FINMAN: A Fishery Institution Management Computer Model for Simulating the Decisionmaking Environment in Tropical and Subtropical Regions

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ABSTRACT

Stock assessment and management didactic tools for tropical and subtropical western central Atlantic fisheries are needed because fishing is a major competing use of the marine environment in these regions. A preliminary version of a user-interactive comprehensive simulation model, **FINMAN** (Fishery Institutional Management training simulator), presently parameterized for grouper (Serranidae) and coastal herring (Clupeidae) life histories, is written in **BASIC** and implemented on the Apple IIe, IIc, and IBM/PC microcomputers. The model, which demonstrates a general set of fishery management institution frameworks, is described. **FINMAN** is a biological, sociological and economic model which simulates transitional and equilibrium states by updating at each iteration fishery assessment, socio-economic, and political statistics through an information base. The completeness, accuracy and precision of the information update is influenced by the institution's budget level and budget allocation decisions made by the user during previous iterations. The model demonstrates system behavior in a manner which teaches the operator to appreciate large-scale interactions and the frequent counter-intuitiveness of the response surface. **FINMAN** is constructed as a game, not only to enhance user interest, but also to demonstrate the outcomes of behavioral traits like risk taking and risk aversion and to provide students with a simulated learning-research experience that now requires years in several types of responsible fishery management positions.

INTRODUCTION

Fisheries in the tropical and subtropical western central Atlantic are under increasing pressure for rigorous management policy due to competing uses for available oceanic resources from both commercial and recreational interests in these regions. Conflicts over (1) who will catch which fishes, (2) what gear can be used, and (3) how much will be caught provoke great and long debate and are commonplace in the newspapers, federal, state and island legislatures and the Fishery Management Councils. Concomittantly, increased attention is being given to fishery management around the world, particularly in Third World countries. Fishery management decisions are based on complex variable systems; "success" of the system depends on the decisions made by fishery managers, fishery agency administrators and fishery research supervisors. In general, a smoothly functioning fishery management institution builds user confidence. However, with escalating resource usage managers are increasingly under the gun to make immediate and spontaneous decisions on the regulation and allocation of marine resources that have significant biological, economic and social impacts. Thus, fishery managers, agency administrators and research supervisors need to understand the complex relationships among them, and to anticipate future situations.

An educational tool has been needed to assist students, professionals and fishery management appointees in gaining systemwide experience in making fishery management and fishery research program decisions. Simulation models are designed and used with a goal of learning about a process (Van Horn, 1971). Computer simulation can be used to provide "Link-trainer-like" experiences. Paulik (1969) more than 15 years ago, provided a good review of simulation modeling in fisheries. He somewhat arbitrarily divided models into three categories, those for management, research or training. The teaching model, as described herein, is not used specifically for making management decisions nor to elucidate scientific principles, but rather it demonstrates system behavior in a manner which teaches the operator to appreciate the large-scale interactions and the frequent counter-intuitiveness of the response surface (Gales, 1972). Numerical simulation models offer the most flexible and realistic representation for complex problems of any quantitative technique. No such tool tailored to tropical and subtropical fisheries has existed until now for providing this systemwide experience. The computer model, **FINMAN**, is designed to meet this need and is being implemented on the Apple IIe, IIc and IBM/PC microcomputers which are widely available in the fishery institutions of Florida, the southeast United States, the Caribbean and the western central Atlantic region.

BACKGROUND

The situation outlined here often creates strained relationships among the component members of the fishery management institutions:

1. Research Scientists who are called upon to provide scientific advice for management.

2. Research Program Managers who are pressed to develop timely results for today's and not tomorrow's decisions.

3. Fishery Managers who are under the gun to make immediate decisions regarding allocation and use of marine resources that have significant biological, social and economic consequences.

Communication breakdown can result when the component groups do not have a clear understanding of the problems of the others, and further, not being as responsive as each group feels the other needs to be to identify and effectively solve problems. When the fishery management institution does not function smoothly, resource user confidence is diminished. Under a poorly functioning fishery management institution, not only is it difficult for the institution to make and implement decisions and regulations, but resource user support for them and cooperation with those regulations enacted is minimal. Remarkably, there is bound to be an attempt to judge the efficacy of regulation merely by the changes in yield or catch per unit effort that are observed; and indeed, as far as the fishing industries are concerned, these are, ultimately, the only criteria. A smoothly functioning fishery management institution builds user confidence. Under these "optimal" conditions resource problems are recognized by all concerned, leading to as nearly a "win-win" resolution as possible, thereby minimizing any subsequent difficulties. However, "losers" in any allocation decision, of course, will be by definition, not completely satisfied.

Thus, a major key to a smoothly functioning fishery management institution is the clear understanding of each component's needs and the bases for each component's actions. Under ideal conditions:

1. Fishery Managers need to understand the decisions before them, and should anticipate those which will arise in the future and be able to articulate specific requirements to research program managers. Fishery managers also need to understand the costs in funding, manpower and time required for obtaining their requirements and the need for balancing a research program to meet longterm as well as today's needs and the motivations of research scientists.

2. Research Program Managers must realize that fishery managers are not omniscient and they must learn to interpret vague requests, to anticipate the longer term needs of the managers, and have the ability to articulate the necessity for longterm investments. Program managers must also understand, and work to provide, the research climate which optimizes their scientists' output into the institution.

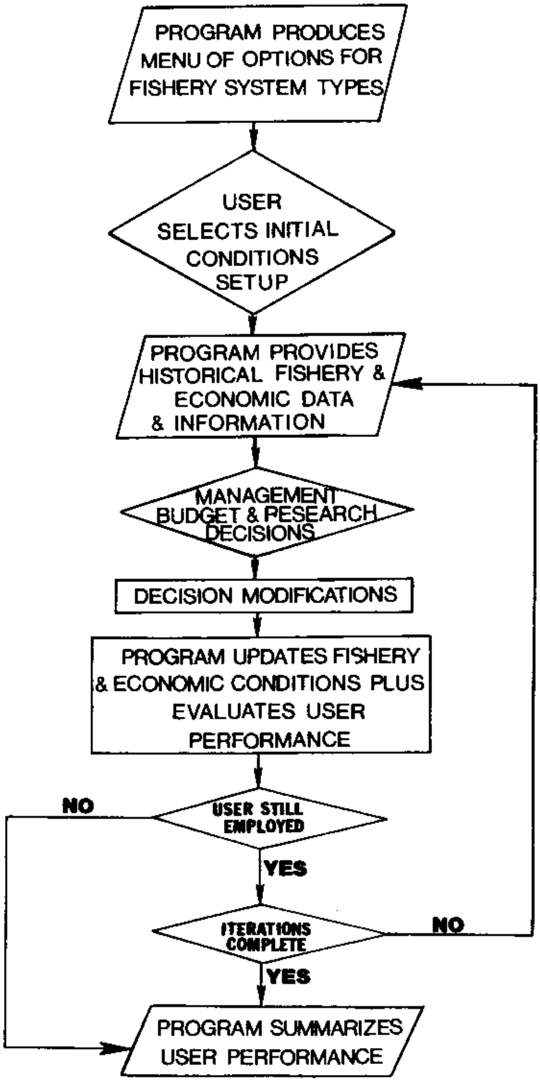
3. Research Scientists need to understand not only the rigors of their disciplines, but the institutional process and how to integrate and articulate their results in a readily usable manner.

The precepts outlined may seem trivially obvious, and it is recognized that ideal interactions within the institution are never fully realized. However, this ideal can be approached through an individual receiving extensive experience in each of the three major components of the fishery management institution. Historically, the usual paradigm for individual development within the institution was to enter it in the research component and with seniority, experience and success, then sequentially graduate to the research program management components. Relatively recently there has been a greater overall tendency for fishery managers (and even research program managers) to enter the institutional framework laterally rather than sequentially, bringing with them valuable expertise in resource use or general management skills. While this approach clearly has certain advantages, it exacerbates the communication problem within the institutional framework. Neither pathway necessarily provides direct experience in the two management components for research scientists or in the fishery management component for research program managers.

Tropical fisheries are combinations of large and diffuse artisanal operations and/or recreational fishing that are compounded with developed or developing industrial fisheries. They attempt to operate on selected species from multiple species assemblages which are frequently estuarine or coral reef based, and that range from some fishes with very short life spans and attendant high recruitment variability, to others with long life spans and extremely complex life history strategies. Development of a tool for providing simulated "hands-on" experience in making fishery management decisions and fishery research program management decisions for tropical and subtropical fisheries situations was needed to assist individuals in gaining system-wide experience within this framework. To deal with these complex biological and management systems, the computer model **FINMAN** has sufficient generality within a spectrum of management scenarios which demonstrate large-scale interactions and provides system-wide exposure. This experience is not otherwise possible without long and voluminous time series of data collection and/or extensive experience by the user. Our user-interactive microcomputer simulation model being developed at the University of Miami provides students and professionals alike with such "Link-trainer-like" experiences. The understanding created through the use of the tool hopefully will make for more thorough and better use of existing data and better planning for collecting and analyzing new data in support of fishery management.

MODEL DESCRIPTION

The flow of the user-interactive age-structured simulation model, **FINMAN** (Fishery Institution Management simulator) is shown in Figure 1. **FINMAN** will produce a menu of options from which selections can be made by the user; the management system type, management scope or competence, general life history of the fish stock to be managed, the fishing pressure pattern, the stock(s) existing condition, and the depth of the fishery and economic information available (Figure 2). 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 then queries the user on a series of budget and management decisions that must be made. To establish the constraints to be placed on your management authority and abilities within a particular fishery, a series of options are shown so that an initial conditions information base, used to



Flow Diagram of FINMAN

Figure 1. Flow diagram of the Fishery Institution Management Computer Simulation Model **FINMAN**.

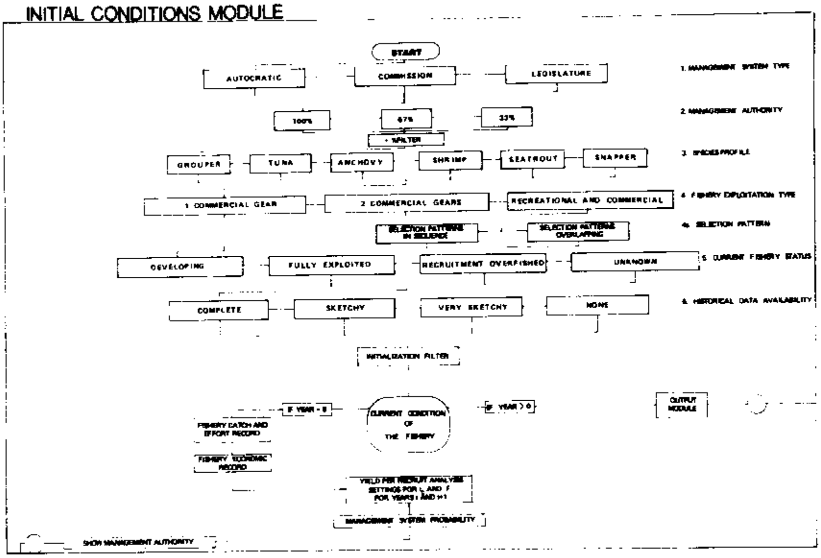


Figure 2. Flow diagram of **FINMAN** Initial Conditions Module.

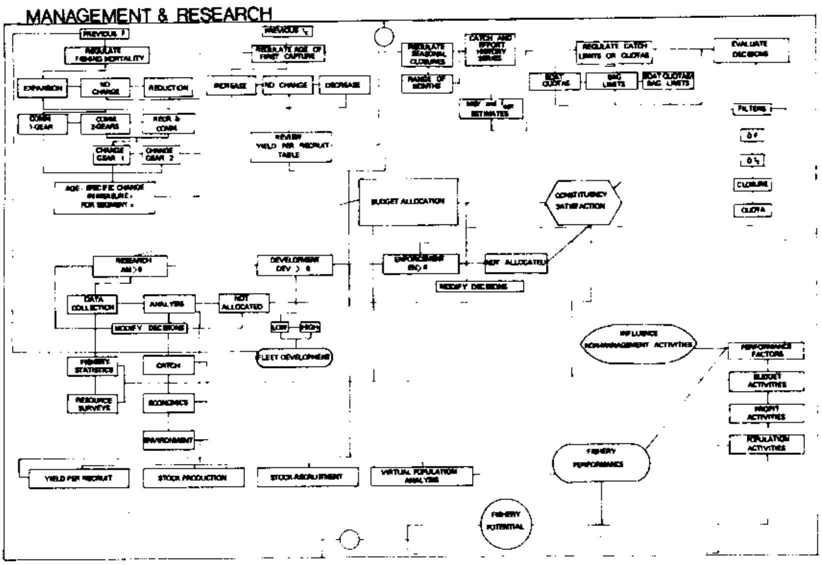


Figure 3. Flow diagram of **FINMAN** Management Research and Budget Module.

make basic decisions regarding management measures and institutional budget allocations, can be generated. These decisions include (1) any management measures to be implemented, (2) overall budget allocations among research, enforcement and "influence" with constituents and (3) research budget allocations among data collection and analysis projects (Figure 3). **FINMAN** will then update the present and historical conditions of the fishery management network. The basic fishery-specific model is an extension of Fox's (1973) generalized exploited simulator (Figure 4). The precision and/or accuracy of the output is controlled in part by the budget allocations and particular management decisions of the user. Since most things have a measure of chance in them, the program uses stochastic (or chance) variables in formulating each "annual" update. When the user's employment is terminated due to lack of sufficient performance, or after a selected number of iterations is attained, **FINMAN** provides a summary of the user's performance.

A given simulation exercise of **FINMAN** is characterized by one of three levels of complexity or difficulty for each of six different program elements (Figure 2). The experimenter selects a set of tests from the many possible - a standard problem of balancing the cost of testing against the cost of an incorrect inference. The management system ranges in the degree of control the user has over the actual implementation of management measures the user deems appropriate, both in terms of the political system through which management measures are enacted and the degree of control exerted over the stock. Your control over the type of fishery to be managed includes an array of choices ranging from sequential competition (i.e., one segment of the fishery operates on a younger portion of the stock than the other), to the most difficult level where non-consumptive values also compete with consumptive values.

Two important functions of fishery maintenance are (1) to ascertain whether the steady state approached after regulation has been put into effect is within predicted limits, and (2) to analyze the subsequent history of the fishery with a view to detecting the occurrence of any changes that would necessitate revision of the particular regulative measures adopted. The simulation model can be used to evaluate the expected transitional states from an annual fishery as well as the expected equililbrium. A socioeconomically feasible strategy may be determined given the current state of the fishery. At each "annual" iteration of **FINMAN**, certain information is displayed for the user (Figure 5). The completeness, accuracy and precision of the information is controlled by the institution's budget level and the budget allocation decision made by the user during previous iterations. Statements relative to what the constituency "desires" and "thinks" of the user's performance are provided to guide the user in his decision making. A utility function (Keeny and Raiffa, 1976) calculates the user's performance in a manner which allows comparisons among simulation exercises to be made and the relative orientation of the manager and his constituency. The updated information base

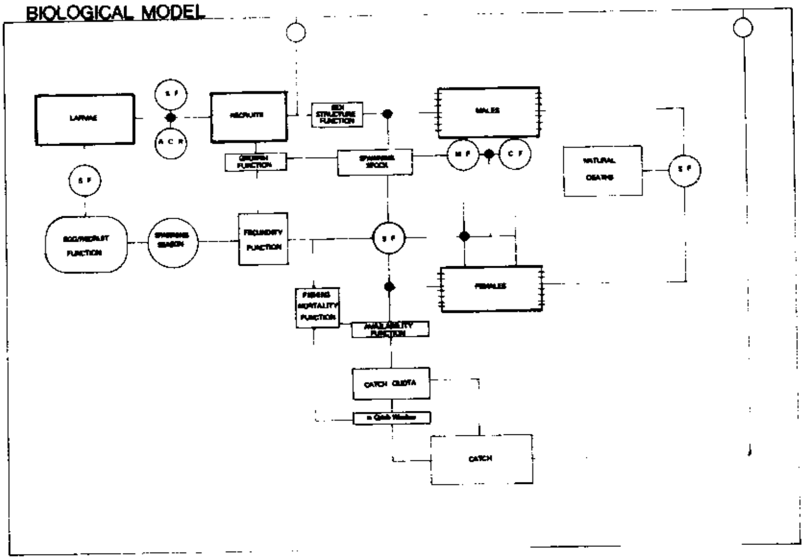


Figure 4. Flow diagram of **FINMAN** Biological Fishery Sector Module. **RF** = recruitment function, **SF** = stochastic function, **FF** = fishing mortality function, **MF** = sex specific maturation function, **CF** = copulation function.

FINMAN Information Base

I. FISHERY STATISTICS

- o CATCH
- o EFFORT
- o PARTICIPANTS
- o NET RETURNS

II. ASSESSMENT

- o STOCK AND RECRUITMENT TRENDS
- o MSY ESTIMATE
- o YIELD PER RECRUIT ANALYSIS
- o ENVIRONMENTAL INFLUENCES

III. POLITICAL

- o CONSTITUENCY EXPECTATIONS
- o OBJECTIVE FUNCTION VALUE

Figure 5. **FINMAN** Information Base.

is used to make the basic decisions regarding management measures and institutional budget allocations outlined (Figure 3). The performance of the fishery is controlled through the management measures and the degree of enforcement exerted. The larger the enforcement budget is, greater compliance is obtained with the management measures - very large enforcement budgets, however, create criticism from the constituency. The larger is the assessment and monitoring budget, the more accurate and precise is the assessment information. A large development budget results in the faster development of a developing fishery and placates constituency criticism.

EXAMPLE: A GROUPER POPULATION

FINMAN was designed to be useful for examining system responses to biological, socioeconomic and political fishery management decisions and fishery research program management decisions in tropical and subtropical fishery situations. Although the simulation model has been developed along generalized lines to accommodate a variety of single and multispecies fishery complexes, the impetus here was to examine the response to exploitation and the attendant management structure decisions of a grouper life history. The grouper comprise an important component of commercial and recreational catch in tropical and subtropical western central Atlantic fisheries. These species exhibit life histories which suggest that populations essentially behave as unit stocks. Groupers are protogynous hermaphrodites, i.e., individuals mature as females but later transform to males. While extensive simulation studies investigating the effects and management implications of all sectors of the grouper model (and 5 other life history strategies) will be published subsequently, one particular study of the effect of a particular effort development strategy and a pair of budget allocation schemes will be useful for illustrating the utility of **FINMAN**.

Assume that a very low level artisanal fishery has existed on the grouper population of concern prior to the appointment of the present manager. In an ambitious plan to produce economic and other fishery related benefits to his constituency, the manager recommends that a 25% annual increase in effort be allowed. The manager, knowing little or nothing about the optimal allocation scheme for resolving the system, must allocate funds to the various assessment and monitoring activities, enforcement and development sectors. We have demonstrated the effects of two separate allocation schemes: (1) the finite funds case where allocations are constrained by a low ceiling budget and thus allocations remain 50% below optimum for the entire simulation sequence, and (2) the learning case where with time the manager begins to recognize deficiencies in his allocations and moves towards optima (Figure 6A). The actual exploitation history is shown in Figure 6B along with the estimated effort derived from an allocation scheme that typified the finite funds scenario. When this allocation scheme is applied to sampling one of the fishery parameters, such as

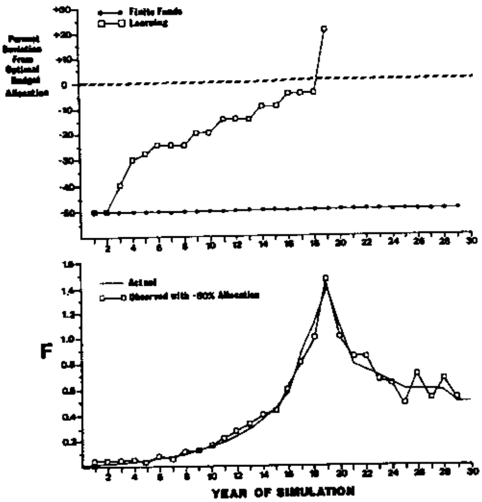


Figure 6. Trends in (A) Budget allocation, and (B) Fishing effort for 30 Year Simulation Sequences.

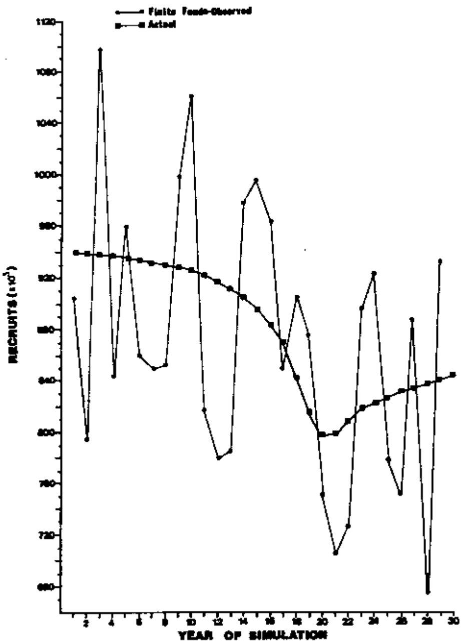


Figure 7. Recruitment trends observed by the Finite Funds scenario (dark circles), and the underlying true progression (dark squares) for the 30 year simulation sequence.

recruitment, the resulting observed variation in the parameter occludes the ability of the individual to discern the underlying true relationship (Figure 7). On the other hand, when the manager is equipped with an adequate budget, but still has to learn about the allocation process, his ability to resolve the system is obscured initially but improves sequentially, where by year 19 of simulation he has developed a clear understanding of the sampling budget requirements (Figure 8). Note that any allocation to a sector larger than optimum represents misallocated funds, as no greater resolution than optimum can be obtained. These misallocated funds could have been diverted to more productive sectors such as improving precision in less resolved sectors of the management system or economy.

Exploiting the simulated grouper population as delineated in Figure 7B produced the relationship between transitional yield and fishing effort (= instantaneous fishing mortality coefficient since the catchability coefficient was assumed to be 1.0) given in Figure 9. Maximum yield was achieved with a fishing effort of 0.9; however, the profitability from the fishery became negative after this year, and thus the reversal in fishing effort. Three things of interest are to be noted here: (1) the significant variation of the observed production relation under the finite funds scenario relative to the actual due to sampling covariance of values in both the ordinate and the abscissa; (2) that with the reduction of fishing effort the values do not track back up the curve as equilibrium theory suggests, this is due to the transitional nature of the curve and the loss of the more reproductively productive age classes under the initial fishing regime; and (3) the extent of the spiraling oscillation of the finite funds observed values around the actual during the last 10 years of the simulation sequence which is also a result of diaxes covariation.

At no point has this management scenario been suggested to be optimum, however, it does serve to exhibit some need for considering the implications of effort strategies coupled with budgetary allocations in evaluating management alternatives. Thus, one can utilize the model for planning, alternative evaluation, organization and identifying sensitive areas of the system.

SUMMARY

In summary, the user's goal is to maximize the objective function through a utility function that allows comparisons of varying manager's orientations and 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." The overall objectives of this model are to simulate the effects of approximately six fish stock life history strategies (grouper, shrimp, coastal herring, tuna, multispecies benthic (shrimp/sciaenid), multispecies pelagic (herring/mackerel)) and fishery types (artisanal and/or recreational alone, industrial alone, or both types

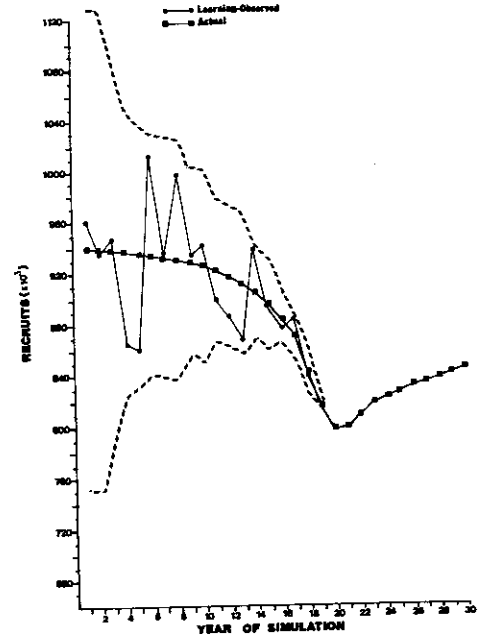


Figure 8. Recruitment trends observed by the learning manager (dark circles) and the true progression (dark squares) for the 30 year simulation sequence. Dashed line represents envelope of possible observed values for the learning sequence.

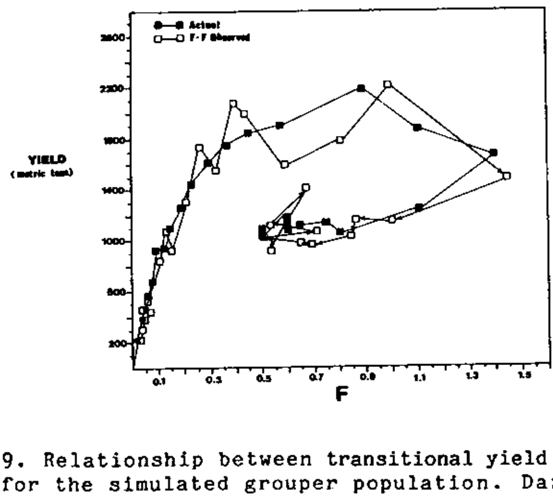


Figure 9. Relationship between transitional yield and fishing effort for the simulated grouper population. Dark squares represent the actual simulated values and open squares the observed values under the **finite funds** scenario.

interactively); coupled with attendant economic and social parameters which encompass a representative sample of the broad range of conditions likely to be encountered by fishery managers dealing with the specialized situations peculiar to tropical and subtropical fisheries. For this reason, **FINMAN** is constructed as a game, not only to enhance user interest, but also to demonstrate the outcomes of behavioral traits like risk taking and risk aversion; and to provide students with a simulated learning-research experience that now requires years in several types of responsible fishery management positions.

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