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Northeast Fishery Management Task Force

Methodology for Identification and Analysis of Fishery Management Options

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PREFACE

This document is the result of studies originating within the Northeast Fishery Management Task Force. The Task Force, organized in 1979 by the New England and Mid-Atlantic Fishery Management Councils and funded by the NMFS, seeks to promote discussion and dialogue on the major issues of fishery management and to explore the effects of various fishery management alternatives.

Composed of representatives from the fishing industry, Regional Fishery Management Councils, federal and state agencies, academic institutions, and general public, the Task Force will operate in three phases. The first phase will assemble background information for identifying and analyzing management options. The second phase will examine this background information to determine the data requirements, regulatory measures, administrative procedures, and enforcement methods associated with each management option. The third phase will critically review the various options for application to specific fisheries, particularly the Atlantic demersal finfish fishery.

This document is one of eight developed under Phase I operations, all of which are being issued in the *NOAA Technical Memorandum NMFS-F/NEC* series. This document and six others functionally serve as appendixes to the eighth and leading document for Phase I operations—"Overview Document of the Northeast Fishery Management Task Force, Phase I."

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NOAA Technical Memorandum NMFS-F/NEC series

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INTRODUCTION

Fisheries management is always difficult, for it involves many complexities. For example, fish stocks are naturally variable, making it difficult to predict their abundance; fishing is often intense, giving the impression that stocks are overfished; and limited communication between fishing and regulatory groups generates continuing conflict. These are just some of the difficulties that contribute to the fact that an explicit multiple-species approach to fishery management has seldom been pursued.

Prior to 1976, fishery management in what is now the U.S. conservation zone was not in general addressed directly; in fact, management tended to be reactive and piecemeal, lacking overall goals. However, in 1976, the Fishery Conservation and Management Act (FCMA) was passed to alleviate this problem by requiring strategic decision-making and public participation in the fishery management process. But, implementation of these new requirements would be difficult; new and different management institutions would be needed.

When the FCMA was enacted, the domestic New England fishery management environment had not been examined in terms of the complexities that it faces today. The New England Fishery Management Council had relatively little information for decision-making; it was thought that many of the stocks were overfished; the fishery was based on at least 20 species and stocks requiring simultaneous consideration; and fishermen at different ports had varying objectives, capabilities, and outlooks. Further complicating the already difficult fishery management environment, the FCMA specified rigorous and sometimes abstract conditions for management. The New England fisheries catch and effort data base concentrated on the traditional species. The research-vessel trawl survey which began in 1963 provided a very valuable fishery-independent set of data on the fish stocks over the whole region. Certainly one of the most comprehensive assessment and management regimes in the world was developed under the International Commission for the Northwest Atlantic Fisheries (ICNAF). However, two things became apparent very quickly when the Councils began to work. The delivery of assessment information to the Councils in the ICNAF format was not meeting the needs of the more localized domestic management problems; and the available data on economic and social structure were neither adequate nor in the right format for easy and quick application. It was evident that the evolving regulatory regime would be rife with time-consuming, redundant, and costly paperwork.

The New England Fishery Management Council began its work on haddock and yellowtail flounder, using a preliminary management plan prepared by the U.S. Department of Commerce as a point of departure. Simple quotas were prescribed in a first attempt to develop management measures. It was soon realized, however, that the desired effects could not be obtained by simple quotas, and as a result, a number of "patchwork" procedures were put into place. Even now, additional temporary procedures are contemplated. The potential effects of some of these "patchwork" management measures were unfortunately not always clear when the measures were adopted, pointing up the need for analysis and discussion of new management measures, so that at the very minimum, decision-makers—e.g., Council members—have a common understanding of the complex potential effects of even simple management measures.

Given the difficulties of the fishery management environment, it is not surprising that management in the U.S. North Atlantic waters operates reactively rather than strategically, and that the existing management system is perceived as producing frequent and confusing regulatory changes. Furthermore, there is a lack of confidence in quotas, data, and stock assessments, and a general concern with the adequacy of the management process.[1]

In the face of all of these difficulties, the Councils have made substantial progress toward development of management plans. It becomes clear, though, that management plans by themselves do not ensure a totally successful fishery-management regime. There are other components in the system that must be given explicit attention with respect both to their internal workings, and to the way that they interrelate to various parts of the system. These parts include statistics gathering, statistical summarizing, the development of management rules and regulations, the deployment of fishing effort, and enforcement. In addition, it is essential that the budgetary and human resources of all entities involved in fishery management—the Councils, the States, the Research Centers and the Regional Offices of the National Marine Fisheries Service (NMFS)—be brought to bear in an appropriate fashion to solve the problems of fishery management.

The Northeast Fishery Management Task Force was organized to consider and develop possible management options directed toward these problems as they exist in the North Atlantic and elsewhere. This paper is a contribution to the deliberations of the Task Force. Its purpose is to provide a framework and methodology for the identification and analysis of management options or systems. (For example, some that have been discussed are: eliminating quotas and managing only by means of closed areas and adjustment of mesh sizes; providing "tax" incentives and/or disincentives to encourage fishermen to adopt particular management strategies; maintaining the *status quo;* stock certificates; *laissez-faire;* self-management; and a fishery development bank.) The paper considers: (1) why it is necessary to develop a management system, (2) methodology for analyzing management objectives, (3) the framework for developing management options, (4) some of the criteria that can be used to select management options, and (5) the next steps for implementation.

WHY A MANAGEMENT SYSTEM?

Management is basically a decision-making activity. In some instances management decisions are simple—(if today's price of apples is less than five cents a pound, store the apples and wait for tomorrow). In more typical instances, though, management decisions involve much greater complexity. In fisheries, for example, the managers must identify important management questions; obtain appropriate data; synthesize data; generate management rules or regulations dependent upon the data; deploy and monitor fishing effort to the extent required by regulation; and institute cost-effective enforcement and administrative regimes.

To be effective, management must coordinate and organize all of these diverse and complex activities so that the total management process is beneficial, cost-effective, and reasonably predictable. Coordination and organization will not happen by themselves, but require a system for their accomplishment. Such a system will resolve many difficulties that are inherent in contemporary fishery-management.

By analogy, consider a large complicated fishing operation. Its success requires teamwork: the captain is the manager, the engineer makes sure that the hardware works, the electronics specialist ensures that the fish-sensing and communication devices are at the state-of-the-art and in good working order, the leading fisherman uses his intuition and the electronic devices to locate the fish, and the officers select the fishing grounds (a business decision balancing running costs with potential catch). These people, the engineer, the electronics specialist, the leading fisherman, and the rest of the crew, might individually be the best in the world, but if they do not understand the captain's objectives, or if they communicate poorly, then the fishing operation will be poorly managed and unprofitable. These difficulties could be remedied by development of a system for management, one which provides for simultaneous and planned consideration and integration of all aspects of management. Important events take place and they take place on time because it was planned that way.

A management system is more than a management plan. It is a mechanism that facilitates: (1) preparation of fishery management plans that address the "right questions," providing approaches for their solution; (2) the actual working of the plan; (3) systematic revision of the plan; and (4) the development of a structure for relating management plans to one another as required. A conventional fishery management plan might be compared to an automobile engine which is in perfect working order, but which is completely useless because it has no gauges, wires, fuel tank, transmission, etc. A management plan might be the best in the world, but without accessory parts—a management system and the necessary information to make it work—the plan cannot be effective.

Development of a successful management system requires a strategic approach. Strategy implies "doing the right thing" as opposed to "doing the thing right." The strategic approach may be compared with short-range tactics:[2]

Strategic Approach	Short-range Approach
• Broad scope	• Narrow scope
• Long time horizon	• Short time horizon
• Considers relation of one problem to the others	• Considers only solution of particular problem
• Concentrates on objectives	• Concentrates on feasibility

The comparison shows that even the best short-range approach may have limited utility since it could be addressing the wrong management problem. On the other hand, an excellent management strategy that ignores aspects of the short-range implementation questions will result in inefficient and muddled execution.

A responsible decision-maker will insist on a management system that has sufficient strategic content so that it:

- deals directly "with changing patterns of multiple purposes and objectives . . ." dealing with all relevant variables whether or not they are easily measured.
- views the decisions that are made in the context of other decisions.
- is innovative and creates new values or norms where necessary.
- does not subordinate longer-range considerations for short-term solutions.

Responsible decision-making can arise only from systematic analysis of the problem it addresses. In carrying out such an analysis, one must consider objectives, options, criteria, and the consonance of conclusions with objectives. It is evident that responsible decision-making requires various options or systems for management and that development of such systems or options is a critical task in fishery management.

METHODOLOGY FOR THE IDENTIFICATION OF MANAGEMENT OBJECTIVES

Identifying fishery management objectives is a critical task. Objectives must be realistic and achievable. They must also be mutually understood by those involved. If objectives are not clearly stated, then individuals in the management system may think they are striving to attain a common objective, while they work at cross purposes. If, however, objectives are clearly stated and there is disagreement with respect to their rationality or intent, then it is possible to focus on differences, resolve points of contention, and possibly arrive at even better objectives.

In this section we discuss some of the general problems of objective identification and then consider specific issues related to fishery management objectives.

GENERAL PROBLEMS OF OBJECTIVE IDENTIFICATION

A number of studies have developed general criteria for objective identification. These criteria are important for management system development because, as indicated earlier, efficiency in any management option or management system is promoted by rational, operationally sensible objectives.

There are two particular pitfalls to worry about in developing criteria to identify and evaluate objectives. The first is setting objectives which are too idealistic to be useful practically, and the second is setting objectives which take into account only a small part of the entire problem.

Objectives that are too idealistic are commonly called "motherhood" objectives, or in systems jargon, "overdetermined" objectives. Typical overdetermined objectives are stated in such terms as "for the maximum benefit of mankind", "maximize social welfare", or "catch all the underutilized fish in U.S. waters." A little reflection will reveal that objectives stated in such terms have different meanings for different people, by themselves providing little operational guidance.

The second class of objectives, those that take into account only a small part of the entire problem, are frequently called "suboptimal objectives," since concentration upon such objectives may yield an optimal solution for a small piece of the problem, but not for the object of concern, the entire problem. Taking a strategic approach as previously outlined is the best safeguard against this pitfall.

There are two consequences of taking too narrow a view. In the first, the *view* or definition of the problem is suboptimal. In the second, the *approach to the solution* of the problem is suboptimal in the sense that there is an over-concentration of effort on only parts of the problem, so that a total solution, however superficial, is never arrived at. Analysis which concentrates only upon determination of objectives and which ignores the process for attaining the objectives is a typical example.

While the identification of appropriate and useful objectives is critical, the development of procedures for attaining the objectives is also of considerable importance. Even the best objectives will *never* be attained unless there is a process in place for their attainment. Thus, the development of any management system or option for management requires as much concentration on the system for attaining the objectives as on the objectives themselves.

SPECIFIC FISHERY OBJECTIVES

In this section, specific fishery objectives are considered in the context of our general discussion on setting objectives. First, we discuss objectives set forth in the FCMA; next, we review typical fishery management objectives.

The FCMA adopts the principle of optimum yield (OY) as its guiding light for an ideal management regime. The Act says that optimum yield shall be taken from each stock that comes under the authority of the Act (principally stocks that are fished in the conservation zone, generally 3-200 miles from the coastline). The Act defines optimum yield as the catch, ". . . which will provide the greatest overall benefit to the nation with particular reference to food production and recreational opportunities." The Act not only defines optimum yield, but it also specifies a process for its calculation, saying that optimum yield shall be determined by first calculating maximum sustainable yield (MSY) and then modifying MSY by relevant economic, social, and ecological factors.

The definition of OY and the process described for its calculation raise a number of issues which must be addressed to appreciate fully the role which optimum yield is evidently intended to play, under FCMA, as a management objective. With respect to the definition of OY, how shall ". . . the greatest overall benefit to the nation with respect to food production and recreational opportunities" be interpreted?

With respect to the process, how do we interpret "MSY?" How are OY and MSY ultimately integrated to give a consistent approach to fishery management?

The Greatest Overall Benefit to the Nation

Benefits must be perceptible on a national scale in order to judge among alternative benefits, concluding that some particular activity will yield "... the greatest overall benefit to the nation." It is relatively easy to estimate the effect of a change in steel or oil production on the national economy (one would think), but it is not easy to perceive the effect of a small change in fish production upon either the national economy or the national food industry. If the economic impacts of the commercial fishing industry are difficult to perceive, then the benefits of providing recreational opportunities must be even more difficult to quantify.

When considering "benefits to the nation" in terms of per-capita food consumption, fish are seen to be a relatively small component. Similarly, while there have been no studies, to our knowledge, of the contribution of sport fishing to total recreation, the time spent sport fishing must be only a small fraction of total recreational time.

While contribution of fishing to food supply or recreation may be perceived as very small in terms of total national benefits, it can be argued that this apparent unimportance is merely a function of the way in which the statistics are computed. The value of fish may be underestimated, because a national calculus for measuring food or recreational benefits understates the great impact that fish have in certain regions, where they may be the basis of important recreational or commercial components of the economy. Further, the degree to which derivative industries such as the tackle and bait industries or the restaurant industry depend upon the availability of fish is neither fully understood nor included in national analyses of benefits.

The discussion reflects that it is probably impossible, at this time, to estimate how much fish contribute to the relative or absolute "national benefit," or to quantify the abstraction: "maximum benefit to the nation in terms of food and recreational opportunities." If "maximum benefit to the nation" is an abstraction, it follows that "optimum yield" is itself an abstraction.

Because of this, it is important to develop operationally relevant approximations to optimum yield. In deriving such approximations, it is essential to compare the optimum-yield objective with the process for attaining that objective for consistency between the objective and the process. In other words, is there a logical consistency between "A yield that generates the greatest overall benefit to the nation with respect to food production and recreational opportunities" and "MSY as modified by social, economic, and ecological factors?" If we assume, as it is reasonable to do, that benefits to the nation may accrue in social, economic, and ecological terms, then we can see that MSY does not necessarily limit the outcome of the optimum yield calculation (According to FCMA, MSY needs only be calculated before the social, economic, and ecological factors are reckoned.); OY, we recall, is determined by first calculating MSY, then estimating a deviation from MSY, by giving appropriate weight to "social, economic, and ecological factors."

MSY: Economic, Social, and Ecological Deviations

In this section, the utility of MSY and the nature of economic, social, and ecological deviations from MSY are considered.

First, it is important to determine how MSY relates to optimum yield. As discussed above, the Act permits apparently great deviations from MSY as a result of ecological, social, or economic considerations. Because of the large deviations permitted, one could argue that apart from the specification that it be calculated, the MSY parameter was of little importance or use.

In understanding the role of MSY, it is important to recognize what it is and how it arrived at its present state of disrepute.

The MSY concept is quite simple and has been used as a point of departure for the management of many fish stocks. In Europe after World War II the MSY model—owing to its simplistic pooling of such critical population-dynamic variables as growth, recruitment, natural mortality, and fishing mortality—became subservient to the yield-per-recruit type of model since this took into account all of the factors mentioned except recruitment. Nevertheless, the MSY model defines, within some strict and probably realistic assumptions, the magnitude of catch that offsets natural population increase; not only do we obtain estimates of this equilibrium catch, but we also find that level of effort which yields the maximum equilibrium catch, the MSY. This is a convenient concept for the manager.

The utility of the MSY concept has been its definition of a single value. As we enter the realm of ecological, economic, and social factors, however, we must deal with the reality of multiple factors. The science of ecology as applied to the marine ecosystem has not provided much practical advice on how its modifying force may be considered. The studies in recent years have become more relevant to management concerns; nevertheless, there is still a certain "fuzziness" in the concepts. Very basically, there are two aspects important to management. To what extent is the recruitment of fish subject to environmental factors compared to spawning stocks? How do species interactions modify the implications drawn from single-species studies?

With respect to economic benefits, the concept of social surplus is used as an index. Basically, this concept states that producers and consumers have an interest in any commodity. Benefits to the consumer are measured as a maximal quantity of a commodity at the lowest possible price; benefits to the producer derive from production of a maximal quantity of a commodity at the highest price. Maximum social surplus, is the maximum joint benefit to both the consumer and the producer. In general, changing the *status quo* in regard to social surplus involves lowering the cost of production of fishing or increasing the demand for fish. If we maximize social surplus, then for the purpose of our first approximation, we say that we are being economically efficient. It is important to note that even if data are not available, the directional influence of certain management actions on social surplus can often readily be ascertained.

For example, for some resources, domestic markets are weak or nonexistent, yet significant foreign markets exist or could be developed. The export alternative broadens the consumer sector and may increase the social surplus.

Maximization of social surplus and economic efficiency are just part of the picture. There is also the question of how the "maximum wealth" is distributed among members of society; the distribution of wealth is an important sociological consideration. The social-surplus calculus provides a first cut at distribution, in that it specifies the shares of producers and consumers. The options beyond this are so numerous that special consideration should be given to each fishery.

Optimum Yield, MSY, and Time

It is important to recognize that optimum and physical yield change with time, and that both are calculated quantities. Optimum yields are calculated on the basis of actual or theoretical social values, MSY's on the basis of actual historical yields or theoretical biological models. The quality of the estimates has important consequences which must be considered (Figure 1).

Commonly Used Objectives in Fishery Management

In this section, commonly used objectives in fishery management are discussed relative to the principles for identification of objectives outlined above.

Some management objectives are phrased in such terms as "maximizing the overall good to society." Such "overdetermined" objectives can be interpreted in many different ways, and as a practical matter, without further detailed specification, they are not likely to be measurable or attainable.

For objectives related to multiple-species fisheries, there is always a question whether management should focus on one, several, or all of the species. Analysis of such a question requires the costs and benefits of each alternative to be examined. If only some species are included in the management strategy and there is no analysis of the rationale for their inclusion, then there is a serious danger of suboptimization—that is, optimizing the management of the selected species, when optimization for another set of species, or for all of the species in the fishery, would yield the maximum net benefit.

Objectives phrased in terms of maintaining a particular stock size, a minimum stock size, or a particular number of spawners also cause problems. There is often little or no theoretical guidance on the appropriate stock size and if there were, there would be uncertainty as to when the stock had actually reached the appropriate theoretical level. In any event, manipulating stock size is really a method to achieve some social goal.

Objectives that are intended to operate over too long a time period present their own difficulties. For example, multiple-year planning horizons are theoretically ideal, but the fact must be recognized that the period can be so long that the risks of planning exceed the benefits. To take an extreme example, financial planning for the year 2079 involves so much uncertainty that its practical benefits are difficult to perceive. This problem is reduced by improvements in our ability to forecast the future, and by adopting plans that are sufficiently flexible to accommodate any uncertainty.

It is important to develop alternative objectives. This is of course much more difficult than criticizing extant objectives. Since so many objectives tend to be overdetermined, it is necessary to develop criteria for setting more practical objectives which are both attainable and consonant with the more philosophical "asking the right question" strategic objectives.

Practical objectives are attainable in measurable terms. It would be difficult to know if many overdetermined objectives were in fact attained simply because such objectives are often so general as to defy measurement or evaluation.

The availability of information is thus one important criterion for setting the appropriate degree of "determination" in an objective. For example, compare two hypothetical objectives. The first is to catch 10 tons of fish and the second is to maximize net social benefits. The information required for the first is simple, but that required for the second is most complex, so much so in fact, that an index of net social benefits would be almost impossible to agree upon.

The best available fishery information is most often limited when compared to the amount generally thought to be required for management. Practical objectives must therefore be consonant with strategic objectives, but they must also not require information beyond that readily available unless plans for acquiring more data and information accompany them. Areas where data tend to be lacking include stock variability, interspecific interaction, and the relationship among biological, economic, and social variables.

As an example of a limited-information approach to management, consider the following scheme for a shrimp fishery.[3]

a. Examine the extent of the area involved, and estimate, on the basis of comparison with other areas, the likely number of trawlers required for operations at the optimum level (for example 50).

b. Issue licenses for the operation of rather less than this optimum number (say 30). A condition of obtaining a license would be provision of full statistical data on the operations, including catches of each size of shrimp, fishing effort, and location of fishing.

c. Allow the operation of these vessels for two or three years without modification. Then examine the statistical and other data, assess the stock and obtain a revised estimate of the optimum number of vessels (e.g., 55). This may be above or below the original estimate.

d. Issue further licenses to bring the total number of vessels licensed closer to, but still below, the revised estimate of the optimum (e.g., 45).

e. Make economic studies to estimate the likely profitability of each boat when the fleet approaches its optimum size.

f. Decide, particularly if this profit is large, what use should be made of it, and introduce appropriate additional conditions on license holders, e.g., substantial license fees, commitment also to land defined quantities of fish, etc.

g. Repeat steps c. to f. at intervals.

A simple scheme for setting alternative objectives might involve the following:

MSY's of various stocks are first determined; economic, social, and ecological modifications are then determined to satisfy OY; catch goals are established consistent with these determinations; and the catches are monitored frequently and adjusted as necessary.

It should be possible, based on past experience, to estimate the likely reproductive success of various parent-stock sizes. A range of alternatives could be computed, and keeping in mind the inherent errors in this process, it would be possible to set flexible stock-size goals.

It should also be possible to think of management measures that involve as many species as possible. Starting with the maximum number of species (perhaps even all in aggregate) and reducing the number for practicability might be a better strategy than starting with the minimum number and later being incapable of increasing the number of species.

These observations suggest a need to begin with simple objectives that are consonant with the FCMA. These simple objectives need to be based on the MSY's of the stocks under consideration, taking into account appropriate economic, social, and ecological functions. Since these economic, social, and ecological functions are not likely to be known or even measurable, considerable systematic trial and error will be necessary. As the stocks increase in value and more knowledge accrues, management might need refinement, but this should be based upon additional information; the information can be acquired directly or indirectly through trial and error.

DESIGN AND ANALYSIS OF MANAGEMENT OPTIONS

In the first part of this paper, the importance of objectives and the principles for identifying and selecting them were discussed. This section considers the process for attaining objectives once they are identified, concentrating on the design and analysis of management options or system.

At the outset, let us define "management option." Such an option includes both an *objective* and the *process* for attaining that objective. Process is often viewed too narrowly; it is expressed simply in terms of catches, quotas, or some particular fishing program. The kind of fishery management we aim toward, however, is much broader in scope. In addition to the traditional rules on such factors as catch or effort, it considers data collection, storage, and retrieval; tactics of fishing effort deployment; fishing effort monitoring; management performance measures; fishery development; and improvement of the regulatory regime. Management must consider these items individually, and also, how they relate to one another, not forgetting the personnel and funds necessary to make the entire system work. In other words, any particular option for management is a system in which all components are identified, each component is given appropriate consideration, and interrelationships among components are planned. *Management is much more than a plan; it is a system that develops plans—but it also enables plans to work.*

GENERAL PRINCIPLES

The design and analysis of particular management options or management systems are based on certain general principles. In the section which follows, we will consider: (1) control and ownership, (2) communication, and (3) management unit identification.

In analyzing management options or management systems, we need to consider the degree to which fishing is controlled and the character of the group controlling it. To being with, "boundary" conditions for management-control and ownership need to be examined. For example, "zero control" implies that fishing operates on a *laissez-faire* basis. By contrast, "maximum control" implies a management authority which controls every fishing action and possibly all processing as well.

Under zero control, fishing intensity would be influenced by economic considerations rather than by regulation. In a "perfect" economy, zero control would, in fact, be ideal because the amount of fish landed would be that which consumers desire, and the combined benefits to both producers and consumers would be maximized.

The zero-control option implies what is caught is the optimal yield, but there are problems which must be considered.

A. If stocks are intensively fished, then the catch per unit of effort (CPUE) will decline to a point where it will not be profitable to fish. At the point where fishing ceases, there should be a residual spawning stock capable of perpetuating the population. Although it is not necessarily true that the "uneconomic point" will negatively affect the viability of the stock, there is a point of view that high discount rates will cause an uncontrolled fishery to have this effect. This is only true, however, if the value of catch is sufficiently high relative to the salvage value of the capital in the fishery, and if there are no alternative uses for the capital.

B. Economic signals are often transmitted with considerable time lag; while the performance of a zero-control system might trace the economic optimum, oscillations about that optimum might be great enough to generate genuine hardship. Time lags are particularly critical because investment is often geared to conditions at the time it is made. Fish stocks are notorious for their fluctuations and once a boat is built, it is a financial commitment for a number of years, during which stocks may deteriorate.

Thus, a zero-control system will need to take into account questions of minimal stock size and, also, ways of dealing with time lags in economic signals, a "market failure" situation which may be a significant constraint against optimality. It is interesting that both of these problems can be dealt with in a relatively cost-effective manner. The conservation question involves quotas, and the economic-signal problem involves development of appropriate data flow and systems models.

Under maximum control, the amount of effort and its deployment would be controlled by a single entity, which would buy and sell boats, hire fishermen, generate fishing strategies, etc. Vertical integration might involve control over the processing sector of the industry as well. With a single entity managing the fishery, profits and/or rent would be maximized, dependent upon the management entity's ability.

Such a system has drawbacks: there would be no competition to stir innovation, and the marketplace could be completely controlled by the management entity, leading to a monopoly disadvantageous to the consumer. Further, it would be difficult to change the entity if it were not competent.

Let us now examine the question of ownership. Ownership could vary from one extreme, at which there is complete public "ownership" of the stocks, to the other, at which ownership is vested in the private sector. The stocks of fish are owned by the public, but because public ownership can be abstract and diffuse, the best return is not necessarily guaranteed by such ownership. Prior to the FCMA, public ownership of the stocks resulted in management schemes involving extensive negotiations with foreign states wishing to fish off our coasts. Management results often depended upon a tradeoff between the motivation of foreign countries to fish in our waters and our ability to negotiate the magnitude of their catch.

Passage of the FCMA has reaffirmed public ownership of the fish stocks, but placed the public trust for management of those stocks in the Department of Commerce and the quasi-public Regional Fishery Management Councils.

Despite clearer public responsibility for management, incentives for cooperation by average fishermen have remained more or less as they were. To change the performance of the fishing community materially with respect to management, new incentives must be developed. Many approaches are available, some of them not new. (For example, given certain guidelines for statistics-keeping and management performance, stocks might be leased to a fishing group or company to manage to the best of its ability.)

Questions of control and ownership will be central to any management option; in fact, the appropriate mix of control and ownership may well be the most important strategic question in fishery management (see p. 7-9). Boundary conditions for management and control are set forth below:

Control / Ownership	Zero control	Complete control
Public ownership and mgmt.		
Private ownership and mgmt.		

A full discussion of these boundary conditions is beyond the scope of this paper. The following comments, however, will help to define them.

With zero control and public ownership and management, the management system would theoretically respond to economic and social signals. There might be some additional constraints resulting from fishing mortality. Some believe that under the present management strategy, quotas are generally not constraining fishing. If indeed this is the case, then the present management regime fits within the zero-control category.

With complete control and public ownership and management , a governmental agency or a quasi-public company (such as the U.S. Postal Service) would "run" the fishery.

With zero control and private ownership and management, the right to fish in a *laissez-faire* system would be accorded either to an individual who would bid for the right to fish, or to a limited group. As such a group became larger, though, private ownership and management would approach public ownership and management.

With complete control and private ownership and management, there would be a shift from controlling the catch to controlling the entities that make the catch. Under this approach, economies of scale might be possible.

Thus, the range of control-ownership options can be bounded. There are no intrinsic reasons why any of them should be excluded from analysis, though they need to be developed further in terms of the mechanisms by which they would be executed (*e.g.*, lease of fish stocks; limited entry; incentive-disincentive taxes; *laissez-faire;* and ownership certificates). One interesting option is the creation of a fishery development bank that manages stocks, finances development, and provides insurance for resource fluctuations.

Communication is another critical component of management systems: when communication is good, ideas and concepts are interpreted exactly as intended; when communication is poor, ideas and concepts are understood differently than intended. Good communication permits a mutual understanding of views regarding the nature of a problem, the kinds of objectives that must be sought to resolve problems, and the processes required to attain objectives. If communications are poor, then situations arise where, for example, a simple viewpoint is thought to represent a multiplicity of views, or, on the other hand, a complex of views might be interpreted as a simple idea. Poor communications often result in fishery managers having an inaccurate view of their decision environment. For example, suppose there is a public hearing on whether the size of trawl mesh should be increased. There are 100 fishermen, but only three think that mesh size should be increased; 97 do not. Five fishermen attend the hearing; three are for the increase and two are against it. The hearing examiner would naturally assume that most fishermen prefer an increase in mesh size. Thus, poor communications between the fishermen and a management agency can result in the agency having a distorted view of the real world. It is particularly important to realize that the decision environment of fishery management requires frequent and numerous decisions. Because there are so many decisions in fishery management (even doing nothing implies a decision to do nothing) it is important that managers consider the results of similar, previous decisions. Basing new decisions on experience or information from previous decisions is called feedback. Without proper feedback, errors in decision-making can be compounded, but with feedback, errors in previous decisions can often be corrected. The feedback problem is of special importance in fishery management because it is the decision-makers who regulate the fishery, but the fishermen who observe directly the effects of the regulations. Most observers agree that communications between the two groups are generally less than efficient. Good communications, like good management systems, will not simply happen; they need to be explicitly planned and resources must be devoted to ensuring their adequacy.

Another principle that requires considerable thought is the definition of an appropriate management unit. It is clear that it will be difficult to consider all of the stocks that live off the northeast coast of the U.S. as a single management unit, but what are appropriate units? As with setting objectives, it is too easy to define units on an intuitive basis. Logical divisions involve biological, geographic, social, and economic considerations (or any combination of these).

The criteria for choosing among alternative management units should include:

- Control
- Management capability
- Economic and social factors
- Regional competence of management bodies
- Costs
- Variability
- Net benefits

THE STRUCTURE OF A FISHERY MANAGEMENT SYSTEM

As a basis, an option for fishery management should reflect explicit consideration of the basic components of a fishing system. The various options or management systems can be structured around the components. Figure 2 displays the elements of a fishery management system. The system operates in a time frame. Management is defined on the basis of certain stocks at a particular time. A description of the system must include in whatever detail is appropriate a description of the stocks, their population dynamics, and the economic and social consequences of catching the stocks.

The system must relate to the kinds of data that are collected, the degree to which the data are representative, and sample sizes. The data must obviously serve as an efficient link between the condition of the fish stocks and the management rules. The management rules include decisions on the intensity and distribution of fishing effort. In addition, management rules must contain formulae for determining the performance of management in terms of both managers and fishermen. Performance evaluation of fishermen with regard to management rules or "enforcement" needs to be part of any fishery management system.

As a result of management rules, fishing effort will be deployed at T and will modify the stocks at time T+1. New data will be used to evaluate the degree to which fishing complies with the management rules; as a result, new management rules will be defined, and the cycle will be completed.

Even a preliminary consideration of Figure 2 reveals some of the problems of present management systems and potential improvements of those systems:

Present System	New System
• Time interval one year or several months	• Time interval that is a function of needs
• Data are collected independent of management rules	• Data collected need to be responsive to management rules

• Fishing effort is deployed, then the effects are measured	• Fishing effort can be forecast
• Stocks of fish are considered by individual species	• Stocks of fish are defined as multi-species economic units
• Measures of performance are not explicit	• Measures of performance need to be made explicit

Partitioning management activities into planning, management, and control functions will relate the various stages of the system to one another and promote further organizational simplicity.

The planning function sets goals or objectives for management and it structures the process for attaining these goals. Preparation of a fishery management plan is integral to the planning function. But management must be more than a relatively simple statement of what can be caught; a plan for management must address data collection, the efficiency with which data will be transformed into management rules, and how the management process is to be evaluated. Management must indicate who is to do what and at what time. Furthermore, as addressed in the section on objectives, it is not uncommon that a plan, because of the way it is structured, addresses intuitive and short-term issues rather than long-term or strategic ones. Intuition, for example, might tell us that the best way of moving traffic across a river is by bridge. A plan for the bridge is made. It is an excellent plan and the bridge is beautiful. However it is later determined that what was really needed was a tunnel. An expensive experiment! Thus, the planning function must not only result in good plans; it must plan the right things.

Any management function is intended to carry out a plan in an efficient way. The management function uses conventional management inputs—budget, human resources, raw materials—to produce a designated product of the management system. In the case of fishery management, the public sector utilizes budget, people, and data to generate a set of management rules under which fishermen produce fish.

The control function is established to evaluate the degree to which the management activity conforms to the plan. In other words, the planning function establishes a direction and measures of performance for the management function, while the control function evaluates the degree to which the management activities conform to the plan.

It is obvious, then, that fishery management involves the interrelationship of a great many events. Some are natural events, such as the occurrence of a large year class of fish, while others, such as a particular management decision, are part of the planning, management, and control process. If the planning, management, and control events happen in a reactive and haphazard way, then management system efficiency will probably be quite low. If, however, there is planned coordination among the natural and management events, then the information generated can be utilized with maximum efficiency, thus contributing to a more cost-effective management system.

The most convenient way of handling all of the diverse components of information, planning, management, and control is through development of a management information system (MIS). Such a system is a systematic ordering of events enabling management to respond to their occurrence in the most efficient, cost-effective, and timely manner. A MIS is part of any management option, and therefore it needs to be treated explicitly.

Figure 3 is an example of the structure of a MIS.

The successful achievement of management objectives depends upon timely and reliable information. Essential is a state-of-the-art and computer-based management information system, designed to collect, store, process, and disseminate a broad range of information for the North Atlantic area.

The MIS should be designed to handle both non-biological and biological data, with algorithms to extrapolate, project trends, and provide alternate "trade-offs." The system should be oriented to management-by-exception and timely management decision-making.

Much of the information put into the system will come from commercial fishermen. To secure their cooperation, it will be important to furnish frequent "feedback" on catch dynamics, trends, trade-offs, etc., to these fishermen.

The North Atlantic regional system should be designed to interface with other regional MIS's and/or any future national MIS.

It should include:

- Remote terminal input and output capability
- Data-base management system
- Variable record length capability
- Password and privacy-protection capability
- A scheme for timely updating of files on a continuing base
- A variety of output mediums, e.g.,
  - Visual display terminal
  - Hard copy
  - Microfilm
  - Plotter

Since the system is intended as a management tool for the Councils, they must participate in its design and specifications, including format and content of graphic and printed output.

IDENTIFICATION OF POSSIBLE OPTIONS

A number of approaches to management have from time to time been discussed. These include:

- Eliminating quotas and managing only on the basis of closed areas and adjustment of mesh sizes
- Providing "tax" incentive and/or disincentive to encourage fishermen to adopt particular management strategies
- Maintaining the *status quo*
- Issuing stock certificates
- *Laissez-faire*
- Self management
- Establishing a fishery development bank
- Limited entry

These approaches will require analysis, and it needs to be stressed that such approaches are not in themselves complete management options or management systems, which require all system components to be described: from statistics collection through the development of performance standards as well as cost/benefit analysis.

Choices will need to be made among management systems or combinations of systems, and these choices must take into account possible changes in stock structure or stock abundance and national or global changes in the fish-commodity system (see Figure 4—a fisheries commodity model for forecasting these changes). In addition, various costs and benefits need to be examined. Costs include:

- Data costs
- Management costs
- Enforcement costs
- Research costs
- Administrative costs
- Costs of possible lost benefits to fishermen and consumers

Benefits include:

- Tonnage of various kinds of fish
- Value of fish ex-vessel and at various levels of the economy
- Numbers of fishermen and other employment
- Consumer surplus
- Revenue and profit

In addition to these more-or-less easily quantifiable criteria, it is important to assess the human impact of any management system.

PHASE II IMPLEMENTATION

Implementation of the next stage of the planning process, Phase II, requires:

- Teams to work on each management option; identification of team leaders; a work plan which makes the work of each team comparable
- A model relating catch of several species to nominal fishing effort
- A first-phase commodity model
- A plan for intercouncil communication
- Specifications for a management information system
- Development of "data-free" management procedures
- Detailed discussions on control and "ownership"

APPENDIX: EFFECT OF FOREIGN FISHING

In considering "benefits to the nation" it is important to consider the various alternative uses for fish. The implications of one particular use of fish, allocation of fish to foreign fishermen, is not commonly understood. Any allocation of fish to foreign fishermen will generally represent a cost to domestic fishermen, because a foreign allocation will increase per-unit-cost of fishing to domestic fishermen. Even if there is no domestic fishery, the lowered levels of stock abundance brought about by foreign fishing may serve as a disincentive for domestic fishery development.

FOOTNOTES

1. U.S. Government Accounting Office. 1976. The U.S. fishing industry—present condition and future of marine fisheries. Vol. 1. Report to Congress by the Comptroller General.

2. The discussion on strategy is based on: (1) Rothschild, B. J. 1973. Questions of strategy in fishery management and development. J. Fish. Res. Board Can. 30:2017-2030; (2) Gross, B. 1971. Management strategy for economic and social development. Part I. Policy Sci. 2: 329-371; and (3) *idem* 1972. Management strategy for economic and social development. Part II. Policy Sci. 3:1-25.

3. Gulland, J. A. 1972. Some introductory guidelines to management of shrimp fisheries. U.N. Indian Ocean Program Rep. No. IOFC/DEV/72/24. 12 p.

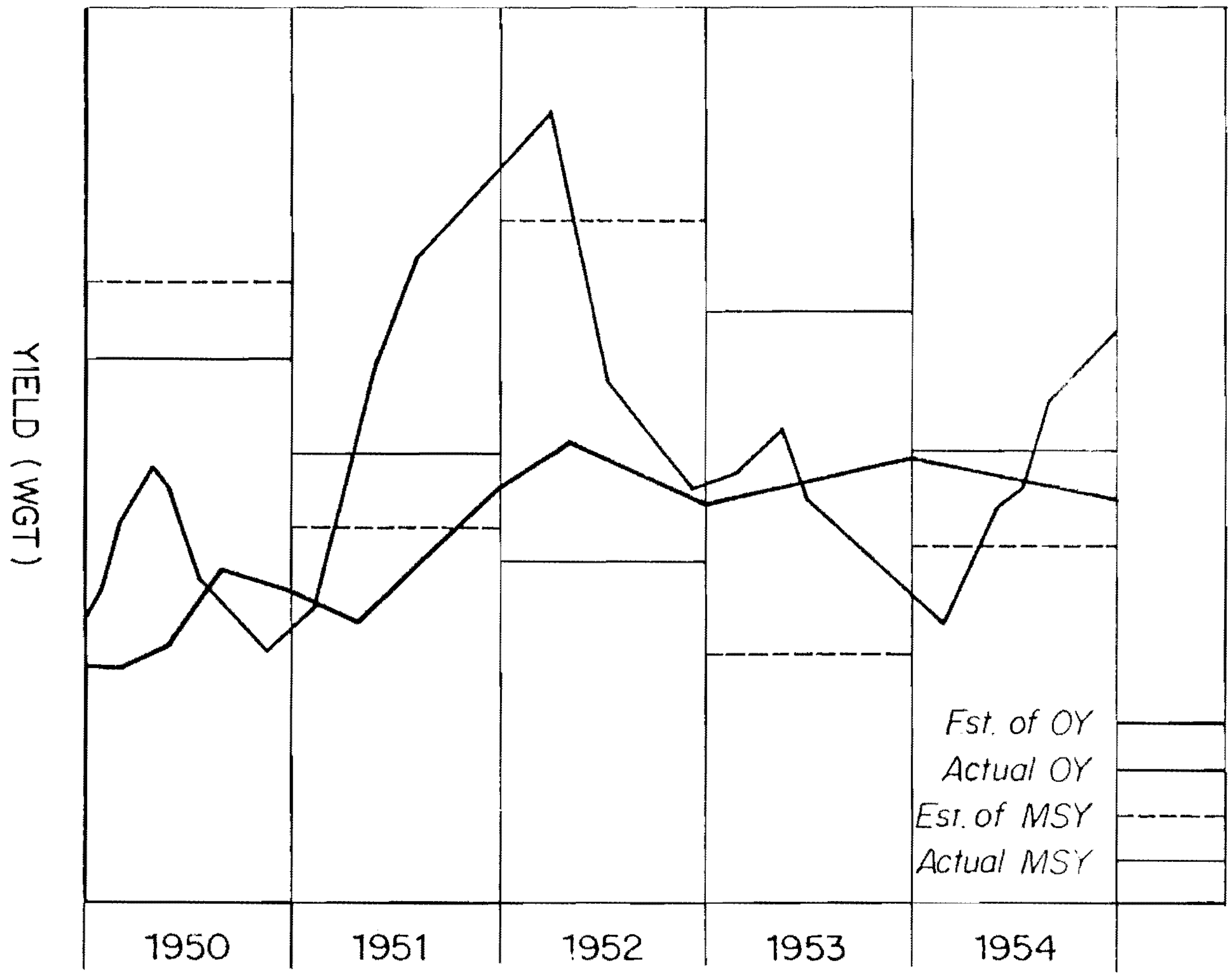

Figure 1. Hypothetical time series showing actual maximum sustainable yield (MSY) (solid horizontal lines) and estimated MSY (dotted horizontal lines) for each year; actual optimum yield (OY) (light continuous line) and estimate of OY (dark continuous line) for each year. Several features of this figure are evident: (1) once MSY is calculated it usually has a constant value; (2) there is a difference between the estimated values of OY and MSY and the actual values; under- or over-estimation reflects considerable economic costs; and (3) while MSY tends to be constant over the fishing year, actual OY tends to vary continually, as does its estimate.

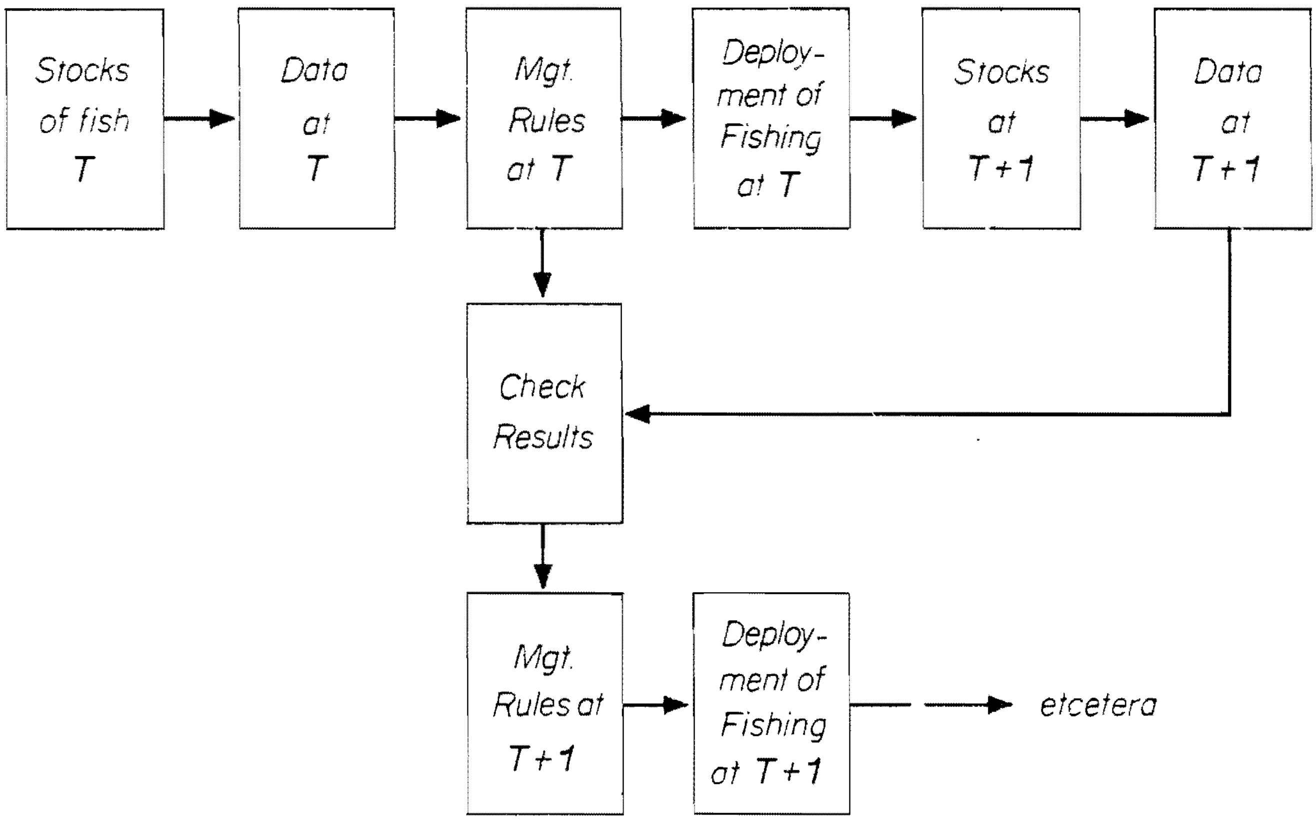

Figure 2. Components of a fishery-management system. The figure shows only one cycle between time T and time T+1. Actually, the system would continue indefinitely.

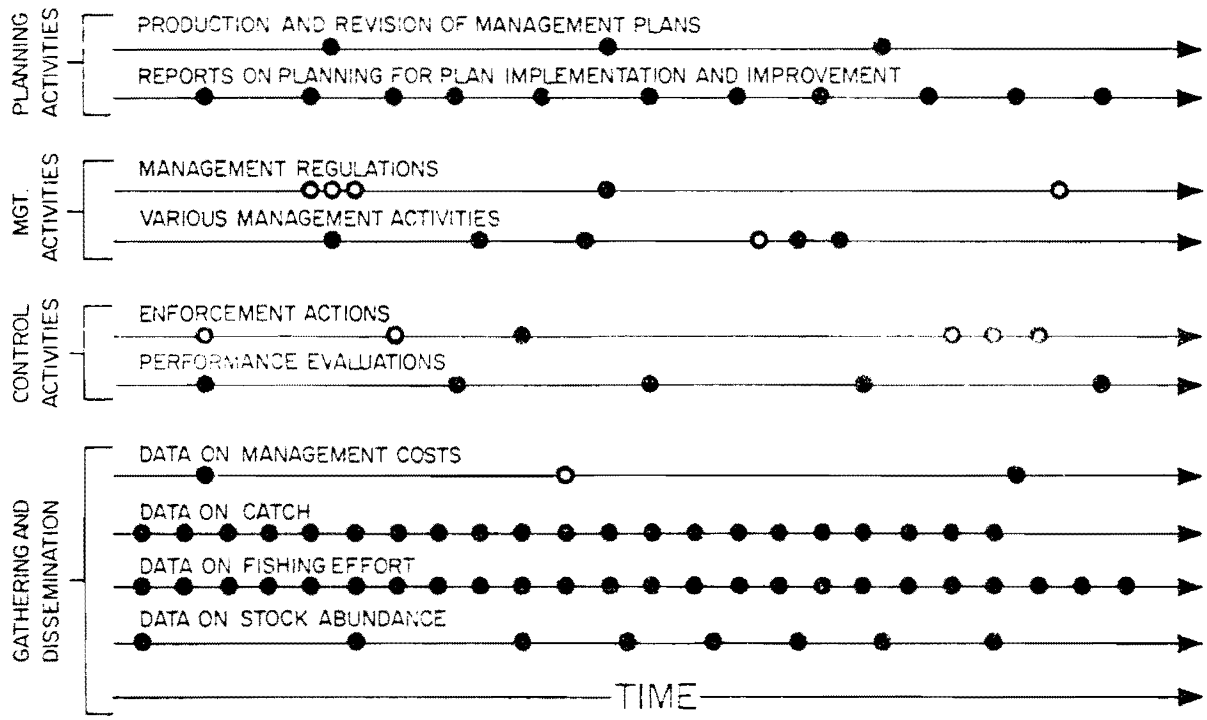

Figure 3. Hypothetical output from management information system (MIS) showing schedule for data synthesis, reports, and various management actions. The solid circles represent regularly scheduled events and the open circles represent events that are timed on the basis of other events. The systematic arrangement permits coordination of all the events and tends to maximize the effectiveness of the decision process.

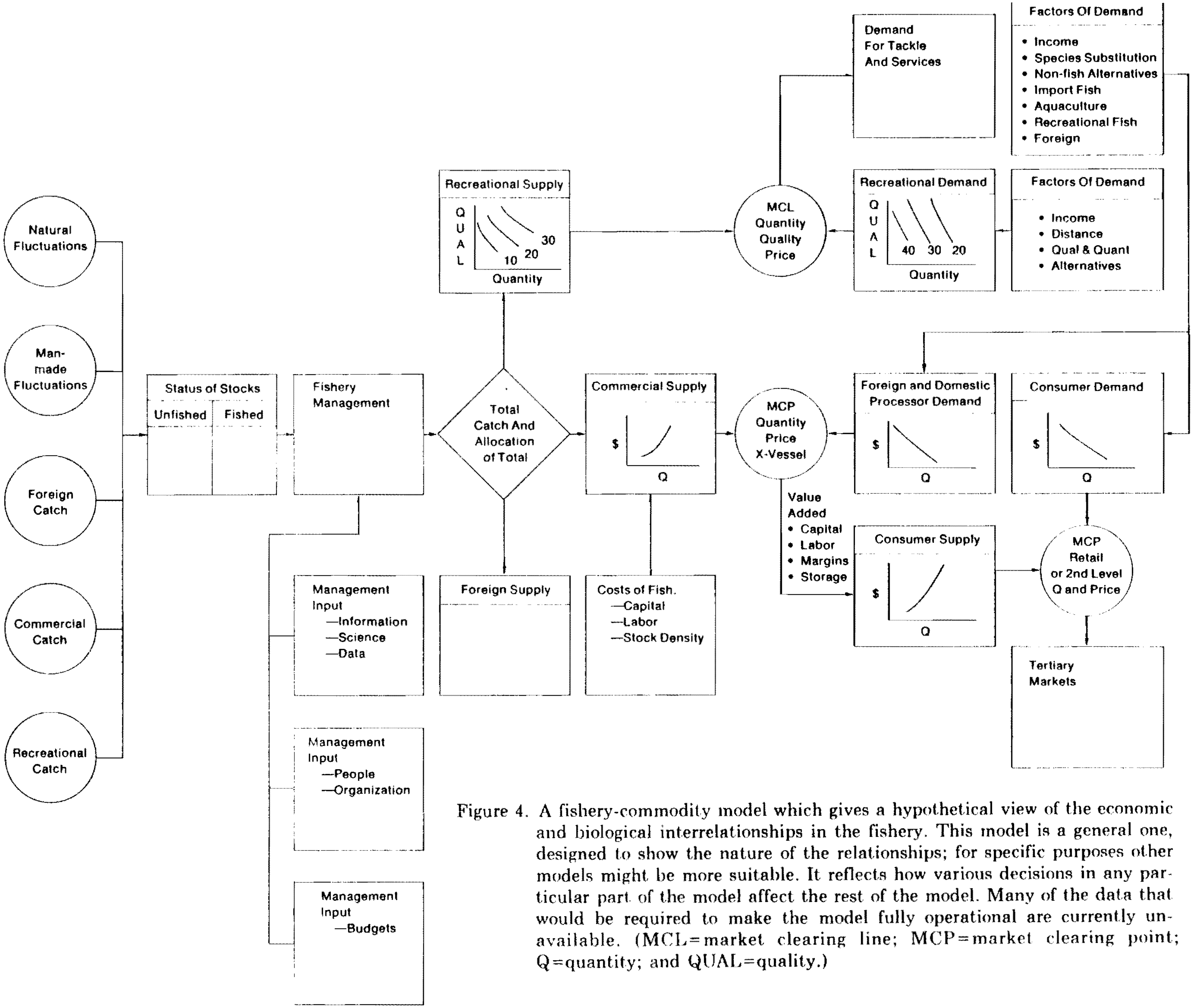

Figure 4. A fishery-commodity model which gives a hypothetical view of the economic and biological interrelationships in the fishery. This model is a general one, designed to show the nature of the relationships; for specific purposes other models might be more suitable. It reflects how various decisions in any particular part of the model affect the rest of the model. Many of the data that would be required to make the model fully operational are currently unavailable. (MCL=market clearing line; MCP=market clearing point; Q=quantity; and QUAL=quality.)

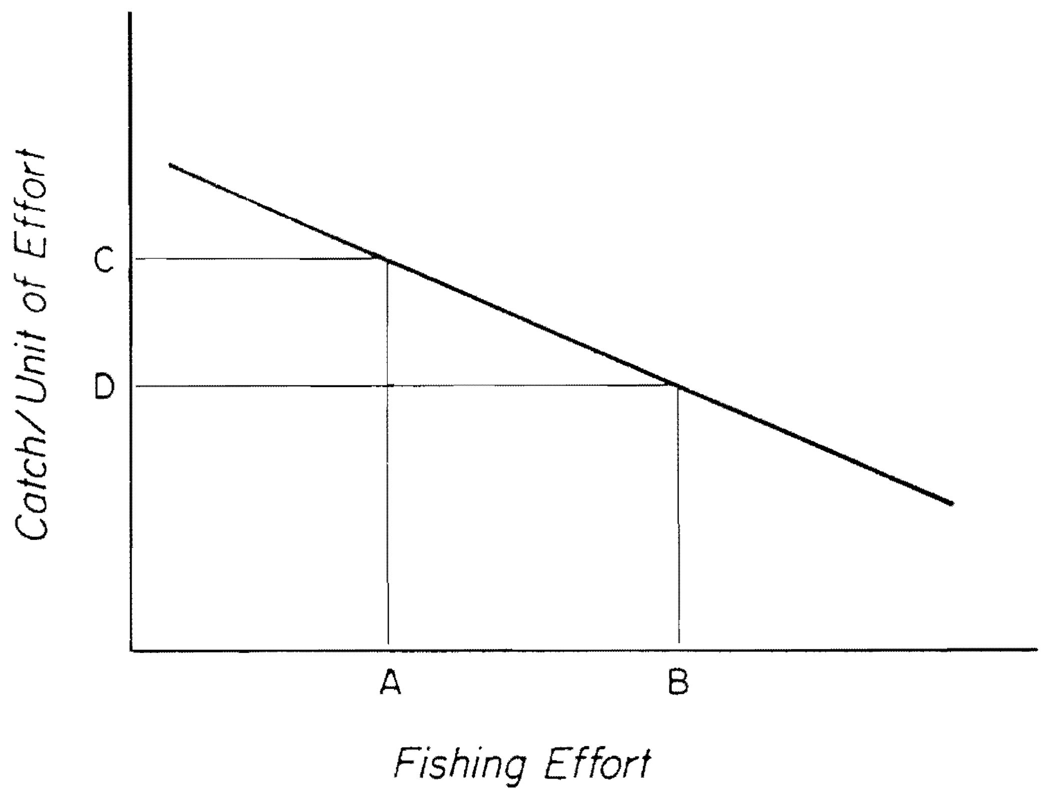

Figure 5. The relation between catch-per-unit-of-effort (CPUE) and effort usually shows a decline in CPUE with increasing fishing effort. If A is the amount of effort expended by the domestic fleet, then the domestic fleet will have a CPUE of C. If, however, in addition, there is foreign fishing the total amount of effort, domestic plus foreign, will be B. With the amount of fishing set at B, the CPUE will drop to D. The difference between C and D reflects the quantity of additional effort or cost of fishing that a domestic fishermen experiences because of foreign fishing.

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