	.5
7	.5	.5
8	.5	.5

Maturity Fractions

Age	Female	Male
9	.5	.5
10	.5	.5
11	.5	.5
12	.5	.5

15.5.4 Reproduction Parameters

The fecundity coefficients for Seatrout are as follows:

Age	Fecundity
1	Ø
2	Ø
3	93,327
4	122,962
5	306,615
6	314,040
7	379,350
8	2,155,027
9	2,450,000
10	3,100,000
11	3,457,120
12	5,035,240

15.5.5 Recruitment Parameters

Number of Year Classes = 12

Age (in months) at First Recruitment = $t_r + 1 = 2$

Month Spawning Begins = t_s = 1

Month Spawning Ends = t'_s = 1

Year of First Maturity = t_m = 3

Rate of Contact = k_c = 1

Recruitment Function Parameters: A1 = 1.0E-07 , A2 = 7.E+04

Level of recruitment variability about mean = RVL = 2

Percentage variability for recruitment = VP = 0.25

15.5.6. Economic Characteristics

15.5.6.1 Optimal Assessment Allocations

Basic fishery statistics = OMA(1) = 50,000

Resource surveys = OMA(2) = 50,000

Catch analyses = OMA(3) = 50,000

Economics = OMA(4) = 50,000

Environmental effects = OMA(5) = 50,000

15.5.6.2 Fishing Effort Unit Costs

Single gear = CO(1) = 10,000

Commercial gear 1 = CO(2) = 4,000

Commercial gear 2 = CO(2) = 5,000

Commercial gear competing with recreational = CO(4) = 4,000

Recreational = CO(5) = 25

15.5.6.3 Ex-Vessel Value of Catch per Unit Weight

Value of catch = VA(I) = 4.4 , I = 1 TO N1YC

15.5.6.4 Catchability Coefficients

Single gear = Q(1) = .0001

Commercial gear 1 = Q(2) = .0001

Commercial gear 2 = Q(3) = .0001

Commercial gear competing with recreational = Q(4) = .0001

Recreational = Q(5) = .000001

15.5.6.5 Scaling Parameters

Virgin population size = MX = 23,700,054

Optiumum rate of profit = MZ = 40.0

Starting management budget = BUD(1) = 1.OE+06

Optimum population size = OPTP = 9,933,530

Maximum equilibrium yield: YMAX(2) = 11,984,500; YMAX(3) = 13,966,859

Optimum fishing effort: MF(2) = 8,808; MF(3) = 4,205

Default selection settings for two fleets:

1. Maximum age fished by fleet-type 1 = SE1 = 6.
2. Minimum age fished by fleet-type 2 = S2 = 7.

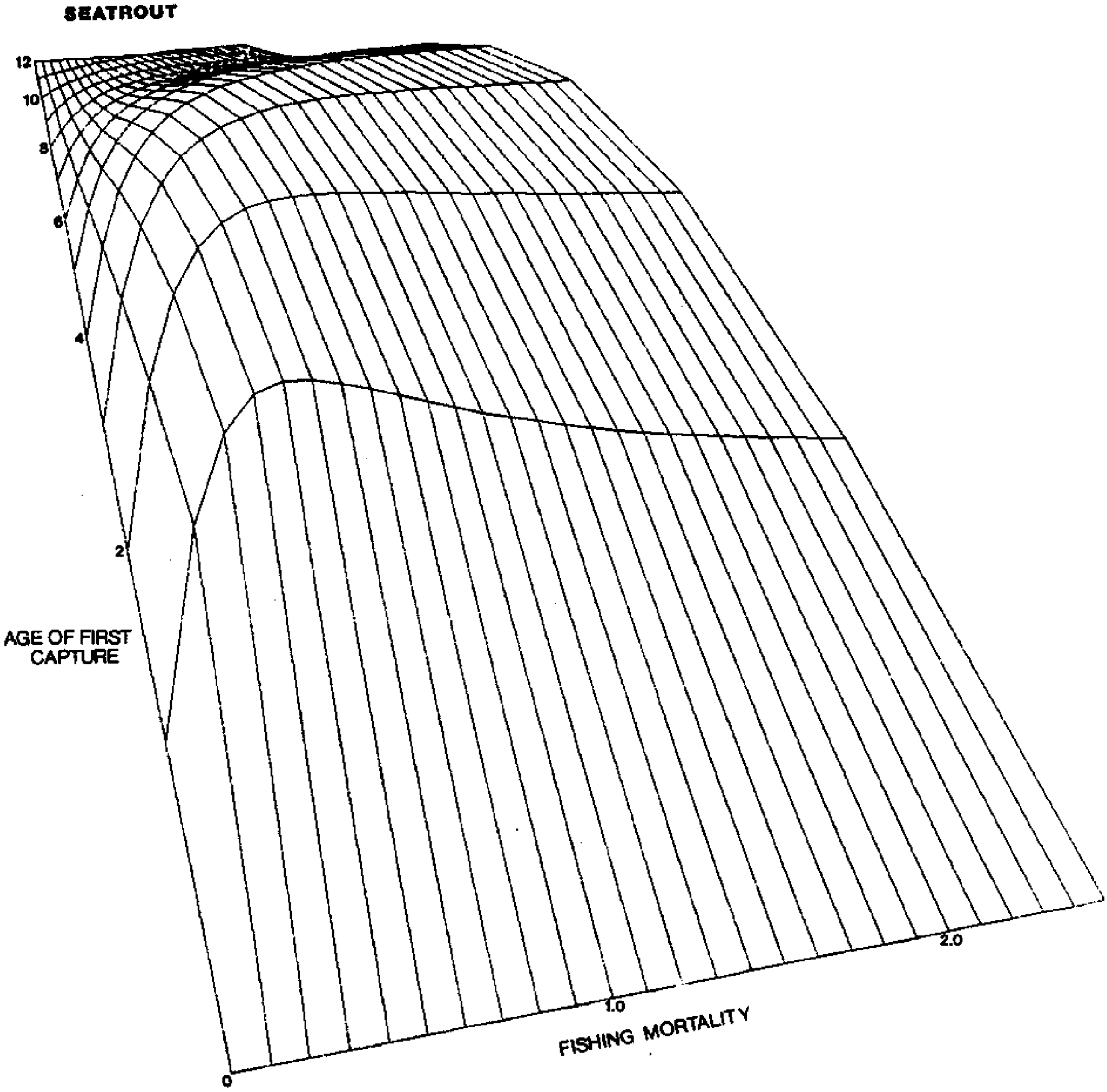


Figure 15.5.7: Equilibrium Yield Surfaces for Simulated Seatrout Population.

15.6 Vermillion Snapper, Rhomboplites Aurorubens

15.6.1 Natural Mortality

Age specific natural mortality is estimated to be age-constant at M = 0.492 in the model.

15.6.2 Growth Parameters

Growth in length and weight of the Snapper is represented by the von Bertalanffy equation. The equation parameters are:

W_∞ = 2.9829355 kg

L_∞ = 626.5

k = 0.198

t_0 = -.1277

15.6.3 Maturation Parameters

The fractions of females and males reproductively mature by age-class at spawning time are:

Maturity Fractions

Age	Female	Male
1-2	.45	.55
3	.53	.47
4	.57	.43
5	.58	.42
6	.58	.42
7	.59	.41
8	.61	.39

15.6.4 Reproduction Parameters

The fecundity coefficients for Snapper are as follows:

Age	Fecundity
1-2	0
3	93,327
4	122,962
5	306,615
6	314,040
7	379,350
8	2,155,027

15.6.5 Recruitment Parameters

Number of Year Classes = 8

Age (in months) at First Recruitment = $t_r + 1$ = 2

Month Spawning Begins = t_s = 1

Month Spawning Ends = t'_s = 1

Year of First Maturity = t_m = 3

Rate of Contact = k_c = 1.0

Recruitment Function Parameters: A1 = 1.0E-06 , A2 = 7E=04

Level of Recruitment Variability about Mean = RVL = 2

Percentage Variability for Recruitment = VP = 0.10

15.6.6 Economic Characteristics

15.6.6.1 Optimal Assessment Allocations

Basic fishery statistics = OMA(1) = 50,000

Resource surveys = OMA(2) = 50,000

Catch analyses = OMA(3) = 50,000

Economics = OMA(4) = 50,000

Environmental effects = OMA(5) = 50,000

15.6.6.2 Fishing Effort Unit Costs

Single gear = CO(1) = 250

Commercial gear 1 = CO(2) = 110

Commercial gear 2 = CO(2) = 125

Commercial gear competing with recreational = CO(4) = 110

Recreational = CO(5) = 20

15.6.6.3 Ex-Vessel Value of Catch per Unit Weight

Value of catch = VA(I) = 9.9, I = 1 TO N1YC

15.6.6.4 Catchability Coefficients

Single gear = Q(1) = .001

Commercial gear 1 = Q(2) = .001

Commercial gear 2 = Q(3) = .001

Commercial gear competing with recreational = Q(4) = .001

Recreational = Q(5) = .0001

15.6.6.5 Scaling Parameters

Virgin population size = MX = 757,753

Optiumum rate of profit = MZ = 4.0

Starting management budget = BUD(1) = 1.OE+06

Optimum population size = OPTP = 691,753

Maximum equilibrium yield: YMAX(2) = -- ; YMAX(3) = --

Optimum fishing effort: MF(2) = -- ; MF(3) = --

Default selection settings for two fleets:

1. Maximum age fished by fleet-type 1 = SE1 = 4.
2. Minimum age fished by fleet-type 2 = S2 = 5.

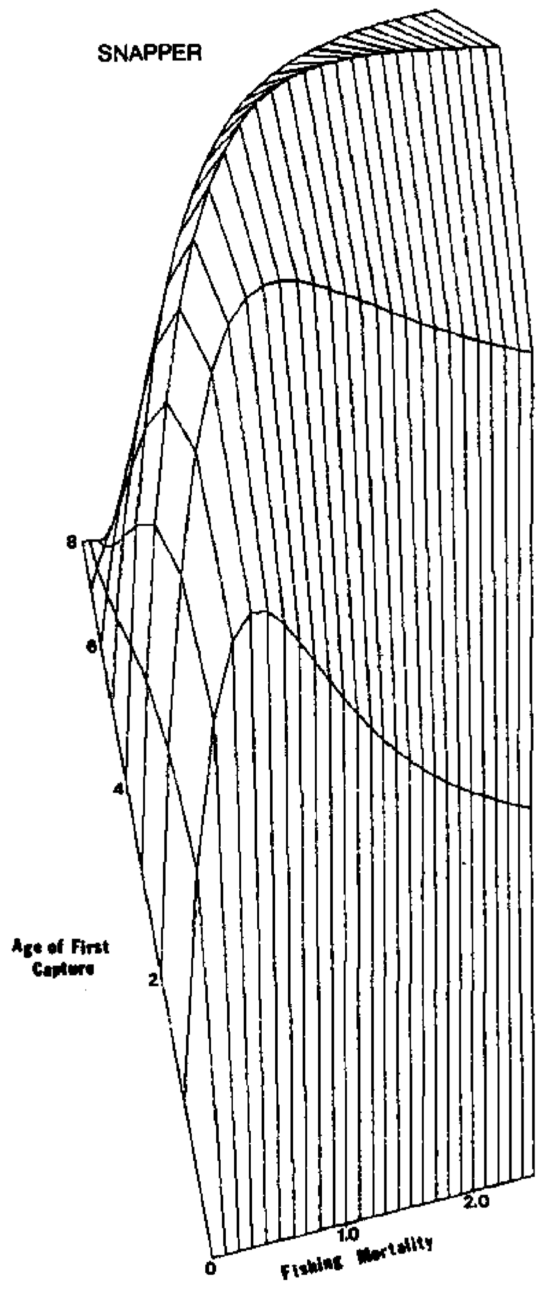


Figure 15.6.7: Equilibrium Yield Surfaces for Simulated Snapper Population.

16.0 Computer Code Variable Lists

16.1 Program FINMAN: Alphabetized Composite Variable List

A

A$
A( )
AA
ABREV
AC AC( )
AE
AL
AM
AN
AO
AR
AS
AV
AW
A1
A2
A5NM
A7W
A8W

B

B%
BP%
B( )
BB
BDG( )
BFS BFS( )
BGL
BL
BR
BUD( )
BX
B1
B2
B3
B4
B5
B6F
B7F
B8F
B9F

C

C$
CE$
C( )
CA
CBL
CCF
CD
CE
CF
CHOICE
CL
CM
CO( )
CPP
CQ
CR
CT CT( )
CUB
C1( )
C2( )
C3( )
C4( )
C5( )
C6( )

D

D%
DP%
D$
D1$
D2$
D( )
DD
DEV DEV( )
DF
DLF
DY
DTA
DX

E

E$
E( )
EAI
EC EC( )
ED
EE EE( )
EF
EI
EM
EN EN( )
EQ
ER
ES( )
EX( )
EYPR( )
E1
E2 E2( )
E3( )
E4( )

F

F%
F$
F1$
F2$
F( )
FANJ
FB
FC( )
FD
FE
FF
FIL
FMF( )
FP( )
FS( )
FT( )
FV
FX FX( )
FZ
F1MF( )
F2MULT( )
F3( )
F4T( )
F5( )
F6( )
F7( )
F8( )

G

G$
GA
GG
GX
G1 G1( )
G2 G2( )
G3 G3( )

H

HDI
HI
HV( )
H1
H2
H3
H4
H5

I

IP%
ILB
IUB
I1
I2

J

JJ%
JL%
JP%
J
JJ
J1
J2

K

K
KA
KKH
KL
KT
K1
K2
K3
K4
K5

L

L
LARVAE
LBAR( )
LC
LD
LEFT
LF
LI
LINF
LL
LP
LT LT( )
LY
L1A
L2A
L9

M

MA( )
MASE
MBYX
MC
ME
MF( )

MFR
MIS
ML ML( )
MM
MQ
MSB
MW
MX
MY
MZ
M1
M2
M3
M4

N

NZ%
N$
N1$
N2$
N5$
N9$
NA( )
NAFMT
NBAR
NET( )
NF
NL( )
NN
NPCF
NR( )
NRE
NU
NV
NY
N1YC
N2YCX

O

O
OA
OLMA
OMA( )
OQC
OPTP
O1
O2
O3
O4CQ
O5CQ

P

P( )
PAS
PBW( )
PCF
PD
PER
PF
PI
PJ
PP
PS( )
PTS
PX
PZ
PØ PØ( )
P1( )
P2
P3
P4
P5
P6
P7

Q

Q$
QQ$
Q Q( )
QA QA( )
QB QB( )
QC
QH
QL
QN
Q2
Q3
Q8
Q9

R

R%
R R( )
RA
RC( )
REC
RG
RM
RN RN( )
ROG
RP
RR
RS RS( )
RVL
RX RX( )
R1N R1N( )
R2G
R3G R3G( )
R4P
R5P

S

SE1
SG
SL
SMA
SNXL
SOLN
SP
SSP
ST( )
SUM SUM( )
SV( )
SXR( )
S1XRS
S2
S3F
S4F

T

T T( )
TA
TC TC( )
TF
THR
TK
TMS
TQ
TRF
TT
TX
TY
TØ
T1L
T2L
T3L
T9

U

U( )
UB
UT( )
U1 U1( )
U2 U2( )
U3 U3( )
U4 U4( )
U5( )
U6( )

V

V( )
VA( )
VC
VN
VP
VSUM
V1( )
V1C
V2C
V3G
V4G
V5G

W

WA
WBAR( )
WT WT( )
WX
W2
W3
W9

X

X
XAKV
XC
XFE
XH
XKC
XM( )
XOMEG( )
XSM
XX
XØ XØ( )
X1MA
X2M( )
X3
X4
X5
X7MF( )

Y

Y( )
YA( )
YM
YMAX( )
YN( )
YPR( )
YR
YW( )
YXN( )
YZN
Y1N
Y2W( )
Y3N
Y4N
Y5W
Y6W
Y7N
Y8W

Z

Z$
Z
ZETA
ZLY( )
ZT
ZZ
ZØ
Z1LY( )
Z2
Z6( )
Z7( )