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FISHERIES MANAGEMENT UNDER THE FISHERY CONSERVATION AND MANAGEMENT ACT, THE MARINE MAMMAL PROTECTION ACT, AND THE ENDANGERED SPECIES ACT

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16. Abstract
The purpose of this report is to determine what steps might be taken to ensure that fishery management plans (FMPs) developed under the Fishery Conservation and Management Act (FCMA) are ecologically sound and fully consistent with the FCMA and with the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA). The relevant provisions of the three Acts were examined and four FMPs were reviewed in detail. Persons involved in developing, reviewing and implementing FMPs were interviewed. It appears that FMPs are based primarily on single species rather than ecosystem oriented management concepts, so are not fully consistent with the FCMA, and that FMPs do not effectively incorporate potential impacts on non-target species into determining optimum fishery yields, so are not fully consistent with the FCMA or the ESA. In many cases data are sufficient for developing ecosystem oriented management plans. This report recommends that experts on marine mammals, birds, etc. become involved in FMP drafting, that guidelines for FMP preparation be amended to emphasize impacts on nontarget ecosystem components, that FMPs should incorporate predator-prey and ecosystem modeling techniques into evaluations of risk to nontarget species associated with various harvest levels, and that a workshop be convened to identify requirements and procedures for developing FMPs more consistent with the FCMA, the ESA, and the MMPA.

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The views and ideas expressed in this report are those of the author. They are not necessarily shared by the Marine Mammal Commission or its Committee of Scientific Advisors on Marine Mammals.

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ABSTRACT

The Fishery Conservation and Management Act of 1976 (FCMA) established an exclusive U.S. Fishery Conservation Zone extending two hundred miles seaward from the U.S. coast, created eight regional fishery management councils and charged them with developing fishery management plans according to national standards set forth in the Act, and assigned authority and responsibility for implementing and administering the Act to the Secretary of Commerce. Some of the first fishery management plans, developed pursuant to the Act, did not appear to be fully consistent with the intents and provisions of the Act or other related legislation, such as the Marine Mammal Protection Act (MMPA) and the Endangered Species Act (ESA). Therefore, in September 1978, the Marine Mammal Commission contracted for a study to determine what setps might be taken to better ensure that fishery management plans are ecologically sound and fully consistent with the intents and provisions of the FCMA, the MMPA, and the ESA. This paper reports the results of that study.

To provide the information needed to determine steps that might be taken to better ensure that fishery management plans fully consider and reflect the intents and provisions of the FCMA, the MMPA and the ESA, the relevant provisions of the three Acts were examined, a representative sample of persons involved in developing, reviewing and implementing fishery management plans was interviewed and/or contacted by mail, and four fishery management plans - the Final Northern Anchovy Plan by the Pacific Fishery Management Council, the Draft Bering Sea Groundfish Plan by the North Pacific Fishery Management Council, the Draft Spiny Lobster Plan by the Western Pacific Fishery Management Council, and the Draft Squid Plan by the Mid-Atlantic Fishery Management Council - were reviewed in detail with respect to treatment of nontarget species and selection of optimum yield levels in relation to maximum sustainable yield (MSY) estimates and relevant ecological considerations.

From the information compiled and evaluated, it appears that:

1. fishery management plans are being based primarily upon traditional, single-species, MSY management concepts, rather than upon multi-species, ecosystem-oriented management concepts, and, consequently, are not fully consistent with the intents and provisions of the FCMA;

2. possible impacts on marine mammals and other non-target species, endangered or otherwise, are not being considered fully, or effectively incorporated into selection of optimum fishery yields, so that fishery management plans also are not fully consistent with the intents and provisions of the MMPA or the FCMA; and

3. while some scientists and administrators feel that the goals of the FCMA, the MMPA, and the ESA may be incompatible and/or that available data are insufficient to develop multi-species, ecosystem-oriented fishery management plans, the three Acts do appear to be compatible. For many areas, data are sufficient to develop multi-species, ecosystem oriented management plans, and at least to assess the risk of impacting target species, dependent species, associated species and the ecosystems of which they are a part. The scientific question of assessing risk levels and the policy question of the acceptability of those risk levels tend to be confused and should be considered separately.

To overcome these deficiencies and perceptual problems, the following actions are recommended:

1. Persons with expert knowledge of marine mammals, birds, etc., should be included on the scientific and statistical committees of the regional fishery management councils and should be involved in the preparation of draft fishery management plans;

2. The guidelines for preparation of fishery management plans should be amended to ensure that plans take account of the potential impacts of a fishery on other components of the marine ecosystem, i.e., nontarget fish, marine mammals, birds, etc., in order to be consistent with the intents and provisions of the MMPA and the ESA as well as the FCMA;

3. Fishery management plans should contain conceptual ecosystem models to illustrate the trophic and ecological interactions among target and nontarget species; plans should incorporate techniques for modeling predator prey interactions and whole ecosystems into evaluation of impacts on nontarget species, and should include assessments of risk levels associated with alternative harvesting levels; and

4. A workshop or series of workshops should be convened (a) to identify factors that must be considered in making ecologically sound management decisions in the absence of sufficient data, theory, or models; (b) to determine the most appropriate methods and procedures for evaluating and using available data and theory; and (c) based upon the findings and conclusions relevant to tasks (a) and (b), to develop a fishery management plan for the Bering Sea or some similar area that can be used as a model for other areas and/or fisheries.

I. INTRODUCTION

Fisheries management has traditionally been based upon the concept of maximum sustainable yield (MSY), which is single species in orientation, involving no consideration of the relationships between target species and the ecosystems of which they are a part, or of changes in the physical and biological environment of target species. However, it is now recognized that fishery yields and target species population dynamics may both affect and be affected by other ecosystem components, e.g., through interactions such as predation or competition with other populations in the same ecosystem, which may themselves be the targets of fisheries. An awareness of the importance of ecological interactions involving living resources has motivated and been reflected in environmental legislation such as the Marine Mammal Protection Act (MMPA), the Endangered Species Act (ESA), and the Fishery Conservation and Management Act (FCMA).

The Fishery Conservation and Management Act of 1976 established an exclusive U.S. Fishery Conservation Zone (FCZ) extending two hundred miles seaward from the U.S. coastline, created eight regional fishery management councils and charged them with developing fishery management plans (FMPs) in accordance with national standards set forth in the Act, and assigned authority and responsibility for implementing the Act to the Secretary of Commerce. Several of the first fishery management plans, prepared by the regional fishery management councils pursuant to the terms of the FCMA, did not appear to respond fully to the intents and provisions of the Act or of other relevant legislation, especially the MMPA and the ESA. Therefore, in September 1978, the Marine Mammal Commission contracted for a study to:

1. identify actions taken by the National Marine Fisheries Service (the Federal agency to which the Secretary of Commerce delegated authority and responsibility for implementing the FCMA) and the regional fishery management councils to implement the Fishery Conservation and Management Act;

2. compile and evaluate a representative sample of proposed and final fishery management plans;

3. identify marine mammal species, populations, or habitats that might be affected by U.S. fisheries; and

4. identify actions which could be taken by the regional fishery management councils, the National Marine Fisheries Service (NMFS) and/or the Marine Mammal Commission to better meet the intents of the Marine Mammal Protection Act, the Endangered Species Act, and the Fishery Conservation and Management Act.

This paper reports the results of that study.

This report is organized around three aspects of fishery management in light of the FCMA, the MMPA, and the ESA, namely the nature of conservation and management required by the Acts, whether present fishery management plans and practices satisfy those requirements, and how existing management plans and practices can be modified to meet the intents of the Acts more completely. The intent of this report is to document that the ecological awareness reflected in the three Acts requires an ecosystem level perspective on fisheries management, and that the fishery management plans developed to date do not fully reflect that ecological awareness. Suggestions are made for broadening fisheries management perspectives to include ecological interactions and thus to better meet the intents of the FCMA, MMPA, and ESA.

II. METHODS

Work began on this study in October of 1978. The first major task was a review of the general intents and relevant provisions of the MMPA, FCMA and ESA to identify the general nature of conservation and management they required. The Acts were reviewed with respect to the conservation and management standards contained in each and the requirements for the development of fishery management plans in the FCMA.

In addition to information on the legislative requirements of the FCMA, insight into the day to day aspects of implementing the FCMA was required for this study. Thus, the second major task was acquisition of information on the establishment and activities of the regional fishery management councils, the differences in their operating procedures, and the process for drafting, adopting, reviewing and implementing the fishery management plans required by the FCMA. To get this kind of information, representatives of the fishery management councils, their scientific and statistical committees and the National Marine Fisheries Service were contacted. All of the individuals interviewed during the fall of 1978 for the preparation of the first draft of this report are listed in Appendix A. About half of them were contacted through telephone conversations supplemented with correspondence. Many of the individuals on the west coast, in Alaska and in Washington, D.C. were visited by the contractor in the course of several weeks of traveling, The contacted individuals were selected from council and scientific and statistical committee membership lists, from recommendations from the NMFS Office of Plan Review, and from individuals known to the contractor in other contexts. Contacts were selected to sample the viewpoints of each council, of both scientific and managerial aspects of the plans, and of academic, council and NMFS representatives.

The third major task was a review of fishery management plans. All of the plans which were available to the public as of 1978, either in some draft stage or in final form, were collected and examined for content. Four management plans, the final Northern Anchovy Plan of the Pacific Council, the draft Bering Sea Groundfish Plan of the North Pacific Council, the draft Squid Plan of the Mid-Atlantic Council, and the draft Spiny Lobster Plan of the Western Pacific Council were selected for more detailed review because they represented a range of management problems including marine mammal issues, endangered species issues, available data ranging from preliminary fisheries information to fairly extensive ecosystem wide information, management of one or many species, varying dollar values, and east and west coast conditions. The main criteria used to evaluate these four plans were the procedures for selecting optimum yield (OY) and the relationship of the designated OY to MSY estimates, the treatments of possible impacts on nontarget species, particularly marine mammals and endangered species, and the treatment of ecological interactions both affecting and affected by target species and the incorporation of such information in selection of OY levels.

The last major task was consideration of possible modifications of existing management plans and practices to meet the intents and requirements of the Acts more completely. On the basis of the assessment of the requirements of the three Acts, the information provided by contacts, and reviews of fishery management plans in relation to meeting those requirements, consideration was given to actions which could be taken by the councils, the NMFS and the Marine Mammal Commission to better meet the intents and provisions of the three Acts. Alternative management approaches feasible with presently available data were considered. Some advances required for developing a broader ecosystem oriented theoretical basis for fisheries management were determined. In addition, means of influencing the fishery management plan development process, and consequently plan contents, based on aspects of the day to day operations of the councils were evaluated.

The first draft of the report was submitted in January of 1979 to the Marine Mammal Commission as well as to several of the individuals contacted in the fall of 1978. In August of 1979, following internal review, the Commission submitted the draft report for review to the Executive Directors of the eight councils, to the Director of the U.S. Fish and Wildlife Service (U.S. FWS) and to the Assistant Administrator for Fisheries of the NMFS. Comments received from the councils, the FWS and many different units of the NMFS as of December 1979 were incorporated into a subsequent draft and the final report.

III. RESULTS

In order to place the information collected through this study in proper perspective, the concept of MSY is discussed first. The MSY concept is central to traditional fisheries management, related to the selection of optimum yield as required by the FCMA, and part of each fishery management plan. The characteristics of MSY-oriented management are compared to those of a broader based ecosystem level perspective, and modification of the underlying theory is recommended as a means for initiating an ecosystem approach to fishery conservation and management.

CONCEPT OF MSY

Traditional fisheries management has been based upon the concept of maximum sustainable yield, defined as "the greatest harvest that can be taken from a self-regenerating stock of animals year after year while maintaining constant average size of that stock" (Holt and Talbot, 1978). A different level of sustainable yield is associated with each level of population size for a particular stock, assuming a constant environment. The highest of this set of possible sustainable yields is the maximum sustainable yield, associated with one particular population level. MSY is also the greatest of the set of Equilibrium Yields (EYs), which are harvest levels that allow the stock to remain at the same level of abundance.

The concept of MSY depends on some highly simplified assumptions about the way in which the population under exploitation will behave. These assumptions include that the stock is more or less self-contained and is self-renewing, that the population level of an unexploited stock is at carrying capacity, i.e., at the greatest level which environmental conditions will support continuously, and that there are no significant changes in carrying capacity during the period of exploitation. The concept of MSY also assumes that the rates of reproduction, growth and/or natural mortality of a stock are density dependent, i.e., that the rates vary as the population size or density in a particular area varies. MSY further assumes that the kind of density dependence that these rates exhibit is not such as to cause large amplitude fluctuations in stock size and that the process of reducing the initial stock by exploitation is a reversible one (Holt and Talbot, 1978).

The MSY concept rests on the assumption that environmental conditions are constant, and does not consider the interactions between the target species and other species in the same ecosystem which are related to or dependent on it through predation, competition or other types of interactions. In particular, the assumptions underlying MSY are strained when more than one stock is fished in a given area (Gulland, 1978). The MSY concept does not deal with the time scales of changes in population size and population interactions. Such time scales become particularly important when exploitation at more than one trophic level is taking place (May, et al., 1979).

Even with MSY management as a goal, various fish stocks have been overexploited unintentionally. Such overexploitation has been attributed at times to inadequate data and consequent incorrect estimation of MSY. At other times the economic pressures brought to bear by an overcapitalized fishing industry unwilling or unable to restrict catches to MSY levels, or to reduce catch rates in order to allow stock rebuilding, may have contributed to overexploitation. In any case, single species management with MSY as an objective has frequently failed as a continuous management strategy, and has resulted in overexploitation and reduced rather than high sustained yields.

As understanding of ecological processes increases, it has become apparent that there are significant factors affecting renewable resource population dynamics which are not taken into account in the theory underlying MSY and single species oriented resource management.

GENERAL INTENTS AND RELEVANT PROVISIONS OF LEGISLATION

Fishery Conservation and Management Act

In passing the Fishery Conservation and Management Act (Public Law 94-265, 13 April 1976), the Congress recognized the importance to the nation of the renewable fisheries resources of the U.S. continental shelves. These resources contribute to the U.S. food supply, economy and health, and provide recreational opportunities (FCMA, Sec. 2).

Before the passage of the FCMA, fishery conservation and management practices had not been adequate to deal with increasing fishing pressures. Some fish stocks upon which U.S. fishermen are dependent had been overfished substantially. Heavy and frequently unregulated foreign fishing on the U.S. continental shelves has contributed to overfishing and sometimes interfered with domestic fishing efforts or caused destruction of fishing gear. International fishery agreements were not thought to be effective in preventing overfishing or in providing for recovery of overfished stocks. In addition, because it has taken so long to establish effective international agreements, there has been a danger that irreversible effects from overfishing could take place before such agreements could be implemented. A national program for conservation and management of U.S. fishery resources was considered necessary to prevent overfishing, to rebuild overfished stocks, to ensure conservation and to realize the full potential of those resources (H.R. Report No. 94-948 (1976)).

The purposes of the FCMA were to take immediate action to conserve and manage fishery resources of the U.S. continental shelves, to encourage international fishery agreements for the conservation of highly migratory species, to provide sound conservation and management principles for domestic, commercial and recreational fishing, and to encourage the development of fisheries which are underutilized or not utilized by U.S. fishermen (FCMA, Sec. 2)

The Act established a fishery conservation zone (FCZ) contiguous with the U.S. territorial sea and extending 200 nautical miles offshore from the coast (the same baseline from which the territorial sea is measured) of the U.S. and its territories (see Figure 1). The U.S. exercises exclusive fishery management authority over all fish resources in the FCZ except highly migratory species, such as tuna. Under the Act, the U.S. will regulate the activities of both foreign and domestic fishing vessels in the U.S. FCZ. Management authority extends beyond the FCZ for anadromous species spawning in U.S. waters, for continental shelf resources, and for fishing activities of U.S. citizens.

Conservation and management measures are defined in the Act to include measures designed to avoid irreversible or long term effects on the marine environment and measures used or useful in rebuilding, restoring or maintaining any fishery resource and the marine environment. The definition of fishery resource includes the habitat of any fish stock as well as the stock itself. The conservation program should respond to the needs and interests of affected citizens, promote efficiency and draw on federal, state and academic capabilities in carrying out research.

The FCMA provides for the development, implementation, administration and enforcement of fishery management plans and regulations in accordance with national standards for fishery conservation and management. These national standards are:

1. Conservation and management measures shall prevent overfishing, while achieving optimum yield from each fishery on a continuing basis;
2. Conservation and management measures shall be based on the best available scientific information;
3. Individual stocks of fish shall be managed as a unit throughout their range, as far as possible, and interrelated stocks shall be managed as a unit or in close coordination;
4. Conservation and management measures shall not discriminate between residents of different states;
5. Measures shall promote efficiency in using fishery resources;
6. Measures shall allow for variations among and contingencies in fisheries, fishery resources and catches; and
7. Measures, where practical, shall minimize costs and avoid unnecessary duplication.

These national standards are designed to ensure that a conservation and management program takes into account the best available scientific information, resource variability, industry efficiency, consumer needs, and the best interests

Figure 1. U.S. Fishery Conservation Zone, 1 March 1977 (after map from Office of the Geographer, U.S. Department of State). Indicated FCZ is that claimed by the U.S.; some boundaries are disputed by other nations.

of present and future generations. The first standard requires that conservation and management measures be designed to prevent overfishing while achieving the optimum yield (OY) from each fishery on a continuing basis. "Optimum" with respect to fishery yield is defined in the Act as:

> "the amount of fish from a fishery which, if produced, will provide the greatest overall benefit to the nation (especially in terms of food production and recreational opportunities) and which is prescribed for that fishery on the basis of maximum sustainable yield as modified by any relevant economic, social or ecological factor."

Fishery management plans. In order to carry out a national policy for management and conservation of fishery resources in the U.S. FCZ, the Act requires that fishery management plans (FMPs) be developed in accordance with the national standards and any other applicable law. Each plan covers one or more stocks, establishes management and conservation objectives for those stocks, and provides for appropriate regulations to fulfill those objectives.

As specified in the FCMA, FMPs must contain conservation and management measures for both foreign and domestic fishing, and a complete description of the fishery including its history, commercial and recreational interests, stock distribution, gear, economics, and Indian treaty fishing rights. MSY for the fishery must be calculated and documented with the data and formulas used. Acceptable Biological Catch (ABC), which is a seasonally determined catch that may differ from MSY for biological reasons, e.g., fluctuating recruitment or rebuilding of overfished stocks, is then identified. ABC may be greater or less than MSY. Optimum Yield (OY), a further modification of MSY and ABC on the basis of social, economic or other relevant ecological considerations, must then be identified. (Definitions of MSY, ABC, OY and other terms and acronyms used in this report are given in the text and included in glossaries found in Appendices I and J.)

The portion of OY that U.S. fisheries are capable of harvesting must be estimated. If OY exceeds U.S. harvesting capacity, then the difference is the total allowable level of foreign fishing (TALFF). The Departments of State and Commerce allocate TALFF among nations.

FMPs may also provide for permits and fees for domestic vessels, zones or times of limited, prohibited or special types of fishing, catch limitations, gear regulations, incorporation of coastal state conservation and management measures, limited access or other appropriate provisions.

The NMFS has issued Guidelines for Development of Fishery Management Plans (42 FR 34458, July 5, 1977) which include interpretation of the national standards in the FCMA, requirements for plan contents and format, and procedures for the development, review, and amendment of plans.

Regional fishery management councils. Anticipating that the development of fishery management plans would require a large amount of work, the FCMA provided for new agencies, the regional fishery management councils, and charged them, among other things, with the responsibility for developing fishery management plans. Eight councils were established with responsibility for the U.S. FCZ, outside of state waters, divided among them. The designated regions are New England, Mid-Atlantic, South Atlantic, Gulf of Mexico, Caribbean, Pacific, North Pacific, and Western Pacific. The states and territories which each council represents are listed in Appendix B.

The membership structure of the councils is described in detail in Appendix B. For each council there are three types of voting members: those appointed by the Secretary of Commerce for three year terms, those designated by the governors of the respective states to serve as state marine fishery representatives, and the appropriate regional director of NMFS. The councils also have non-voting members who are representatives designated by the U.S. FWS, the Coast Guard, the Marine Fisheries Commission, and the State Department. Council members must be knowledgeable about management, conservation and harvesting of fishery resources. Council decisions are taken by a majority of voting members present and voting.

The Act provides for each council to establish its own scientific and statistical committee (SSC) to provide relevant scientific information and advice. Each council may also establish advisory panels as it deems necessary to provide information from sources outside of the government on issues related to consumer, industrial and environmental interests.

The fishery management councils have various responsibilities, including commenting on foreign fishing applications, conducting public hearings on the development of fishery management plans and providing various reports to the Secretary of Commerce. The most important responsibility of the councils is the preparation of fishery management plans. Councils have the final responsibility for determining management objectives, for selecting optimum yield levels and evaluating the relevant ecological, social and economic factors which those OYs incorporate, for compiling and evaluating information required for the determination of OY, and for identifying data gaps and recommending appropriate research if OY cannot be determined.

Role of NMFS and the Secretary of Commerce. Under the FCMA the Secretary of Commerce is responsible for reviewing all fishery management plans with respect to the national standards established in the Act as well as other provisions of the Act and any other applicable laws. The Secretary also has the discretion to preempt state jurisdiction over waters from 0 to 3 nautical miles from the coast in cases where a state has taken, or omitted to take, action thereby substantially and adversely affecting a fishery management plan. Otherwise, the FCMA does not extend or diminish the jurisdiction of the states which have traditionally managed fisheries in territorial waters.

The FCMA assigns various other responsibilities to the Secretary of Commerce, which have been delegated to the NMFS. Among these responsibilities is collection of information including statistics on fishery conservation and management, biological research on the interdependence of fisheries or stocks, the impacts of pollution, the impact of wetland and estuarine degradation, and matters bearing on the abundance and availability of fish. Collection of such information requires a comprehensive research program initiated and maintained by the NMFS.

Other responsibilities assigned to the Secretary of Commerce and delegated to NOAA and NMFS include the development of preliminary fishery management plans regulating only foreign fishing activities in the U.S. FCZ, providing coordination with other federal agencies, furnishing relevant information to councils, reviewing management plans and amendments (plans must have NMFS approval before they can be implemented), designating which council has the lead in developing an FMP in cases where a fish stock extends into more than one council region, and promulgating regulations to implement FMPs and cooperating with the Coast Guard for their enforcement.

The Washington, D.C. office of NMFS concerned with activities under the FCMA is the Office of Resource Conservation and Management, which includes a Plan Review Division and plan coordinators. The Plan Review Division, Office of General Council, Regulations Division, and other appropriate sections of the NMFS review draft management plans and associated draft regulations. The NMFS assists councils in complying with provisions of the National Environmental Policy Act (NEPA) and implementing Council on Environmental Quality (CEQ) regulations. The NMFS Office of Science and Environment has oversight responsibility for the EIS process.

Marine Mammal Protection Act

Prior to the passage of the MMPA in 1972, marine mammal protection and conservation were the responsibilities of coastal states, such as Alaska, Washington, Oregon, California, etc., and/or international authorities, such as the International Whaling Commission (IWC), the North Pacific Fur Seal Commission, and the International Commission on North Atlantic Fisheries (ICNAF). Management by some of these authorities, particularly the international ones, was not very effective. In the late 1960s this led to expressions of concern, by the American public and the Congress, that certain species and populations of marine mammals were in danger of extinction or depletion as a result of human activities. The regulation of commercial whaling by the IWC, the incidental take of porpoise by the U.S. tuna purse seine fleet, and the clubbing of "baby" harp seals in the North Atlantic were of particular concern (see, e.g., H. R. Report No. 92-707 (1972), H. R. Report 92-1488 (1972), and S. Rep. No. 92-863 (1972)).

The Marine Mammal Protection Act (P. L. 92-522, 21 October 1972) established a moratorium on the taking of marine mammals in U.S. waters and/or the importation of marine mammals and marine mammal products into the U.S. The Act provides a special exemption for the taking of marine mammals by certain natives for subsistence, handicrafts, and clothing. "Take" is defined in the Act as harassing, hunting, capturing, or killing, or attempting to harass, hunt, capture or kill any marine mammals.

The Act provides for waiver of the moratorium and return of management to the states. It also provides for issuing permits to take marine mammals for purposes of public display, scientific research, and incidentally during fishing operations. Under the Act, the Secretary of Commerce is responsible for cetaceans and pinnipeds other than walrus, while the Secretary of Interior is responsible for all other marine mammals (i.e., walrus, manatees, dugongs, sea otters, and polar bears). The Secretaries of Commerce and Interior have delegated responsibilities to the NMFS and the U.S. FWS, respectively.

The Act created the Marine Mammal Commission and charged it with overviewing all U.S. activities bearing upon the conservation and protection of marine mammals. The Commission consists of three individuals, knowledgeable in the fields of marine ecology and resource management, and is appointed by the President. The Commission has an Executive Director and staff, and a nine member Committee of Scientific Advisors on Marine Mammals.

The primary objective of the MMPA is to maintain the health and stability of the marine ecosystem and, whenever consistent with this primary objective, to obtain and maintain optimum sustainable populations of marine mammals. The Act defines "optimum sustainable population" (OSP) as:

> "the number of animals which will result in the maximum productivity of the population or the species, keeping in mind the optimum carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element."

"Optimum carrying capacity" is defined in the Act as:

> "the ability of a given habitat to support the optimum sustainable population of a species or population stock in a healthy state without diminishing the ability of the habitat to continue that function."

The statutory definition of OSP has been interpreted in regulations of the NMFS which define it for application in the management context as follows:

> "Optimum sustainable population is a population size which falls within a range from the population level of a given species or stock which is the largest supportable within the ecosystem to the population

level that results in maximum net productivity. Maximum net productivity is the greatest net annual increment in population numbers or biomass resulting from additions to the population due to reproduction and/or growth less losses due to natural mortality." (50 CFR 216.3)

This operational definition of OSP has been used in the course of decisions concerning the status of porpoise stocks impacted by the yellowfin tuna purse seine fishery (Smith, 1979), and the waiver of the moratorium on taking marine mammals in Alaska (44 FR 2540-54, 11 January, 1979).

In 1976, the MMPA was amended by Section 404 of the FCMA to include within the term "waters under the jurisdiction of the United States" the waters of the U.S. FCZ established by the FCMA.

Endangered Species Act

Prior to passage of the Endangered Species Act (P.L. 93-205, 28 December 1973) the U.S. had become a party to several international agreements concerning various species of fish, wildlife or plants which were verging on extinction, including the Convention on International Trade in Endangered Species of Wild Fauna and Flora. The ESA provided national recognition that species of fish, wildlife and plants which have aesthetic, ecological, educational, historical, recreational and scientific value have become extinct or presently face extinction as a consequence of economic growth and development without adequate concern for and conservation of such species.

The ESA recognized that endangered and threatened species depend for their existence upon the ecosystems of which they are a part. One of the purposes of the ESA was to provide a means for conserving such ecosystems. Other purposes included provision for a program for the conservation of endangered and threatened species, and the taking of appropriate action to achieve the purposes of treaties and conventions concerning endangered species to which the U.S. is a party. It was congressional policy that all federal departments and agencies use their authority in furthering the purposes of the ESA and conservation of endangered and threatened species.

The term "conservation" is defined in the Act to mean:

> "to use, and the use of, all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this act are no longer necessary. Such methods and procedures include, but are not limited to, all activities associated with scientific resource management, such as research, census, law enforcement, habitat acquisition and maintenance, propagation, live trapping and transportation and, in the extraordinary case where population pressures within a given ecosystem cannot be otherwise relieved, may include regulated taking."

The term "endangered species" is defined in the Act as:

> "any species which is in danger of extinction through all or a significant portion of its range, other than a species of the Class Insecta, determined by the Secretary to constitute a pest whose protection under the provisions of this Act would present an overwhelming and overriding risk to man."

The term "threatened species" means "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range". The definitions apply to the animal and plant kingdoms.

The Act requires the Secretary of the Interior to develop a list of endangered and threatened species and to publish that list in the Federal Register. After consultation as appropriate with the relevant states, the Secretary may designate certain "critical habitats" for particular threatened or endangered species.

The Act prohibits the taking, importing, possessing, delivering, carrying or selling of threatened and endangered species, including live animals, dead bodies or parts of bodies.

Section 7 of the ESA requires all federal agencies to consult with the Department of Commerce (NMFS) or the Department of the Interior (FWS) to insure that any actions taken do not jeopardize threatened or endangered species or result in the destruction or modification of any critical habitat. The Act as recently amended also requires that recovery plans be developed for all endangered or threatened species.

IMPLEMENTATION OF THE FCMA

Councils. In order to put the FCMA into practice, regional fishery management councils have been established as required in the legislation.

Fishery management councils are "quasi-federal" agencies. They operate under a cooperative agreement for administrative and contract work from the Department of Commerce. Most councils have a staff of seven to nine individuals, including experts in biology and economics. Councils meet approximately monthly.

The regional councils are responsible separately or jointly for the development of FMPs for various fishery stocks. The choice of management objectives for an FMP is a critical one. Councils may hold public hearings on management objectives for particular FMPs.

Committees: Each council has established its own scientific and statistical committee (SSC) and advisory panels. Membership lists for the councils and SSCs as of late 1979 are in Appendix C. Most SSCs have 10 to 20 members who are academic, federal or state employees, or private individuals, including economists, statisticians and biologists. The SSCs function to ensure the scientific validity of management plans, advise on the attainability of objectives, make sure that expectations of the data are realistic, review objectives and test assumptions. Individual SSC members may work in plan drafting groups, but the SSC as a whole does not do any drafting. SSC members are aware of research in progress and available data. They identify data gaps and suggest data requirements. The SSCs may recommend members of plan development teams, review proposals and contract submissions, and provide technical review or data analysis for calculations of MSY, ABC, EY and OY.

The councils also have established stock specific advisory panels of locally knowledgeable individuals representing various interest groups, including commercial and recreational fishermen, consumers and environmentalists.

Differences Among Councils: Although councils share common structure and objectives, their day to day workings differ.

The North Pacific Council supports about $0.5 million of research annually, a large amount in comparison to other councils. Council sponsored research is largely aimed at data gaps in the FMPs and supports short term projects which are not funded elsewhere. Alaska has 33,000 miles of coastline and a very large FCZ. Half of the dollar value of fisheries covered by implemented or drafted FMPs as of November 1978 came from North Pacific FCZ fisheries (see Table 1). The North Pacific Council works closely with Alaska's Board of Fisheries and Board of Game which have final authority over state regulations. For the crab and troll salmon management plans there has been cooperation to coordinate regulations from 0 to 3 miles and 3 to 200 miles. The North Pacific Council usually has draft management plans developed by contract.

The Pacific Council usually uses plan development teams rather than contracts for drafting management plans. There appears to be excellent cooperation among the state and federal agencies involved in fisheries management on the west coast. The SSCs of the Pacific and North Pacific Councils are considered by several NMFS personnel who have worked with them to be exemplary, because of the quality and diversity of expertise represented on those SSCs and the extent of SSC-Council interactions. Those SSCs are used extensively by the respective Councils so that work on the SSC is quite demanding.

The Western Pacific Council deals with the FCZ around Hawaii, Guam, American Samoa, the northern Marianas and several scattered uninhabited possessions. The total land area is 7,450 sq. mi. The total surrounding FCZ area is over 3 million sq. mi.

On the east coast, councils deal with a larger number of states apiece and with state fish and game agencies which in some cases are not as active as those on the west coast. Consequently, operations differ.

The Atlantic Groundfish Plan prepared by the New England Council, implemented on an emergency basis in March 1977, was the first FMP to be implemented under the FCMA. The draft plan was prepared by council staff and NMFS staff. A new long term management document for that fishery is being developed by the council staff, with data collection and

Table 1. Summary of OY and estimated $ values for fisheries covered by implemented and drafted management plans as of November 1978. (Supporting calculations in Appendix D.)

Council	Total OY (mt)	Total $ Value
North Pacific - Gulf of Alaska	392,000	59,731,000
North Pacific - Bering Sea/ Aleutian Islands	1,649,240	356,847,000
Pacific	650,200	100,500,000
Western Pacific	2,351	1,551,800
New England	202,900	62,245,000
New England and mid-Atlantic	385,200	70,002,500
New England, mid-Atlantic, South Atlantic, Gulf of Mexico, and Caribbean	15,484	7,568,000
Total	3,297,375	658,458,800

analysis done by contract. For other plans, the New England council anticipates descriptive biological and socio-economic information, and staff preparation of additional analysis and alternative management strategies.

Draft plan development: The councils identify the need for plans and define the fishery stock. They may act on their own initiative or in response to requests for development of a plan. Councils adopt the management objectives for a plan by majority vote. Once objectives are established, the actual drafting of an FMP may be done by council staff, by a plan development team, or wholly or partially by contract. A council may contract for data collection if necessary. A lead agency may be designated to coordinate plan development. State and federal officials are usually involved to some extent in plan drafting. There is always liaison with council staff as well as input from SSCs and advisory panels during the drafting process. There may be public hearings on various aspects of the draft. A majority vote is required for adoption of a draft FMP by a Council. Plan adoption usually follows identification of the need for the plan by a year or more.

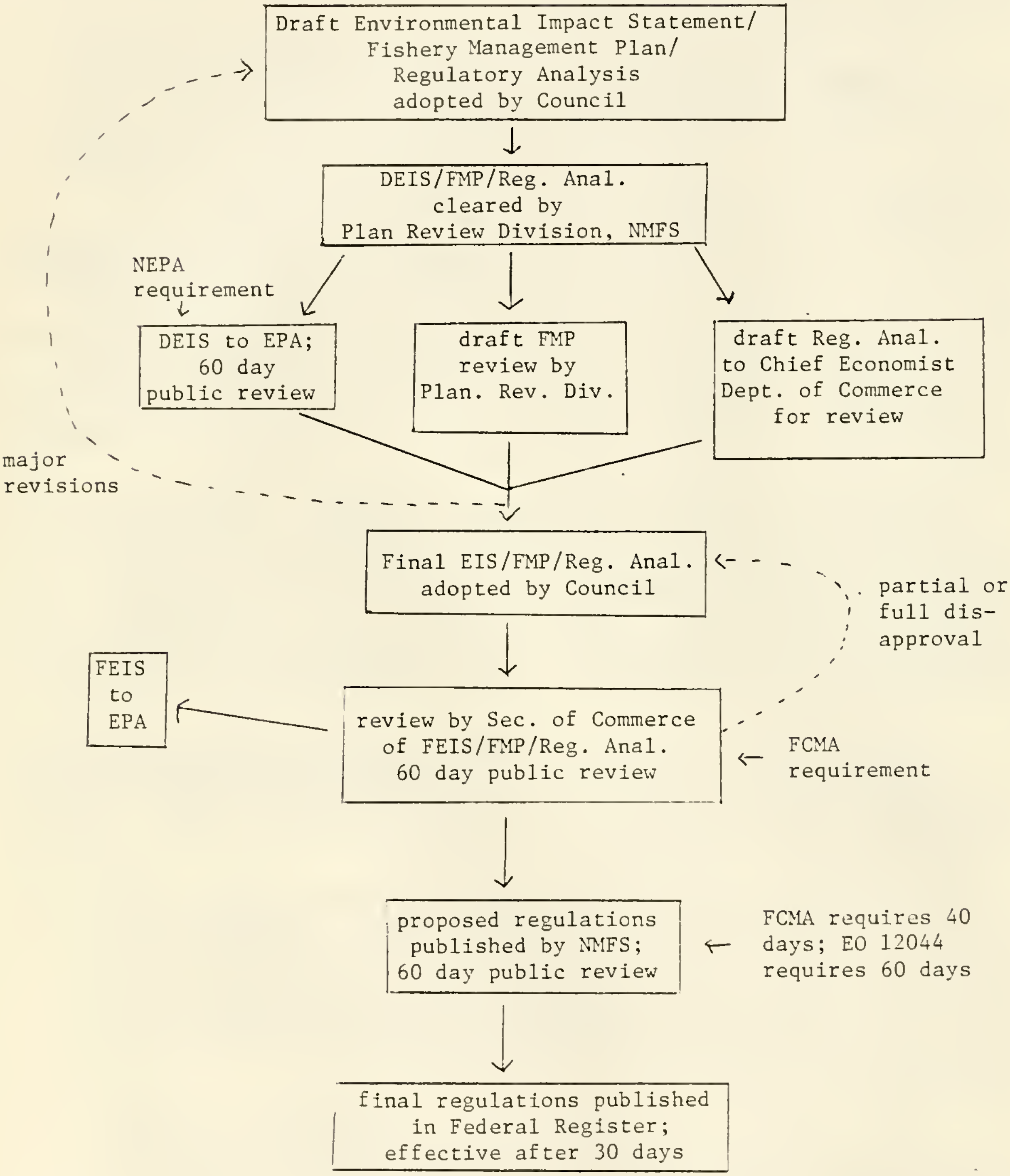
Plan approval and implementation process. After adoption by the council, a draft plan must undergo review requirements established by the FCMA, requirements for an environmental impact statement (EIS) under the NEPA and subsequent CEQ regulations, and requirements for a regulatory analysis concerning its impact on the economy as required under Executive Order 12044 of 1979. The approval process under ideal conditions is diagrammed in Figure 2.

A draft FMP must be accompanied by a draft EIS as well as a draft regulatory analysis. The draft EIS and draft regulatory analysis are usually prepared by the council, but may be prepared by the Plan Review Division of NMFS which oversees the implementation process.

In response to comments from the various reviews, revisions may be required in the draft plan. Allowing for time required to revise and transmit the draft plan to the various agencies, a plan without major revisions may take nine months from adoption of the draft by the Council to effective implementing regulations. With major revisions, the approval and implementation process could take up to two years, or more.

After regulations are in force, a mangement plan may still undergo annual updating or major revisions as new information becomes available, with regulations revised accordingly.

Figure 2. Ideal fishery management plan approval and implementation process as of December 1979.



Existing plans: As of late 1979, plans for Atlantic groundfish, Atlantic herring, Atlantic mackerel, squid, butterfish, surf clam and ocean quahog, Gulf of Mexico stone crab, Pacific commercial and sport salmon, northern anchovy, Alaska coast tanner crab, Gulf of Alaska groundfish, and high seas salmon have been implemented. Many other plans are in the drafting stage or close to completion, and are listed in Appendix E.

REPRESENTATIVE FISHERY MANAGEMENT PLANS

The four fishery management plans chosen for detailed review in this report were selected to represent a range of the problems faced in fisheries management under the FCMA, MMPA and ESA. The draft Bering Sea Groundfish Plan of the North Pacific Council involves many species in an area from which considerable fisheries data as well as information on other components of the ecosystem, such as marine mammals, are available. This plan involves fisheries of a very large magnitude in terms of both tons and dollars. The final Northern Anchovy Plan of the Pacific Council deals with only one species, but again in an area where there is considerable information available on the ecosystem, in this case, the California Current. This plan includes specific consideration of an endangered species. The draft Squid Plan of the Mid-Atlantic Council deals with only a few species, all squid, in a situation in which data are considerably more sparse. Because of potential interactions between squid and pilot whales, this plan also involves a marine mammal species. The fourth plan chosen for review, the draft Spiny Lobster Plan of the Western Pacific Council, has a very clear relationship to an endangered marine mammal, the Hawaiian monk seal. The plan concerns a fishery with little available data, and with a presently small dollar value, but with considerable potential for growth. These plans illustrate the spectrum of ways in which the objectives of the FCMA have been incorporated into the development and implementation of fishery management plans. More detailed information on and evaluation of each of these four fishery management plans is found in Appendix F of this report.

Northern Anchovy Final Plan, 1978

The Pacific Council's Northern Anchovy Management Plan includes as an objective the maintenance of a population sufficient to sustain adequate levels of predator fish, birds and mammals. While no definition is attempted for "adequate" predator levels, benefit to the nation from leaving anchovies in the water is recognized.

The California Current ecosystem, in which the northern anchovy plays a major role at the forage fish level, is characterized by large and visible populations of marine mammals and birds. The endangered brown pelican, which may require high anchovy density for successful breeding, is noted in the plan. While no specific action was taken, the plan recommended monitoring brown pelican populations; funds for monitoring are not guaranteed.

Predator prey relationships involving anchovies, other fish, mammals and birds received a very broad brush treatment, particularly in comparison with the detailed social and economic descriptive sections. The analysis of predator needs and interactions was confined to the observation that during 1951-61 when spawning biomass was below 2 million tons (as opposed to the present 3 - 4 million tons) predators did not appear to decline. For marine mammals, population data are not available to support or refute this assumption.

MSY for northern anchovies was estimated in the plan to be 484,000 tons at an average spawning biomass of 1.8 million tons. MSY was determined not to be a practical management goal for this fishery because variations in recruitment to the anchovy population are very large, and cause large annual variations in population size and consequently in sustainable yield. The plan concluded that to achieve MSY would require a fishery with no catch two years out of three, and extremely large catches in other years. Such variability would be disruptive to the fishing industry. Consequently, the OY formula designated in the plan was intended to allow for high sustainable yields, but with less variability in allowable catch from year to year than would be provided under MSY. The OY formula in the plan is as follows:

1. When the estimated spawning biomass is less than 100,000 tons, OY is 0;

2. When the estimated spawning biomass is between 100,000 and 1 million tons, OY is 18,000 tons for the non-reduction fishery catch (the reduction catch, distinct from commercial live bait and recreational catch, is processed for fish meal and oil); and

3. When the estimated spawning biomass is 1 million tons or greater, OY for the combined reduction and non-reduction fishery is 18,000 tons or 1/3 of the biomass in excess of 1 million tons, whichever is greater.

Under this formula, OY at a biomass of 1.8 million tons spawning biomass would be 267,000 tons, considerably less than the MSY figure of 484,000 tons of the same biomass. In contrast, OY for a spawning biomass of 3.6 million tons, the estimated population for 1976, would be 870,000 tons, much greater than the 1976 harvest of about 200,000 tons.

The OY formula is expected to reduce the impact of exploitation when anchovy biomass is low, and to protect the long-term productivity of the resource. The plan concludes that a long-term average anchovy biomass in excess of 2 milion tons should not have a severe adverse impact on predators. Under the OY formula determined in the plan, spawning biomass is anticipated to fluctuate around an average of 2.5 million tons.

Bering Sea Groundfish Draft Plan, 1978

The North Pacific Council's Draft Bering Sea Groundfish Plan covers many species, including Alaska pollock, yellowfin sole, turbot, other flatfish, Pacific cod, rockfish including Pacific ocean perch, sable fish, Atka mackerel, squid and others. The plan, in fact, covers all groundfish except herring and Pacific halibut. The plan includes as an objective designing fishing strategy to minimize effects on other fisheries and on the environment.

The Bering Sea has some very productive waters and consequently high densities of fish, marine mammals and birds. Fish fauna are dominated by pollock. A computer simulation model, DYNUMES III (Dynamic Numerical Marine Ecosystem Model) has been developed for the fish of this region (Laevastu and Favorite, 1978). The DYNUMES model considers growth, recruitment or production, and mortality of individual fish species or groups of species. The model also considers predation on groundfish by marine mammals, birds, and other fish. In the plan, fish consumption by predators is estimated to be 5.8 million metric tons on the basis of the DYNUMES model. However, no estimates were made of changes in the availability of food to predators which might be associated with various proposed fishing levels in the plan, even though the DYNUMES model uses information on which such estimates could have been based.

MSY levels were estimated separately for species such as pollock, yellowfin sole, cod, sable fish, Atka mackerel and Pacific halibut, and for groups such as turbot, other flatfish, rockfish and squid. Equilibrium yields (EYs) were also calculated and were similar to MSY except for rockfish, Pacific halibut, and sable fish in the Bering Sea, which are all depleted stocks. The sum of estimated MSY for all species combined was 1.7-2.3 million metric tons. The combined EYs were 1.414-1.451 million metric tons.

OY levels were set at conservative estimates of MSY for most species, and at EY levels for the depleted stocks. The combined OYs in the draft plan were 1.444 million metric tons. Of that total, pollock alone account for 1 million metric tons.

Bering Sea groundfish comprise an enormous fishery, representing about 2% of the entire world marine catch, and a third of the fisheries covered by existing final or draft management plans for the U.S. FCZ as of the end of 1978. OY in the plan was at the same level as recent unregulated fish catches in the region. Very little of the recent catch, about 400 metric tons, has been taken by domestic fisheries, and domestic use of the resource is expected to remain at this low level.

Squid Draft Plan, 1978

One objective of the Mid-Atlantic Council Draft Squid Plan was maintenance of an adequate food supply for predators. The plan recognized that several years of intensive fishing on squid could affect food for pilot whales. However, no calculations were included on the predator prey relationships of squid or of the possible impacts of proposed fishing levels on food availability for predators.

MSY estimates in the plan were 44,000 tons for longfinned squid (*Loligo*) and 40,000 tons for shortfinned squid (*Illex*). The council considered these estimates of MSY to be conservative.

For longfinned squid, the OY selected was the MSY estimate. For shortfinned squid, the OY was set at 75% of the MSY estimate, since the MSY estimate was considered unreliable because of incomplete data.

Squid are both predators and prey in the marine ecosystem. Some 54 species of fish have been identified as predators of adult squid. The pilot whale (*Globicephala melanea*) also feeds almost exclusively on shortfinned squid. The plan indicated that while overexploitation of squid might result in the decrease of other marine species which compete with fisheries to use squid as food, on the other hand substantial increases in squid might threaten species that are preyed upon during their early life stages by squid.

Spiny Lobster Draft Plan, 1978

The Western Pacific Council's draft Spiny Lobster Plan involved a potential impact on the endangered Hawaiian monk seal (*Monacus schauinslandi*) which feeds on lobsters, among other species. The relative importance of lobsters in the monk seal diet is not known. One objective of the plan was to minimize the environmental and ecological impacts of the lobster fishery, particularly on the monk seal.

As required by the FCMA, MSY for lobsters was estimated in the plan at 552,000 to 690,000 lobsters. However, this estimate was based more on extrapolation from other lobster fishing regions than on the sparse data from Hawaii, and was not considered to be a reliable estimate.

OY was not established for the fishery. Instead, management measures were designated which consisted of regulations on the sex and size of the catch, and on areas for fishing. Prohibitions on landing females with eggs and on most fishing in waters shallower than 10 fathoms were intended to protect the lobster spawning stock and to minimize direct interaction between fishermen and seals. At the same time, these measures would allow a substantial, perhaps tenfold, increase in the lobster catch, which was about 60,000 lobsters a year before 1968. The stock is relatively unexploited so that the possibility of a very rapid increase in the fishery exists. It is not known whether prohibiting fishing in waters shallower than 10 fathoms will avoid impacting monk seals.

Characteristics Shared by the Four Plans

The four plans included varying amounts of information on the ecological role of target species. While the presence of natural predators on target species was mentioned in each of the plans, there were no calculations or attempts at even rough quantitative estimates of the potential impact of various levels of proposed fishing on the food available to predators, or on other aspects of the population dynamics of nontarget species. There also was no consideration of the effect of nontarget species on the population dynamics of the target species, other than an estimated predation rate, assumed to be constant, which was part of the MSY calculations.

The treatment of marine mammals as nontarget species in the plans was limited to the question of incidental take and the minimization of entrapment of marine mammals in fishing gear. There are both direct (ecological interactions) impacts of marine mammals on fisheries and of fisheries on marine mammals. Only the direct impacts were considered in the plans. The impacts of marine mammals eating fish which had already been trapped with some kind of fishing gear were mentioned, but the impacts of a fishery on marine mammal population size and on food availability for marine mammals, as well as the impacts of large marine mammal populations as additional pressures on fishery populations undergoing increasing harvesting, were not considered.

IV. DISCUSSION AND CONCLUSIONS

CRITIQUE OF SINGLE SPECIES MANAGEMENT

The conceptual and practical problems with single species, MSY-oriented fishery resource management are considered in this section of the report. Appendix G contains more detailed discussion of the theory underlying MSY calculations, data requirements, and the limitations inherent in the assumptions of the MSY concept.

Fisheries management has traditionally been concerned with a single species, its population dynamics, and its maximum sustainable yield. MSY has been treated as an inherent property of the population dynamics of a particular target stock. The development of methods for calculating MSY has focused on the target stock itself, the pattern of growth over time of its individuals, the birth rate and the rate of survival to an age or size subject to being fished, and the rate of fishing mortality and its relationship to fishing effort.

The physical and biological environment of a target stock have not been treated with a corresponding degree of detail. Instead, environmental conditions have been assumed to remain constant and the carrying capacity of the surrounding ecosystem for the target stock has been assumed to remain unchanged throughout the duration of fishing on that stock.

The constant environment assumption appears to be contradicted by fluctuations observed in unexploited fish populations indicating that there are environmental factors which can change the carrying capacity of an ecosystem for a particular species. Such changes may even occur over relatively short periods of time, particularly if they are due to factors such as increasing pollution levels. The synergistic effects on a resource population of the combination of fishing and other stresses due to a changing environment should be taken into consideration in predicting the impacts of proposed fishing levels, but consideration of combined stresses is not possible in the MSY framework which assumes a constant environment.

The applicability of the MSY concept is limited by the underlying assumption of a constant environment. Another limitation of the MSY concept is the lack of appropriate consideration of any of the ecological relationships affecting the target species, which results in incomplete consideration of the impacts of a fishery on both target and non-target populations.

The only relationship between a target species and its ecosystem that has been considered directly in the MSY concept is the rate of natural mortality, i.e., mortality from all causes except fishing, primarily predation, but also disease, pollution, old age, etc. However, the treatment of natural mortality is incomplete and hence unrealistic. The rate of natural mortality is assumed to remain the same over time and with or without a fishery. That assumption does not allow for any feedback in interactions between the predator and prey populations. Instead it implies that predation rate is independent of predator population size, and consequently that the amount of prey consumed annually depends only on the size of the prey population, whether predators are abundant or scarce.

The MSY concept does not allow for any predator population responses to changes in the availability of target species prey populations.

However, the response of the size of a predator population to changes in size of its prey population is a classic part of predator prey theory, which also recognizes that time is required for predator abundance to adjust to changing prey abundance. This adjustment time is called a time lag. Consideration of time lags such as the time required for predator populations to adjust to changed prey abundance and the feedback of the predators on the prey during that adjustment is essential to sound ecosystem level management (May, *et al.*, 1979). The MSY concept does not incorporate any theory of predator prey interactions, and consequently fails to consider feedback known to occur within an ecosystem.

Accounting for the impacts of harvesting on nontarget species is one of the objectives of ecosystem oriented management. It has been argued that MSY management does not affect the biomass or quantity of prey (target) species available for consumption by predators, and consequently that no impacts on natural predators are anticipated, because an estimate of natural mortality is included in MSY calculations. This inferred absence of impact can be contradicted from two perspectives. First, even if all the conditions of the MSY concept are fulfilled, and the rate of natural mortality remains the same with or without a fishery, the annual total biomass of prey taken by predators is still expected to be reduced. Under MSY management, a reduction in standing stock, from a carrying capacity level to a lower population size level at which MSY is theoretically produced, is a management goal. Thus with a reduced average standing stock of target or prey species, the total annual biomass of prey taken by predators can be expected to be similarly reduced, even if the rate of natural mortality remains constant, because total biomass consumed under MSY assumptions is a function of the prey standing stock as well as of the predation rate. The reduction in prey availability may affect predator population size, or may result in increased predation pressure on alternate prey species, some of which may also be harvested populations. Predators may respond to threshold densities of prey, and responses may be expressed through behavior, through change in age of first reproduction or fecundity, or in other ways. Second, the treatment of predator prey interactions in the MSY concept is too simplified even to incorporate the interactions of classical predator prey theory, so does not predict impacts of fishing on the predators of target species. It seems reasonable to conclude that single species, MSY oriented management does not account for either maintaining annual total food supply for predators or the potential responses of predators to changes in food availability.

In addition to the conceptual problems with MSY, there have been practical difficulties with MSY application and, as a consequence, many fishery resources and marine mammal stocks have been overexploited. One difficulty with the application of MSY has been the collection of data on which the estimation of MSY is based. With incomplete data, estimates may be inaccurate and consequently management goals inappropriate, leading to reduction in a stock rather than to sustained yields. Even where the MSY estimates are thought to be fairly accurate, overcapitalization of a particular fishery may result in economic pressures to exceed sustainable yields by a constant increase in fishery yields year after year, as opposed to a reduction or a leveling off at MSY levels.

Insufficient data is not the only problem with the application of MSY concepts to fishery resource management. When several populations are harvested simultaneously in one ecosystem, stock recruitment relationships are blurred, and the constant environment assumptions underlying MSY are particularly strained (Gulland, 1978). Consequently, it seems reasonable to infer that MSY has often been applied in situations that do not meet the requirements for its application, which may be partly responsible for some of the problems with MSY oriented management. If MSY is not applicable, then increasingly refined calculations of MSY estimates based on increasingly complete data will not solve the problem of finding an appropriate management strategy. Even if environmental conditions are sufficiently constant so that there is an MSY characteristic of a particular stock, and even if that MSY value can be estimated accurately, MSY still may not be an appropriate management goal because it does not take into account relationships between the target species and other populations within the ecosystem.

It is important to recognize that management for MSY for several stocks simultaneously does not constitute ecosystem level management. No matter how many stocks are to be managed, MSY is in essence a single species approach because it does not deal with interactions among the stocks that an ecosystem perspective would consider.

Unfortunately, there probably is not a simple replacement for MSY (Gulland, 1978). The development of a more broadly based management approach, which would take into account environmental variations and ecological relationships between the target species and those associated with or dependent on it, appears to be necessary. A starting point for changing from single species MSY type management to a broader ecosystem perspective can be consideration of the impact of a fishery on predator prey relationships and food availability to natural predators in the ecosystem. Existing predator prey theory can be incorporated and then improved as more complete or more pertinent data are sought and become available.

Fisheries management should be more broadly based on an ecosystem perspective rather than focused on the target species alone. Fishery resource stocks have traditionally and properly been viewed as renewable resources. Because of the now recognized interactions between particular fishery resource populations and other populations which may also be harvested, or have aesthetic or other values not associated with harvesting, or which may be threatened or endangered populations, it seems clear that a broader perspective is also appropriate, namely that an ecosystem is a renewable resource.

LEGISLATIVE INTENT

Ecosystem Orientation

The FCMA, MMPA and ESA are examples of legislation concerned with the treatment of renewable resources and the environment. A comparison of certain provisions of the three Acts (Table 2) indicates an ecosystem orientation in all of them: Conservation principles concern habitat and ecosystems as well as populations, while resource definitions include environment, habitat or ecosystems. OY as defined in the FCMA has a component of ecological considerations. The primary objective of the MMPA is to maintain the health and stability of the marine ecosystem. The purpose of the ESA is conservation of endangered or threatened species and their supporting ecosystems. Each of these Acts considers resource populations of particular concern, but also places these resources in an ecological context, thus taking a broader perspective on resource conservation and management.

Activities of Concern

The activities of concern clearly include fishery resource harvesting for the FCMA. For the MMPA and ESA, activities of concern are any affecting populations or habitat of marine mammals or of endangered or threatened species, including fishing. Consequently, it seems clear that fishery management plans should consider the marine environment and marine ecosystems, not only stocks, in developing conservation and management measures for and in anticipating the environmental impacts of fisheries.

Compatibility of the FCMA, MMPA, and ESA

From some of the reviewers' comments on the first draft of this report, it appears that some scientists and administrators perceive that the FCMA and MMPA may be incompatible.

Table 2. Comparison of certain provisions of the FCMA, MMPA, and ESA (Respective Act section numbers in parentheses)

	FCMA	MMPA	ESA
Purpose	conserve and manage fishery resources, both stocks and habitat (2)	conserve and protect marine mammal populations and the ecosystems of which they are a part (2)	conserve endangered and threatened species and the ecosystems upon which they depend
Activities of Concern	foreign and domestic harvesting (303)	harvesting and any other human activities affecting marine mammal populations or habitat (2,3)	taking of and trading in endangered or threatened species (9); any activities affecting critical habitats (7)
Optimality	maximize overall benefit to the nation in using fishery resources; optimum yield is MSY modified by relevant ecological, economic, and social considerations (3)	optimum sustainable populations; maximum productivity taking into account optimum carrying capacity and health of the ecosystem (2,3)	recovery of threatened or endangered species (3)
Ecological Orientation	conservation definition refers to marine environment; definition of fishery resource includes habitat; OY includes ecological considerations (3)	overall goal to maintain health and stability of marine ecosystems and marine mammal populations as significant functioning elements of ecosystems (2)	conservation of ecosystem and critical habitat supporting threatened or endangered species (7)

The main concern appears to be whether it is in fact possible to harvest certain fishery resources at optimum yield levels while at the same time allowing the marine mammal populations which are predators of harvested fish species, to be maintained at or above levels allowing maximum productivity. Similar concerns have been expressed about the impact of fish harvesting at OY levels on the rebuilding of stocks of threatened and endangered species which may depend on them for food. The perceived incompatibility in part appears to rest on an interpretation of the optimum yield concept defined in the FCMA as simply MSY. However, the definition of OY is not synonymous with MSY, and incorporates, among other things, a departure from MSY for ecological reasons. Such ecological considerations could and should include the health of the marine ecosystem, the maintenance of optimum sustainable populations of marine mammals, and support of critical habitat for endangered or threatened species. If the ecological factors incorporated in OY are given serious consideration, then an interpretation of incompatibility of the FCMA and MMPA does not seem either warranted or possible.

The concepts of OY in the FCMA and maximum productivity in the MMPA are like two sides of the same coin. The FCMA focuses on potential yield from a given resource population level, while the MMPA emphasizes the production required to support that yield as well as non-consumptive uses of the resource. A discussion of potential yield is not separable from a discussion of the productivity of a resource. Consideration of productivity merely shifts emphasis from the amount of the resource that can be removed to what makes the yield possible in the first place.

If a fishery is treated as the addition of a predator to a system which already has some natural predators for the target species, then the question of optimum yield for the fishery can be considered as an allocation of production among various predators, taking into account the relative importance of, or value placed upon, each predator and the requirements of each.

It seems clear that with appropriate ecological considerations, OY for a fishery can be consistent with support of maximum net productivity of predator populations such as marine mammals. The question of whether MSY, in contrast to OY, is likewise compatible with optimum sustainable populations of marine mammals has not been answered, but will have to be addressed as part of the process of fisheries management that is compatible with both the FCMA and MMPA. The resolution of that question will be based in part on better operational definitions of optimum sustainable populations in order to provide some, ideally quantifiable, criteria for OSP. While the question of compatibility of MSY for fisheries and OSP for mammals is not resolved, that does not imply incompatibility of the MMPA and FCMA, because OY is not identical to MSY. It appears at present that none of the requirements of the MMPA or ESA are so restrictive as to indefinitely prohibit harvest as a use of either marine fish or mammals.

The perceived incompatibility of the FCMA and MMPA may also be attributable in part to confusion of scientific and policy questions. The simultaneous optimization of both fishery yield and populations of marine mammals and other ecosystem components cannot be completely addressed by either scientific or policy considerations alone. The scientific aspects of the question include determination of the ranges of optimum sustainable population sizes for marine mammals and other ecosystem components and of the range of potential fishery yields which are consistent with both the FCMA and MMPA. These ranges may be determined from analysis of biological data with appropriate statistical qualifications to allow for incompleteness of data and imprecision of estimates. Within the allowable ranges of population sizes and fishery yields which can be determined from scientific criteria, the selection of the set of optimum fishery yields and optimum sustainable populations that would constitute the maximum benefit to the nation is a policy question. The policy decisions will depend on a judgment of the relative importance of productive, aesthetic, recreational and other values of the various resources under consideration, and also on a judgment of what constitutes an acceptable level of risk of damage to any of those populations. The determination of and balancing of relative values of various resources is a very important policy question which should be addressed explicitly rather than be resolved by default.

From this examination of the intents and requirements of the FCMA, MMPA and ESA, it seems reasonable to conclude:

1. that the three Acts are compatible; and

2. that taken together they mandate an approach to the management and conservation of fishery resources

    a. that is ecosystem level rather than single species in perspective, and

b. that takes account of the impact of proposed harvesting strategies on nontarget species, including marine mammals and threatened or endangered species, and on the health and stability of the marine environment as well as on the harvested resource, itself.

EVALUATION OF REPRESENTATIVE FMPs

The FCMA, MMPA and ESA each and together reflect an awareness of the importance of the ecological relationships involving target species. Consequently they require an ecosystem as opposed to a single species perspective on the management of fisheries resources. In order to determine how this ecological awareness has been reflected in the development of fishery management plans, and to what extent management plans meet the intents of the MMPA and ESA as well as the FCMA, four representative plans have been reviewed. The four plans encompass marine mammal and endangered species issues, different amounts of available data on target and nontarget species, and both single and multiple species considerations. The plans were evaluated with respect to the selection of OY levels and the relation of OY to MSY and to relevant ecological considerations, and with respect to the treatment of nontarget species in the plans, particularly marine mammals and endangered species. Some aspects of the four representative plans are compared in Table 3. The evaluations of the four plans that are summarized in this section of the report are presented in greater detail in Appendix F.

Northern Anchovy Final Plan

The Northern Anchovy Plan dealt with only one species, but that species is very important as a forage fish, providing food for a number of predator populations including marine mammals and at least one endangered species, the California brown pelican. The Northern Anchovy Plan included a description of the ecological role of anchovies, although with a fairly broad brush treatment in comparison with the detailed social and economic information found in the plan. The plan included the provision of food for predators as one of its objectives, and the OY formula selected was intended to recognize the value of fish left in the water for predators and to assure that anchovy densities remain sufficient to support predator populations in the California Current ecosystem.

Table 3. Comparison of certain aspects of representative FMPs

Aspect	Pacific Council final 1978 Northern Anchovy	North Pacific Council draft 1978 Bering Sea Groundfish	Mid Atlantic Council draft 1978 Squid	Western Pacific Council draft 1977 Spiny Lobster
recent catch	1975, 200,000 tons spawning biomass 3.6×10^6 tons	1976, about 1.4×10^6 metric tons (mt)	1976 74,000 mt (ICNAF TAC 74,000 mt)	60,000 lobsters
MSY	not meaningful; highly variable recruitment 464,000 t at spawning biomass of 1.8×10^6 tons	1.71 - 2.33 $\times 10^6$ metric tons (mt)	*Illex* 40,000 mt *Loligo* 31,000 - 50,000 mt	preliminary estimate 552,000 - 690,000 lobsters
OY	sliding scale; 267,000 t at spawning biomass of 1.8×10^6 tons	1.44×10^6 tons	*Illex* 30,000 mt *Loligo* 44,000 mt	not set; catch regulated by lobster size and sex
marine mammals mentioned	California Current marine mammal populations	high pinniped populations	pilot whale	Hawaiian monk seal
endangered species mentioned	California brown pelican	none	none	Hawaiian monk seal
ecosystem interactions mentioned	objective: maintain population sufficient to sustain predators	objective: minimize effects on other fisheries, environment; DYNUMES model cited	objective: maintain adequate food supply for predators	objective: minimize effect on endangered seals

Ecological interactions did play a role to some extent in the selection of OY levels. The rationale was qualitative in nature, however, and rested on the assumption that the average anchovy density expected in association with the proposed fishing regime has not in the past been associated with any observed decline in predator populations such as marine mammals. While that assumption cannot be discounted on the basis of available evidence for the 1950-1960 period, it cannot be supported by that evidence either.

Some quantitative analysis of the impact of proposed fishing levels on the forage available to predators would have been possible based on the data provided in the plan. In the northern anchovy section of Appendix F, an example calculation of changes in forage availability is presented. The example is based on estimated rates for natural mortality, fishing mortality and somatic growth rate for the population presented in the plan, as well as on estimates of the expected median annual abundance for anchovies under the proposed OY regime. The example uses standard fishery calculations of natural mortality given the population growth rate assumptions, but interprets the calculations in a new way. The long term reduction in anchovy consumption by predators with the proposed OY catch of several hundred thousand tons per year is estimated in the example in Appendix F to be on the order of 1.2 million tons per year, half of the predation on anchovies in the absence of a fishery, or one quarter of total forage fish consumption. The impacts of such a large change in food availability on ecosystem carrying capacity and predator populations, the availability of alternate prey resources, and the impacts on those alternate prey of increased predation were not discussed in the plan. While the performance of the calculations in Appendix F demonstrates that such a quantitative analysis would have been possible given information provided in the plan, no rough quantitative evaluation of the impact of proposed harvest levels on anchovy predators was attempted in the plan.

The Northern Anchovy Plan dealt with an endangered species, the California brown pelican. However, the recommendation of monitoring of pelican populations appears to be equivalent to a "wait and see" attitude toward the pelican, particularly since the council itself will not be responsible for monitoring the pelican populations. In effect, the treatment of pelican populations in the plan would seem to require that an adverse impact on pelican populations will have to be demonstrated before any action on OY would be taken to mitigate such an adverse impact. The ESA requires that federal agencies ensure that actions authorized by them do not jeopardize an endangered species or its habitat. Therefore, it might have been more appropriate for the council to demonstrate that a lack of adverse impact on the pelican, or at least an acceptably low risk of adverse impact on pelican populations, would be associated with the selected OY formula.

The Northern Anchovy Plan has dealt with the issues of ecological relationships of the target species, even if only in a qualitative manner. Therefore, the Northern Anchovy Plan does illustrate a beginning of ecosystem level as contrasted to single species fishery management. The OY formula selected in the plan would result in harvesting levels considerably lower than MSY levels, on the basis of ecological considerations including the role of anchovies as forage fish.

Bering Sea Groundfish Draft Plan

In contrast to the Northern Anchovy Plan, the Bering Sea Groundfish Draft Plan covered many species. Like the Anchovy Plan, however, it dealt with an area in which there are abundant mammal and bird populations and on which considerable ecosystem level data are available.

In the Bering Sea Groundfish Plan, the OY levels selected were essentially the same as MSY, except for depleted stocks where OYs were set at EY levels. For depleted stocks no recovery would be anticipated except through immigration. It seems apparent that the selected OY values represent very intense fishing on the stocks of the Bering Sea.

Because the domestic fishery is such a small part of the total fishery in the Bering Sea, estimated at most on the order of 1% of the total harvest, there would have been room to reduce OY levels without adversely affecting the domestic fishing industry. One possible motivation for reducing OY levels from MSY levels could have been the ecological consideration of reducing the considerable risk of adverse impacts on the groundfish and the marine ecosystem from such intensive fishing.

Another reasonable potential ecological consideration not even mentioned in the plan is the possible recent reduction in northern fur seal populations which may have been associated with the intense groundfish harvesting of the 1970s in the Bering Sea (U.S. Department of Commerce, 1979).

Marine mammals were mentioned in the fishery management plan, but only with respect to the direct marine mammal impacts on fisheries, namely the consumption of fish already caught in some kind of fishing gear but not yet removed from the water, and the indirect impact of marine mammals on fisheries, namely the high estimated fish consumption of marine mammals in the Bering Sea. The corresponding potential reduction in food available to marine mammals associated with proposed OY levels was not considered in the plan. Maintenance of optimum sustainable populations or maximum net productivity of marine mammals were not addressed in the plan.

The plan acknowledged the different kinds of biological data available for the Bering Sea with reference to the DYNUMES model and the kind of information it contains; however, no further use of that quantitative data was reflected in the plan. It would have been possible, as illustrated with the northern anchovy example, to do rough quantitative estimates of the changes in average fish standing stock anticipated with the selected OY levels, and a corresponding change in total food production available to predators. However, no such calculations were carried out, nor were similar qualitative evaluations made.

The management strategy in the Bering Sea Groundfish Draft Plan seemed to be single species in essence even though many species of fish were considered. MSY was calculated separately for each species, with no allowance for the effects of the intense fishing on other species in the same ecosystem on the assumptions underlying the MSY calculations. The multispecies nature of the report appeared to be a matter of organizational convenience rather than conceptual approach to the management of the overall fishery.

The intents of environmental legislation were recognized in this fishery management plan in the stated objectives. However, they were not reflected in the conservation and management measures, namely the selection of OY levels.

Squid Draft Plan

The Mid-Atlantic Draft Squid Management Plan provided an example of a plan dealing with only two species groups, longfinned and shortfinned squid. For this plan, data both on the fishery and on other resource populations in the same area were not as abundant as for either the Bering Sea or the California Current.

The sparse data problem was dealt with by setting OY levels for shortfinned squid to 75% of MSY, as opposed to 100%, to allow for the incomplete data. In effect, the data problem was apparently treated in the plan as an attempt to manage for MSY without knowing MSY accurately, so that the management objective was still single species in essence. However, the setting of OY below MSY could have been interpreted as minimizing the risk of adverse impacts in the face of limited knowledge of a resource, illustrating one aspect of an ecosystem level perspective on the fishery.

In addition to inadequate data problems, the squid management plan illustrated the issue of consumptive vs. nonconsumptive values for a fishery resource. Because squid have a short life span, one to two years, individuals which are not taken by a fishery in a given year are lost to the fishery, even though they are still a part of the food cycle within the ecosystem. The plan indicated that squid which were not harvested were "wasted", reflecting a lack of consideration of the nonconsumptive values, or a rather low importance associated with those nonconsumptive values.

While the plan recognized the potential adverse impact on pilot whales of several years of squid scarcity, it was assumed that, under the proposed OY levels, years of squid scarcity would not result. Marine mammals were not addressed further. It would have been useful for the plan to at least acknowledge the optimum sustainable population question, and even more useful to attempt a preliminary quantitative evaluation of the impacts of proposed squid harvesting on pilot whale food supply.

Spiny Lobster Draft Plan

The Western Pacific Council's Spiny Lobster Plan concerns a fishery with a potential impact on an endangered species of marine mammal, the Hawaiian monk seal.

The impact of an increased fishery on monk seals is unknown. The plan acknowledged that the MMPA and ESA completely protect the monk seal. The council has elected to encourage an increasing fishery, and recommended monitoring monk seal populations. The council will not be responsible for the monitoring, however. In effect, the plan assumed that the fishery will increase until an adverse impact on the monk seals can be documented and evidence brought to the councils' attention. Because marine mammals are long-lived, a number of years may pass before impacts of fisheries will be expressed in terms of a detectable reduction in population size. The minimization of risk of reducing monk seal populations in the light of the conservation intents of the ESA and MMPA through more gradual fishery growth would have been a more appropriate council action. This plan illustrated differing assumptions about acceptable risk and about where the burden of proof lies for documenting risk or impact levels.

Characteristics of Management Plans

The ecosystem level management orientation of the ESA, MMPA and FCMA was recognized in each of the four fishery management plans reviewed in detail. Unfortunately, that recognition was reflected in OY selection and conservation and management measures in only one plan, the Northern Anchovy Management Plan. In that plan OY was selected to be considerably less than MSY based on the ecological consideration of predator food requirements. The selection of OY to be 75% MSY in the Squid Plan, in order to provide a safety margin in light of inadequate data, can serve as an example of one type of action which might characterize an ecosystem level approach to fishery management. Consideration of the requirement for a safety margin should include the ecological role of the target species, and not simply reflect an imprecise MSY estimate in an essentially single species management strategy.

Endangered species and critical habitats are considered explicitly in two of the management plans, the Northern Anchovy Plan for the California pelican and the Spiny Lobster Plan for the Hawaiian monk seal. However, the respective councils have elected only to monitor the endangered species, for which the councils will not themselves be responsible, rather than to ensure that the proposed actions would not have an adverse impact on endangered species as required by the ESA. Thus the fishery management plans seem to fall short of meeting the intents of the ESA.

Similarly, marine mammals are mentioned in each of the four plans reviewed. However, the question of optimum sustainable population and maximum net productivity for marine mammals was not addressed in any of the plans. The plans should have at least indicated whether present data were adequate for determining OSP levels. If the issue was considered by the councils, it was not reflected in the text of the management plans. The plans also appear to fall short of meeting the intents of the MMPA by not considering the needs of marine mammal populations or the impacts of proposed catch levels on those populations. At least some preliminary treatment of the impacts on predator prey interactions could have been made with the data available in the plans.

The broad brush treatment of ecological relationships in fishery management plans, in comparison to the detailed information included on economic and social aspects of a fishery, in part reflects the nature of the NMFS Guidelines for Development of Fishery Management Plans (42 FR 34458, July 5, 1977). In the sections on definitions and standards, the Guidelines make occasional references to habitat but no specific references to marine mammals, endangered species, or nontarget species. The section on plan contents considers interrelationships of species and habitat in very broad terms. Similarly, the section on plan format contains only one item for ecological relationships, but seventeen items for economic and social characteristics of the fishery. While data on ecological interrelationships are seldom as abundant or detailed as those on economic and social characteristics, ecological data can be organized around relevant considerations such as populations of marine mammals in relation to optimum carrying capacity and maximum productivity, or the status of endangered species and the respective required recovery plans. For other nontarget species, an eventual selection of management and conservation measures that constitute maximum benefit to the nation will require information on the trophic and ecological relationships involving target and nontarget species, the commercial, recreational, and aesthetic values of nontarget species, and their role in maintaining the health of the marine ecosystem in terms of its diversity, stability and resilience.

The failure to attempt an ecosystem level perspective in the management plans has been attributed in part to a lack of the data required for such an undertaking. However, even the available data have not been used to the fullest extent in order to estimate impacts on predator prey relationships, or risk of adverse impacts to marine mammals or endangered species, for example. It seems clear that more comprehensive data analysis could have been undertaken in the plans. The data required to fill the gaps which prevented consideration of impacts on nontarget populations should have been identified.

Even when the best scientific information is fully used, however, there is still room for differing interpretations of that information with regard to the levels of risk to nontarget marine mammals and endangered species associated with various levels of harvesting. Where the data do not clearly demonstrate risk levels, a range of interpretations is possible, with the two extreme positions being:

1. that an adverse impact of a particular level of fishing cannot be demonstrated conclusively and,

2. that the safety or lack of adverse impact of a particular level of fishing cannot be demonstrated conclusively.

Fishery management plans available as of late 1978 seem to indicate an underlying assumption that the councils do not need to take the responsibility for demonstrating that proposed OYs have acceptably low associated levels of risk to nontarget populations. Instead, the councils apparently intend to wait until adverse impacts of fishing levels on marine mammal or endangered species populations can be demonstrated to have occurred before modifying OY to mitigate those impacts.

ALTERNATIVE APPROACHES

The analysis of the intents and requirements of the FCMA, MMPA and ESA in this report indicates that the three Acts together mandate an ecosystem level perspective for fisheries management as opposed to the traditional single species approach. The analysis of representative fishery management plans indicates that while the plans have recognized the requirement for a more broadly based perspective on fisheries management, in practice they have not fully reflected this recognition in the selection of optimum yields and related conservation and management measures. Consequently, the question emerges of how fishery management plans can be changed in order to more fully meet the intents of the legislation as well as the requirements of sound management.

This section of the report deals with specific suggestions for changing fishery management plans to begin to achieve an ecosystem level perspective on fisheries management. With presently available data and theory from ecology and fishery management, steps toward an ecosystem perspective which are feasible now include developing foodweb diagrams or conceptual ecosystem models, incorporating information on predator prey interactions, assessing the risks associated with various harvesting levels, and using techniques for describing whole ecosystems employed in existing ecosystem models. Future approaches to an ecosystem perspective can be based on improved data and theory for expansion of fisheries management concepts to replace MSY by considering more variables.

Conceptual Food Chain Models

A fairly easy first step in broadening fishery management perspective to a whole ecosystem basis is considering how a target species fits into the foodweb of the ecosystem of which it is a part. For each region and/or major marine ecosystem within the U.S. FCZ a conceptual model should be written down, just a box and arrow diagram, indicating trophic relationships for all fishery resources and other components of the ecosystem. Such conceptual models can provide a very useful framework for viewing the fishery in its ecosystem context. They are an aid to recalling complicated marine foodwebs, and also to recognizing where factors influencing a stock are unknown. Such conceptual models exist in the minds of scientists and managers, but they should be written down in order to be examined and used. Conceptual ecosystem diagrams should appear as a figure in the background material of each fishery management plan. These conceptual models will be of use to various interest groups, federal agencies, and persons not well grounded in fishery ecology, as well as to fishery scientists themselves, as a reminder of the interactions which should be considered in ecosystem level management.

Explicit conceptual foodweb diagrams are the first step in an ecosystem perspective on management of any given target species. They merely reflect current understanding of existing ecological relationships and can easily be modified as that understanding increases. The writing of conceptual models should not be confused with the achievement of an ecosystem level management. Conceptual models are merely the first step, a memory aid for ecosystem level management.

Whole Marine Ecosystem Models

While single species population dynamics models can be quite elaborate, dynamic models of whole ecosystems are in very preliminary stages. However, some models of marine ecosystems have already been developed.

Annual biomass budgets have been estimated for producer and consumer components of ecosystems of the Ross Sea, the Southern Ocean, and the California Current (Green, 1977, 1978). These models contain compartments representing every component of the marine ecosystems; frequently, many components are lumped into one compartment for simplicity. The models consider the nature of material flows between compartments and some of the factors regulating flow rates. These models have the advantage of accounting for material flow and production in an entire ecosystem, and the limitation of highly simplified assumptions about the factors controlling consumption rates.

A more realistic treatment of consumption rates, at least for fish stocks, in the North Pacific FCZ is incorporated in the DYNUMES models (Laevastu and Favorite, 1978). The DYNUMES models concentrate on interacting fish population dynamics, do not consider plankton production dynamics, and use forcing functions rather than population simulations for marine mammals and other predators of fish. The DYNUMES models are so complex that the underlying assumptions are very difficult to discover and evaluate.

These ecosystem modeling attempts demonstrate that some degree of ecosystem level perspective, even for a complex marine ecosystem, is possible with presently available data. A review of existing ecosystem models with respect to their potential applicability to ecosystem level fisheries management would be a useful starting place for the incorporation of ecosystem models into fishery management plans.

Predator Prey Interactions

More detailed models and theoretical treatment are available for predator prey relationships. For marine ecosystems, simple models of harvesting at different trophic levels in a multi-species foodweb have been considered recently (May, *et al.*, 1979). Quantitative treatment of predator prey interactions as influenced by a fishery can and should be the next step in developing an ecosystem perspective for fisheries management. The example presented in Appendix F for estimating the long term effects of the proposed northern anchovy fishery OY on anchovy consumption by predators provides one possible method for estimating fishery impact on food available to natural predators in an ecosystem.

Evaluating the significance of changes in available forage for predators is another aspect of the impacts of a fishery on nontarget species. At the present state of the art of ecology, even if changes in food availability could be predicted with reasonable precision, it would still be difficult to anticipate the exact responses of predator populations to those changes. Predators respond to the size, density and distribution of prey, as well as to the overall amount of prey available. Potential responses include behavioral changes as well as changes in overall population size. In addition, the possibility of a shift of predators to alternative prey species should be considered. For the practical development of ecosystem oriented management, some careful consideration needs to be given to which parameters of predator prey relationships should in fact be measured, what kind of data are practical to collect, and what kind of indicator information needs to be observed to be able to predict overall population responses. Small scale perturbation experiments might be considered as one possible method for investigating how predators and prey respond to changing densities.

Treating a fishery as an additional predator in an ecosystem may be a useful perspective for consideration of the impacts of a fishery on target and nontarget species.

In the same context, a fishery can be viewed as a predator that lacks the regulating feedback that controls natural predator populations in an ecosystem. OY formulations could be designed to mimic natural controls on a predator by using appropriate functions of measured ecosystem parameters such as threshold values for the density of the target species, its other predators, or some indicator species, by very strict limited entry formulations, or by compensating for increased capture efficiency with reduced effort.

Risk Assessment

One approach to evaluating the impact of proposed fishing levels on populations of marine mammals and of endangered species is to assess the probabilities that adverse impacts on those populations would result from various harvest levels. Probabilities of adverse impacts, or lack of them, are the risk levels associated with particular activities. The detailed information on the fishing industry and on social and economic ramifications of proposed management measures found in almost all FMPs demonstrates that levels of economic risk can be evaluated.

The existence of risks to stocks associated with fishing have been demonstrated repeatedly as fishery resources have been overexploited, or reduced through a combination of harvesting and weather stresses. Examples include the great whales, Peruvian anchovies, and California sardines. Experience with these sometimes unanticipated population changes, along with advancing understanding of the ecological relationships that keep an ecosystem resilient or able to recover rapidly from disturbances, make at least preliminary evaluations of risk possible. Focusing only on a particular stock, without also considering associated species and environment, is too limited a perspective for evaluating the risk of adverse impacts on a fishery resource. Interactions between harvesting and other impacts such as pollution, climate change or available alternative habitats must also be considered.

Determining acceptable levels of risk of short or long term adverse impacts on stocks, habitats, or marine ecosystems is a policy question. Environmental legislation dictates caution when impacts of an activity cannot be anticipated, and the minimization of the risk of long term adverse impacts to both stocks and the marine environment.

In cases where risk levels cannot be assessed, the data required to make those assessments should be indicated in the plans. In such cases, gradual as opposed to abrupt increases in fishing would seem in order to allow for time lags and a wide margin of safety with respect to possible adverse impacts on nontarget species.

Future Developments in Fishery Management Theory

The assumptions underlying single species management and MSY calculations are limiting and preclude ecosystem level considerations. The development of new theories for ecosystem level fisheries management will have to begin with changing those assumptions. Ecosystem level management will be more complex than single species management because the problem is more complex. In particular, the number of variables will increase. Aspects of the environment, particularly natural mortality, now assumed to be constant, will have to be treated as variables. Consequently, data requirements will also increase. Some serious consideration of which parameters will be most useful and practical in ecosystem level management should be undertaken by scientists and managers familiar with present ecological theory and fisheries management and with environmental legislation.

IDEAL FMP CHARACTERISTICS

To meet the requirements of good management and the intents of the MMPA and ESA as well as the FCMA, fishery management plans should include explicit consideration of the effects of fisheries on the marine environment, critical habitat for endangered species, important habitat for other species, carrying capacity for marine mammals, incidental take of marine mammals, and the health and stability of the marine ecosystem. Marine mammal distribution in the U.S. FCZ and a provisional list of marine mammal species for each council region are listed in Appendix H.

To begin to meet legislative intents more closely, more ecological descriptive information is in order. The trophic interactions, including competition, predation and prey, of an exploited fish stock at each stage of the species life cycle should be described. Where such information is not available, assumptions made on the basis of similar species elsewhere should be stated. To ensure that ecological interactions are kept in mind, conceptual foodweb diagrams for each marine ecosystem within an FCZ should be developed and included as part of the background information in all fishery management plans affecting that ecosystem.

Estimates of the food requirements for populations which prey on fishery stocks, of the availability of potential alternate prey should be made. The time lags required for long lived predators to adjust to variations in the productivity and density of short lived prey should also be among the ecological considerations involved in OY determination. Since continuing yield is usually a fishery management goal, and since capital investment in vessels and employment for fishermen exert economic pressures against reducing allowable catch levels, a fishery can be viewed as an additional predator in an ecosystem, and a very long lived one. Where quantitative predator prey considerations are impossible, a careful assessment of data required to achieve them should be included in the fishery management plan.

An ecosystem perspective on impacts of a fishery does not imply avoidance of any impacts on the marine environment or ecosystem. Instead it means that those impacts should not go unmentioned, but should be stated in plans, accompanied by associated probability levels, so that the acceptability of the anticipated risk can be evaluated.

Reviewers' comments indicate that precise impacts of different fishing levels on habitats or ecosystems are not usually predictable. If impacts are not considered to be predictable, that should be stated in the plan. The additional data or theoretical developments necessary for improved prediction should be indicated.

V. SUMMARY OF CONCLUSIONS

Although there are differences in the specific intents and provisions of the FCMA, the MMPA, and the ESA, the general intents of the Acts are similar, namely, to protect and conserve living marine resources and the ecosystems of which they are a part. Together, the FCMA, MMPA and ESA mandate an ecosystem level perspective on and approach to fisheries management.

The fishery management plans that have been developed to date recognize, but do not fully reflect, the ecological concepts embodied in the FCMA, MMPA and ESA. While the fishery management plans have recognized that optimum yield must consider biological, ecological and socio-economic factors, in most cases OY has been selected without attempting to take account of the impacts of other species on target species, or of either direct or indirect impacts of fishing on species dependent on or associated with target species or on the ecosystems of which they are a part. The strict single species orientation of most of the management plans is contrary to the intents of the MMPA, ESA, and MMPA and to the requirements of sound management.

Traditional fisheries management has been single species oriented and has not taken into account interactions among species, or changes in environmental conditions. The incorporation of an estimate of natural mortality rate in MSY calculations is often considered to be sufficient consideration of the requirements of natural predators. However, long term changes in the abundance of a target species due to fishing can reasonably be expected to result in long term changes in food available to predators.

Lack of data is generally cited as the reason why fishery management plans do not take account of interactions between species, but in most if not all cases, data are sufficient at least to evaluate the risk or chances that a proposed or alternative management decision would have adverse biological, ecological, or socio-economic effects. The estimation of impacts or risks associated with various harvest levels or strategies is a scientific matter, but the determination of what risk levels are acceptable is a policy matter. The science and policy aspects of risk assessment need to be addressed separately.

Some fishery managers, anong others, perceive the FCMA and MMPA to be incompatible, i.e., suspect that the objectives of both Acts cannot be attained simultaneously. However, this incompatibility appears to be more perceptual than real, and probably results from an overly narrow interpretation of the concept of optimum yield. The NMFS operational definition of optimum sustainable population appears to be that which will sustain optimum yield, as defined by the FCMA to take account of relevant biological, ecological, economic and social factors. The maintenance of optimum sustainable populations of marine mammals and endangered species is a reasonable ecological consideration in the selection of optimum yield levels.

Levels of risk of adverse impact on marine ecosystems or fishery resources and the acceptability of those risks have not been considered explicitly in fishery management plans. Perceptions of responsibility for assessing risks associated with fish harvesting and for providing documenting data differ. These differences need to be discussed and resolved.

Given that the objectives of the FCMA, the MMPA and the ESA are not mutually exclusive, and that available data, theory and models are sufficient to develop fishery management plans which are consistent with the intents and provisions of the three Acts, a multidisciplinary group of scientists and managers should be convened to discuss ecosystem level fishery management. If possible, the group should establish procedures for developing fishery management plans based upon consideration of impacts on nontarget as well as target species rather than traditional single species MSY concepts.

VI. RECOMMENDATIONS

The FCMA, the MMPA and the ESA along with other relevant environmental legislation should be reviewed from both scientific and policy perspectives. The scientific review should address ecosystem level management considerations feasible with existing data and theory, as well as desirable future developments. Consideration of changes in fishery management strategy should be addressed to meeting the requirements of the MMPA, ESA and FCMA for an ecosystem level perspective on fisheries management. To assist in the development of management criteria, operational definitions or criteria for meeting the requirements of each of these Acts should be developed or improved. The policy review should address the questions of acceptable risk levels, interpretation of risk levels in the absence of relevant data, and responsibility for assessing and documenting risk levels.

A workshop should be convened to address the specific scientific and policy questions about fisheries management and to develop criteria for an idealized fishery management plan. The workshop should include representatives from the agencies responsible for implementing the FCMA, MMPA and ESA, as well as scientists knowledgeable about the marine environment, specific resource populations, fisheries management and ecological modeling. To accomplish the objectives of science and policy review, specific tasks undertaken at the workshop should include:

1. a review of the statutory responsibilities and management objectives under the FCMA, MMPA, ESA, and other relevant legislation;

2. a review of current theory and practices concerning population and ecosystem management with a view to incorporating existing techniques into fishery management plans;

3. a review of selected population, community and ecosystem models with a view to better incorporation of existing data and theory into management plans;

4. identification of general deficiencies in existing population and ecosystem theory models and data;

5. identification of factors that must be considered in making management decisions in the absence of sufficient data, theory or models;

6. identification of appropriate methods and procedures for making management decisions in the absence of sufficient data, theory or models; and

7. development of an idealized fishery management plan.

The results of this workshop should be used to:

1. review and revise as necessary fishery management plans which have been developed, approved and implemented;

2. develop as possible standard procedures for preparing and reviewing new fishery management plans; and

3. design and undertake studies needed to fill critical data gaps.

While the scientific and policy review of the FCMA, MMPA, and ESA and consideration of improved fishery management plan characteristics are underway, more attention to marine mammal issues can be encouraged in fishery management plans through the existing process for plan development and review. Marine mammal experts should be represented on the advisory panels and the scientific and statistical committees of the councils. In addition they should participate on plan development teams or in contracts for drafting management plans, both of which are possible without actual membership on SSCs or advisory panels.

The NMFS Guidelines for Development of Fishery Management Plans (42 FR 34458, July 5, 1977) sections 602.2 and 602.3, should be revised to include more detail on ecological relationships involving target species, specific references to marine mammals and endangered species, and assessment of impacts on nontarget species and the health of the marine ecosystem. Suggested changes in the language of the Guidelines are presented in Appendix K.

VII. ACKNOWLEDGEMENTS

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APPENDIX A

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APPENDIX B

COUNCIL STRUCTURE

States Represented by Councils

There are eight regional councils, each representing several coastal states:

New England - Maine, New Hampshire, Massachusetts, Rhode Island and Connecticut

Mid-Atlantic - New York, New Jersey, Delaware, Pennsylvania, Maryland and Virginia

South Atlantic - North Carolina, South Carolina, Georgia, Florida (east coast)

Gulf of Mexico - Texas, Louisiana, Mississippi, Alabama and Florida (west coast)

Caribbean - Puerto Rico and Virgin Islands

Pacific - Oregon, California, Washington and Idaho

North Pacific - Alaska, Washington, Oregon (Arctic Ocean, Bering Sea and Pacific seaward of Alaska)

Western Pacific - Hawaii, Samoa and Guam

Council Membership Composition

Voting members on the councils are:

1. the principal state official with marine fishing management responsibility and expertise in each state (designated by the governor);

2. the regional director of the NMFS for the geographic area (if there are two NMFS regions, the Secretary designates which director shall vote); and

3. members appointed by the Secretary of Commerce, taken from a list submitted by the governor (with at least 3 names for each vacancy) of individuals knowledgeable or experienced with regard to management, conservation, or recreational or commercial harvest of fishery resources.

Number of voting members:

Council	Appointed by Secretary	Designated State Representatives	NMFS Regional Director	Total
New England	11	5	1	17
Mid-Atlantic	12	6	1	19
South Atlantic	8	4	1	13
Caribbean	4	2[a]	1	7
Gulf of Mexico	11	5	1	17
Pacific	8	4	1	13
North Pacific	7	3	1	11
Western Pacific	7	3[b]	1	11

a - 2 territorial representatives
b - 1 state representative, 2 territorial representatives

Non-voting members of the councils are:

1. The regional or area director of the USFWS for the geographic area;

2. Commander of the Coast Guard district for the geographic area which oversees that area. (When there are multiple districts in a Council area, the Commandant of the Coast Guard designates the representative.);

3. Executive Director of the Marine Fisheries Commission (Atlantic, Gulf or Pacific states commissions);

4. A Department of State representative designated by the Secretary of State; and

5. The Pacific Council has one extra non-voting member appointed by the governor of Alaska.

APPENDIX C

MEMBERSHIP LISTS FOR COUNCILS AND SCIENTIFIC AND STATISTICAL COMMITTEES

MARCH 1, 1979

NORTH PACIFIC FISHERY MANAGEMENT COUNCIL

MEMBERS

- * Clement V Tillion, Chairman
  Halibut Cove, Alaska 99603
  (Pouch V, Juneau, 99811 during legislative session)
- * Harold E Lokken, Vice Chairman
  Director, Pacific Fisheries Foundation
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- * Douglas B Eaton Fisherman
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- * Prof. Donald L. McKernan, Director
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- * James O Campbell Businessman
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  Anchorage, Alaska 99507
- * Charles H Meacham, Director
  International Fisheries & External Affairs
  Office of the Governor, Pouch A
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- * Gordon Jensen Fisherman
  P O. Box 264, Petersburg, Alaska 99833
- * Ron Skoog, Commissioner
  Alaska Dept of Fish & Game
  Subport Bldg Juneau, Alaska 99801
  Alternate Don Collinsworth
- * Gordon Sandison, Director
  Washington Department of Fisheries
  Gen'l Admin. Bldg , Room 115
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  Alternate Gene DiDonato
- * John R. Donaldson, Director
  Oregon Fish & Wildlife Department
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  Alternate Robert Mace
- * Harry L. Rietze, Director
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  Alternate Robert McVey

John P Harville, Executive Director
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Alternate. Clarence Pautzke

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Alternate CDR Busick

Carl Price
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Alternate: Ray Arnaudo

Keith Schriener
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Alternate Donald Hales

* *Indicates voting members*

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NEW ENGLAND COUNCIL fall 1979

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NEW ENGLAND COUNCIL   fall 1979

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APPENDIX D

OY AND $ VALUES FOR FISHERIES COVERED BY EXISTING MANAGEMENT PLANS AS OF NOVEMBER 1978

Fisheries covered by existing management plans, North Pacific Council, Bering Sea and Aleutian Island areas.

Fishery	Status	Year	OY (mt)	Est $ Value	Source
salmon	some depressed some healthy	1978	75,140 - 105,504	217,000,000 - 305,000,000	FMP-NP-3
tanner crab	most stocks healthy	77-78	88,422 - 100,444	39,600,000 - 44,987,000	FMP-NP-1
king crab	healthy	1977	37,200		PMP-AL-5
pollock	at or above MSY level	1979	1,000,000	21,980,000	FMP-NP-4
yellow fin sole	at or above MSY level	1979	117,000		FMP-NP-4
turbots	at or above MSY level	1979	90,000		FMP-NP-4
other flatfish	at or above MSY level	1979	61,000	13,725,000	FMP-NP-4
Pacific cod	at or above MSY level	1979	58,700	26,700,000	FMP-NP-4
Pacific ocean perch and other rockfish	poor	1979	21,500	7,072,000	FMP-NP-4
sablefish	overfished	1979	5,000	4,400,000	FMP-NP-4
Atka mackerel	at or above MSY level	1979	24,800		FMP-NP-4
squid	at or above MSY level	1979	10,000		FMP-NP-4
Pacific halibut	overfished	1979	2,000		FMP-NP-4
other groundfish		1979	55,500	26,370,000	FMP-NP-4
shrimp	depressed	1977	0	0	PMP-AL-6
snails	exploited since 1971	1977	3,000		PMP-AL-4

Fisheries covered by existing management plans, North Pacific Council, Gulf of Alaska Area

Fishery	Status	Year	OY(mt)	Est $ Value	Source
pollock	healthy, underused	1978	169,000	3,715,000	FMP-NP-2
Pacific ocean perch	severely overfished	1978	25,000		FMP-NP-2
rockfish	not abundant	1978	7,600	2,500,000	FMP-NP-2
flounders	lightly fished	1978	33,500	7,538,000	FMP-NP-2
sablefish	overfished	1978	13,000	11,450,000	FMP-NP-2
Atka mackerel	MSY attainable	1978	33,000		FMP-NP-2
Pacific cod	MSY attainable	1978	34,800	15,830,000	FMP-NP-2
halibut	1/3 MSY level	1977	10,000		PMP-AL-2
shrimp	has declined	1977	50,000	11,000,000	PMP-AL-6
other groundfish		1978	16,200	7,698,000	FMP-NP-2

Fisheries covered by existing management plans, Western Pacific Council

Fishery	Status	Year	OY (mt)	Est $ Value	Source
spiny lobster	healthy	1979			FMP-WP-1
blue marlin	overfished	1979	266	176,000	PMP-SW-2
striped marlin	good	1979	1,150	759,000	PMP-SW-2
broadbilled swordfish	good	1979	356	235,000	PMP-SW-2
precious coral					
shark	good	1978	449	296,000	PMP-SW-2
black marlin	good	1978	52	34,300	PMP-SW-2
sailfish, spearfish	good	1978	78	51,500	PMP-SW-2

Fisheries covered by existing management plans, Pacific Council.

Fishery	Status	Year	OY(mt)	Est $ Value	Source
salmon	declined	1978	23,900	70,140,000	FMP-PA-1
northern anchovy	recovered	1977	303,000 [a]	12,878,000	FMP-PA-2
roundfish	healthy	1979	182,900		FMP-PA-3
sablefish	healthy, except Monterey	1979	10,000	2,864,000	FMP-PA-3
rockfish	healthy, except Pacific Ocean perch	1979	35,600	8,239,000	FMP-PA-3
flatfish	healthy	1979	29,800	6,379,000	FMP-PA-3
other groundfish	healthy	1979	10,000		FMP-PA-3
jack mackerel	underexploited	1977	55,000		PMP-NW-1

[a] calculated from OY formula, for average spawning biomass of 2×10^6 tons

Fisheries covered by existing management plans, New England Council

Fishery	Status	Year	OY (mt)	Est $ Value	Source
red hake	recovered	1979	32,000	3,042,000	PMP-NE-2
silver hake	recovered	1979	98,800	18,385,000	PMP-NE-2
haddock	critically low	1978	20,000	13,444,000	FMP-NE-1
cod	critically low	1978	26,000	14,080,000	FMP-NE-1
yellowtail flounder	critically low	1978	8,100	11,031,000	FMP-NE-1
Atlantic herring	low	1978-79	18,000	2,263,000	FMP-NE-2

Fisheries covered by existing management plans, New England and Mid-Atlantic Councils

Fishery	Status	Year	OY (mt)	Est $ Value	Source
butterfish	some decline	1979	11,000	6,911,400	FMP-MA-3
river herring	some decline	1979	10,000		PMP-NE-3
other finfish	stable	1979	247,000		PMP-NE-3
squid	declining	1979	74,000	31,172,000	FMP-MA-2
surf clam	relatively stable adult population	1978	14,000	18,000,000	FMP-MA-4
Atlantic mackerel	critically low	1979	15,200	4,046,000	FMP-MA-1
ocean quahog	underutilized	1978	14,000	9,900,000	FMP-MA-4

Fisheries covered by existing management plans, New England, Mid-Atlantic, South Atlantic, Gulf of Mexico and Caribbean Councils

Fishery	Status	Year	OY (mt)	Est $ Value	Source
white marlin, blue marlin	cyclical	1977	3,679		PMP-SE-1
sailfish, spearfish	cyclical	1977	604		PMP-SE-1
swordfish	cyclical	1977	870		PMP-SE-1
sharks	cyclical	1977	6,150		PMP-SE-1
stone crab			1,091	4,368,000	FMP-GM-1
reef fish	at or above MSY	1979	3,090	3,200,000	FMP-CA-1

Calculations for Estimated Dollar Values of Fisheries

PMP-AL-6:

The 1974 shrimp catch ran 10¢ a pound, extrapolated to the recent OY.

PMP-SW-2:

Current ex-vessel price of 60¢ a pound for billfish; assume that half the catch is offered for sale.

PMP-NE-2

For silver hake, 1974 ex-vessel value was $186 per metric ton. That value is extrapolated to OY. For red hake, food fish run 6¢ a pound and industrial fish about 1¢ a pound, with food fish making up roughly 5/8 of the 1974 catch. A weighted average of 4.125¢ per pound is extrapolated to the OY. For silver hake the fraction of industrial fish is such a low part of the catch that it doesn't affect the weighted average of price per pound.

FMP-NP-2:

Price per pound is derived from total value divided by total pounds for each species. Value in pounds are taken from tables for the 1976 catch. Sablefish are 40¢ per pound; cod are 20¢ per pound; pollock are 1¢ a pound; flounders are 10¢ a pound; rockfish are 15¢ per pound; other groundfish are 22¢ a pound.

FMP-NP-1:

For tanner crab 1966, the ex-vessel value was roughly $448 per mt.

FMP-NP-3:

For king, coho, and pink salmon in all Alaskan waters, total value divided by total production is $1.31 per pound.

FMP-NP-4:

Bering Sea groundfish. There is no cost information in the FMP so the information from the Gulf of Alaska groundfish price per pound will be used to estimate the dollar value of the fisheries.

FMP-MA-1:

For Atlantic mackerel, national average ex-vessel price was 12.1¢ per pound in 1976, directly from table 4 on page 53.

FMP-MA-2:

From table 13 on page 38, 1976 total U.S. squid catch was 3708 mt, valued at $1,562,000 or $421.25 per mt.

FMP-MA-3:

From table 22 on page 62, New England and Mid-Atlantic butterfish landings were $865,000 ex-vessel value for 3.033 million pounds, or an average price of 28½¢ per pound.

FMP-MA-4:

Surf clam price is $10 per bushel, with 128 bushels per metric ton; ocean quahog price is $3 per bushel, with 214 bushels per metric ton (G. K. Mahoney, letter to K. Green, 2/26/79).

FMP-GM-1:

OY is specified at 2.4 million pounds or 1,091 mt and represents claw weight. For 1977-78 price was $1.82 per pound from page 56.

FMP-CA-1:

For all species of reef fish lumped, the 1971-75 average was $1.743 million for a catch of 3.704 million pounds, or an average price of 47¢ a pound, from table 4, page 26.

FMP-NE-1:

From the 1-26-79 NMFS News release, 1978 catches and values were $\$16 \times 10^6$ for 65×10^6 lbs. cod, or 24.6¢ per lb.; $\$11 \times 10^6$ for 36×10^6 lbs. haddock, or 30.6¢ per pound.; and $\$13 \times 10^6$ for 21×10^6 lbs. yellowtail flounder, or 61.9¢ per lb.

FMP-NE-2:

For herring, from the 1-26-79 NMFS News release, 1978 catch was 35×10^6 lbs. valued at $\$2 \times 10^6$, or 5.7¢ per lb.

FMP-PA-1:

Salmon. From page 50, table 6, preliminary 1977 ex-vessel prices for Chinook and Coho net fishery vary from 71¢ to $2.40 a pound. The average of the values or $1.33 per pound is used to calculate salmon extimated value.

FMP-PA-2:

Northern anchovy. For the last several years, anchovy price has been $42.50 per ton (A. MacCall, letter to K. Green, 2/2/78).

FMP-PA-3:

From table 5 on page 24 and table 3 on page 19. For sablefish total value of the 1976 catch was $954,828 for a catch of 3.334 mt or an average price of $286.40 per mt. For rockfish in 1976, total value was $3.232 million for a total catch of 13,966 mt or an average value of $231.40 per ton. For other flatfish for 1976, total value is $952,810 for a total catch of 4,451 mt or an average price of $214.10 per mt.

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1978. Final Supplement to the Final Environmental Impact Statement/Preliminary Fishery Management Plan King and Tanner Crab Fisheries of the Eastern Bering Sea. U.S. Dept. of Commerce NOAA/NMFS Alaska Regional Office. 10 pgs.

PMP-AL-6 Alaska Region
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PMP-NE-2 North Eastern Region
1977. Hake Fisheries of the Northwestern Atlantic. Federal Register, Vol. 42, no. 34 - Friday, February 18, 1977 pages 10146-10192.

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PMP-NE-3 North Eastern Region
1977. Preliminary Management Plan for Incidental Catching of Finfish Foreign Trawl Fisheries of Northwestern Atlantic, Federal Register, Vol. 42, no. 33 - Thursday, Feb. 17, 1977, pgs. 9950-9986.

PMP-NE-3 North Eastern Region

1977. Supplement to the Final Environmental Impact Statement/Preliminary Fishery Management Plan Foreign Trawl Fisheries of the Northwestern Atlantic, Nov 1977. US Dept of Commerce NOAA/NMFS.

PMP-NE-4 North Eastern Region

1977. Mackerel Fishery of Northwestern Atlantic. Federal Register Vol. 42 no. 32 - Wed., February 16, 1977 pgs. 9552-9594.

1977. Supplement to the Final Environmental Impact Statement/Preliminary Fishery Management Plan Mackerel Fishery of the Northwestern Atlantic, Sept. 1977 US Dept of Commerce NOAA/NMFS and Northeast Region Office.

PMP-NE-5 North Eastern Region

1977. Squid Fisheries of the Northwestern Atlantic Preliminary Fishery Management Plans. Federal Register Vol. 42 no. 32 - Wed., Feb. 16, 1977, pgs. 9596-9634.

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PMP-NW-1 North Western Region

1977. Preliminary Management Plan Trawl Fisheries of Washington, Oregon, and California. Federal Register, Vol. 42, no. 28, Feb. 10, 1977 pgs. 8578-8593.

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PMP-SE-1 South Eastern Region

1978. Preliminary Fishery Management Plan Atlantic Billfishes and Sharks. Federal Register, Vol. 43, no. 19 - Friday, Jan. 27, 1978 pgs. 3818-3835.

1978. Draft Supplement Environmental Impact Statement/Preliminary Fishery Management Plan for Atlantic Billfishes and Sharks. US Dept. of Commerce Fisheries Management Division, Southeast Regional Office NMFS, July, 1978.

PMP-SW-1 South Western Region
1977. Preliminary Management Plan Seamount Groundfish Fishery of the Pacific; Federal Register, Vol. 42, no. 28, Thursday, Feb. 10, 1977 pgs. 8568-8576.

PMP-SW-2 South Western Region
1978. Foreign Fishing for Billfish and Oceanic Sharks in the Pacific Ocean;Federal Register vol. 43, no. 141, Friday, July 21, 1978 pgs. 31374-31406. (Withdrawn)

APPENDIX E

STATUS OF FISHERY MANAGEMENT PLANS AS OF DECEMBER 1979

Plan	Status	Target Implementation Date
PACIFIC COUNCIL:		
commercial, sport salmon	implemented	
northern anchovy	implemented; 1980 amendment planned	
California, Oregon, Washington groundfish	draft	late 1980
comprehensive salmon	draft	May 1980
herring	draft	May 1981
shrimp	draft	September 1980
squid	draft	December 1980
jack mackerel	draft	late 1980
NORTH PACIFIC COUNCIL:		
Alaska coast tanner crab	implemented; being amended	
Gulf of Alaska groundfish	implemented; being amended	
high seas salmon	implemented; being amended	
Bering Sea groundfish	implemented late 1979	
Alaska coast halibut	proposed	1981
king crab	draft	Council adoption, July 1980
Bering Sea clam	draft	Council adoption, February 1980
herring	public comment	1980
WESTERN PACIFIC COUNCIL:		
coral	Secretarial review	July 1980
spiny lobster	final draft	Council adoption, February 1980
billfish and oceanic sharks	draft	January 1981
bottom fishes	scoping, no draft yet	1981
seamount resources	scoping, no draft yet	1981

Plan	Status	Target Implementation Date
NEW ENGLAND COUNCIL:		
Atlantic groundfish	implemented 1977; being revised	
interim Atlantic groundfish	draft	DEIS Fall 1980
Atlantic demersal finfish	proposed	1981 or 1982
Atlantic herring	implemented	
lobster	draft	
true hake	proposed, not active	
sea scallop	draft	DEIS 1980
MID-ATLANTIC COUNCIL:		
Atlantic mackerel	implemented	
squid	implemented	
butterfish	implemented	
surf clam and ocean quahog	implemented	
shark	hearings on draft	Spring 1980
scup	hearings on draft	July 1980
flounders, except fluke and yellow tail	draft	Fall 1980
sea bass	draft	July 1980
summer flounder		September 1981
tile fish	draft	October 1980
SOUTH ATLANTIC COUNCIL:		
snapper, grouper	draft	DEIS Summer 1980
billfish	draft	hearings, Spring 1980
calico scallop	early draft	Fall 1980
swordfish	early draft	
rock shrimp	waiting for date	

Plan	Status	Target Implementation Date
GULF OF MEXICO COUNCIL:		
stone crab	implemented, September 1979	
reef fish	revising	public hearings, Spring 1980
shrimp		public hearings, November 1980
ground fish	draft	Council adoption, April 1980
king and Spanish mackerel	draft	hearings, January 1980
coral	draft	Council adoption, May 1980
spiny lobster	draft	Council adoption, February 1980
shark	review by NMFS	Council adoption, April 1980
squid	proposed	begin 1981
tropical reef fish	proposed	begin Spring 1980
CARIBBEAN COUNCIL: (information as of October 1978)		
shallow water reef fish	draft	
spiny lobster	draft	Council adoption, January 1979
mollusks	proposed	
deep water reef fish	proposed	
coral	proposed	

APPENDIX F

REVIEW OF REPRESENTATIVE FMPs

APPENDIX F

REVIEW OF REPRESENTATIVE FMPs

Draft Bering Sea Groundfish Plan, 1978

The North Pacific Fishery Management Council developed a draft FMP for the groundfish fishery in the Bering Sea-Aleutian Island Area. This review concerns the July 1978 version of the plan.

Species: Alaska pollock, yellowfin sole, turbots (arrow toothed flounder, greenland turbot), other flatfishes, Pacific cod, rockfishes (primarily Pacific ocean perch), sablefish, Atka mackerel, squid, and others.

This plan covers all groundfish except herring and Pacific halibut. Because the potential of these fisheries to affect Pacific halibut is so great, descriptive information on halibut was included in the plan. OY for halibut will be set by the Pacific Halibut Commission, but halibut must be taken into account in management of other groundfish.

Area: The entire FCZ of the Bering Sea including Bristol Bay, Norton Sound, and that portion of the FCZ adjacent to the Aleutian Islands west of 170°W longitude. The Council determined that fish stocks in this area could be managed as a unit.

Goals for the management plan: The North Pacific Fishery Management Council adopted goals for all FMPs including the following:

1. Promote conservation while providing Optimum Yield in terms of overall benefit to the nation, particularly referring to food production and recreation; avoid irreversible or long term adverse effects on resources and the marine environment; ensure availability of a multiplicity of options with respect to future uses of these resources;

2. As possible, promote efficient use of the fishery resources but not solely for economic purposes; and

3. Promote fair and equitable allocation of identified available resources so that no particular group acquires an excessive share.

Specific objectives for this management plan are:

1. Measures should take into account unpredictable characteristics of future resource availability and socioeconomic factors including the industry;

2. Where possible, manage individual fish stocks as a unit throughout their range with due consideration of other impacted resources;

3. Where stocks are below MSY, promote rebuilding; consideration of the rate of rebuilding takes into account factors other than biological considerations;

4. Management measures should attempt to avoid disruption of existing social and economic structures where fisheries are in reasonable conformance with the FCMA;

5. Allow a safety margin in recommending catches when recommendations are based on questionable data; provide for accessing biological and socioeconomic data where they are inadequate; identify information and research required for further plan development; and

6. Design fishing strategies so as to have minimal impact on other fisheries and the environment.

Ecological description: A pronounced biological characteristic of the Bering Sea and Aleutian Island area is the presence of large numbers of marine mammals and birds. Another biological characteristic is the quantitative dominance of pollock. This degree of single species dominance of fish fauna is not found in any other ocean area. Pollock exhibit pronounced cannibalism, with the large older adults feeding on the younger stages, possibly causing long term fluctuations in the population in the absence of a fishery. In theory a fishery which removes these older individuals will stimulate production of the younger portion of the stock by removing one element of predation. This ecosystem also exhibits abundant benthos supporting flatfish and crab communities, and a very high basic organic productivity.

A computer simulation model, DYNUMES III (Dynamic Numerical Marine Ecosystem Model), has been developed for fish of this region (Laevastu and Favorite, 1978). The model accounts for growth, recruitment or production, and mortality of individual fish species or groups. The model also includes grazing on groundfish by marine mammals, birds and other fish. Such grazing is thought to be the main component of natural mortality. Computations based on conservative mammal population estimates indicate that mammals consume about 2.5 million metric tons per year, about twice as much finfish as taken by the commercial catch. The inference was made in the plan that potential finfish yield is as much a function of mammal abundance as of fishing intensity.

Status of stocks: Except for Pacific ocean perch, Pacific halibut, and sablefish, all other groundfish species in the region are believed to be at or above abundance levels producing MSY.

In 1976 total catch of groundfish by foreign fisheries was about 1.4 million metric tons in the Bering Sea and Aleutian Islands, mostly pollock. The domestic fishery in this region has been very small and is anticipated to remain small in the near future. The present domestic commercial bottom fishery is a small long line fishery for halibut by the U.S. and Canada. The combined U.S. and Canadian catch was around 300 metric tons in 1976 and 400 metric tons in 1977. Native subsistence fishing uses nondemersal fish such as herring and salmon.

Marine mammal interactions: This section contained the only explicit discussion of the MMPA in the plan. Impacts of marine mammals on the fishery were mentioned, but impacts of fishing on marine mammals, such as harassment or incidental take of mammals, were not included.

Restrictions on killing or harassing seals and sea lions result in an unknown but, according to the FMP, probably significant economic loss to setline fishermen, when those animals mutilate or remove part of the catch.

Mammals often congregate around trollers and attack halibut, salmon and crabs which are returned to the sea as a conservation measure. The plan concluded that the presence of large populations of marine mammals has a profound impact on the abundance of commercial fish species. The impact is direct through predation on commercial species and indirect through grazing on the same food resources used by commercial fish.

Optimum Yield: OY for all groups was set equal to ABC, as indicated in Table F-1. No social or economic reasons for reducing the yield below ABC were judged necessary, because of the small domestic involvement in this fishery. OYs for pollock, turbot, other flatfish, cod, squid and other species were set at essentially the same levels as MSY and EY. For yellowfin sole, OY was set at EY so no stock rebuilding would be expected, even though the stock is depleted.

Table F-1. Summary of MSY, EY, and OY estimates for major Bering Sea groundfish species. Units are 10^3 metric tons. (from Table I-1, page I-2, of draft FMP)

Species	MSY	EY	ABC = OY
pollock	1100 - 1600	1000	1000
yellowfin sole	169 -260	117	117
turbots	100	90 - 95	90
other flatfish	44.3 - 76.8	44.3 - 76.8	61
cod	58.7	58.7	58.7
rockfish - BS[a]	75	6.5	6.5 (Pacific ocean perch)
rockfish - AL[b]	32	15	15
sablefish - BS[a]	11.35	3.5	3.5
sablefish - AL[b]	1.85	1.5	1.5
Atka mackerel	33	?	24.8
squid	$\geq$ 10	$\geq$ 10	10
Pacific halibut	5	0.3	to be determined by Pacific halibut commission
other	67	67	55.5
Total	1707 -2331	1414 - 1451	1444

[a] Bering Sea

[b] Aleutian Islands

Pacific ocean perch stocks are at a low level of abundance and in poor condition. ABC for all rockfishes was established at EY for Pacific ocean perch alone, so that catches of perch would be less than EY for that one species and some rebuilding of the stock would be expected to occur.

Sablefish stocks have been overfished and cannot now produce MSY. The source of recruitment to these stocks is unknown but may be spawning in the Gulf of Alaska. In that case rebuilding is a function of the Gulf spawning stocks rather than the Bering Sea-Aleutian stocks. ABC was set equivalent to EY.

For Atka mackerel, ABC was set at 75% of estimated MSY.

Review: The North Pacific Fishery Management Council recognized the inadequacies of the traditional single species approach for present day fisheries management:

> "Changes in abundance and distribution of one species (e.g., caused by a fishery) affect the abundance and distribution of other species as well. Therefore wise management requires the quantitative knowledge of all these interactions; single species population dynamics approaches are no longer fully adequate for modern fisheries management." (1978 draft plan, p. 139).

However, the Council chose to adhere very strictly to single species management techniques in establishing OY for the groundfish fishery.

Even though this fishery management plan covered some 300 species, it was single species in approach. No account was taken of ecological interactions between species, nor of how such an intensive fishery on all of the species affected the assumptions underlying MSY calculations. Calculating all the MSYs separately, and then adding them together, was still single species type management.

OYs were set at essentially the same levels as recent catches. These levels were not necessarily appropriate since catches have been declining from a peak of 2.25 million metric tons in 1972. This decline suggests a history of overfishing in the region, a trend which will not be corrected by continuing intensive fishing.

OY was set essentially at MSY for all species considered except yellowfin sole, Pacific ocean perch and sablefish, which are depleted and presently at population levels well below those producing MSY. For those depleted species OY was set at EY, so that stock size is expected to remain the same without any rebuilding. Such intense fishing on all groundfish in the area is almost certainly overexploitation. The plan objective of allowing a safety margin was not fulfilled in establishing OYs.

The domestic portion of this fishery is very small, on the order of 400 out of 1.4 million metric tons. The estimated physically possible maximum catch by domestic fisheries was about 160,000 metric tons, or slightly over 1% of total OY. There was ample room to reduce OYs, e.g., to half of MSY, to allow an ecological safety margin without restricting the domestic fishery. Such a reduction could have represented a reasonable ecological consideration for reducing OY from MSY, as provided by the definition of OY in the FCMA.

There appears to have been no consideration of endangered species or critical habitat in this fishery management plan. Marine mammals were treated as a nuisance interfering with gear and competing with fishery for fish resources. No apparent attempt was made to evaluate the impact of proposed fishing levels on the carrying capacity of the ecosystem for marine mammals, even though there are indications that populations of North Pacific fur seals have decreased in the 1970's, in conjunction with intense fishing on pollock (U.S. Department of Commerce, 1979). The questions of optimum sustainable populations of and optimum carrying capacity for marine mammals were not addressed as issues under the discussion of the MMPA.

No estimate was made of reduction in food available to predators in conjunction with fishing intensity levels associated with indicated OYs, even though data for such calculations are available and organized in conjunction with the DYNUMES model referenced in the plan. Comments by reviewers on the first draft of this report indicated the implicit assumption that the use of estimates of natural mortality rate in MSY calculations automatically accounts for predator needs. That assumption is not entirely valid, as discussed in Appendix G of this report. The rate of natural mortality, M, (largely predation) may not remain constant when predators shift to alternate food sources, in this case also harvested groundfish, as the density of preferred prey decreases. Even if the rate M remains constant, variation in the standing stock to which the rate is applied (analogous to constant interest rates and varying principal in a bank account) results in variation in the annual total biomass of prey available to predators (analogous to yearly total interest paid).

Estimates cited in the plan indicate that marine mammals and birds consume more groundfish than the fishery removes. In most fisheries, total catch represents only a small part of the total annual production of the stock. It does not follow that the fishery has no impact on the stock or its predators. In the absence of a fishery, all of the production of a particular stock is accounted for by replacing deaths from that stock, most of those deaths due to predation. A fishery can affect predators in two ways. First, it removes fish resources which would otherwise be available for predators. Second, it can decrease the average standing stock of fish which may reduce the density of the fish in the water, affecting predators that depend on concentrations of prey for efficiency in feeding.

Summary: This FMP is an example of the single species approach to fisheries management. MSY was calculated for each species separately, with OY set at MSY for all species except depleted ones, for which OY was set at EY. Fishing at this intensity is almost certainly overexploitation. No safety margin was included in the selection of OY levels, but would have been an appropriate ecological consideration.

No evaluation was made of fishery impact on carrying capacity for marine mammals or other predators, even though there are indications that fur seal numbers have declined recently. The implicit assumption that predator interactions are accounted for through estimates of natural mortality in MSY calculations is not valid. With the DYNUMES model information, at least rough calculations of impacts on predators would have been possible. Although the precise impacts of reduced food availability on predators are not predictable, trends can be anticipated.

The Bering Sea groundfish draft FMP recognized the ecosystem issues addressed by the FCMA and MMPA, but did not apply them to OY selection.

Final Northern Anchovy Plan, 1978

The Pacific Fishery Management Council developed a plan for northern anchovy, implemented in 1978. OY was updated in 1979 and will continue to be revised annually in accordance with the OY formula adopted in the plan. These comments concern the final March 1978 version of the plan.

Species: Northern Anchovy, *Engraulis mordax*

Area: The central subpopulation of the northern anchovy extends from 38°N latitude off Central California to 30°N latitude off central Baja California and out to 200 miles. The entire central subpopulation exceeds U.S. FCZ boundaries and will eventually require cooperative management with Mexico. The U.S. FCZ contains 70% of the stock.

Management objectives adopted in the plan were to:

1. Prevent overfishing of the central subpopulation within the U.S. FCZ and waters under Mexico's jurisdiction;

2. Allow a fishery for anchovies within the U.S. FCZ limited to achieve OY on a continuing basis;

3. Maintain an anchovy population in the U.S. FCZ sufficient to sustain adequate levels of predator fish, birds and mammals;

4. Avoid conflicts between U.S. recreational and commercial fleets; and

5. Promote efficient utilization of the central subpopulation of anchovies within the U.S. FCZ.

MSY was not considered meaningful for the anchovy fishery, since "maximum" and "sustainable" tend to be mutually exclusive in this case. Because of large variability in recruitment, the population level is usually under or over that producing MSY. An MSY of 484,000 tons was estimated in the plan for an average spawning biomass of 1.8 million tons. To maximize total yield over time, a policy of catch smaller than MSY when the population is below 1.8 million tons spawning biomass, and greater than MSY when the population is above that figure, would be used. Unfortunately because of the variability in anchovy biomass, maximizing total yield over a long period of time would require a tremendous variability in the fishery, from no catch 2 years out of 3, to extremely large catches in other years. Such variability would be disruptive to the fishing industry. Another problem with managing for MSY is the unusual sex ratio of the reduction fishery catch. The disproportionate catch of females would lead to a greater impact than predicted.

Ecological interactions: Northern anchovies are a large part of the forage consumed by predator fish and invertebrates, some of which are fished recreationally and commercially and eaten by marine mammals and birds. Anchovies themselves consume large quantities of fish eggs and larvae. No assessment of the impact of the removal of anchovies on the ecosystem was considered possible because of the complexity of the system and the superficial knowledge of it.

Status: The central stock spawning biomass was estimated at 3.6 million tons in 1975. The 1974 year class was weak and the 1975 class was poor. The 1976 year class appears to have been considerably stronger. Overall abundance seems to have been increasing and the stock probably recovered to more normal levels of abundance in 1978. Under existing California management council, the council saw little danger of depleting the stock. However, an independent and unregulated fishery in Mexico was considered cause for concern by the council.

History: The U.S. fishery developed in the 1950s as a substitute for the collapsed sardine fishery. Since 1965 permits have been issued for catch of anchovies to be processed for fish meal and oil. This is called the reduction fishery and has been the largest component of the commercial fishery. Catches for live bait have been a much smaller component of the commercial fishery. There has been some recreational anchovy catch as well. Recent harvest quotas have ranged between 110,000 and 165,000 tons. In 1975 California anchovy landings were 158,511 tons.

Present exploitation: Commercial fisheries in southern California for pelagic schooling fish use various round haul gear, typically purse seines and lampara nets. The major species in the fishery have been northern anchovy, jack mackerel, bonito, blue fin tuna and market squid, and to a smaller degree, Pacific mackerel and other incidental species. An integrated set of management plans covering all of these species was identified in the plan as a long term goal. Anchovy harvest in 1977 was on the order of 200,000 tons by Mexican and U.S. fisheries combined.

OY considerations: Economic and social considerations for determining OY included the economic contribution of the fisheries to the nation, the anti-reduction fishery sentiment among marine anglers, and the per ton value of the live bait catch. Biological considerations included support of abundant predator populations.

Acceptable Biological Catch involved two considerations, the desirability of maintaining a large enough population to minimize the risks of natural fluctuations in recruitment, and the need to account for the sex ratio of the commercial catch which averaged 1.73:1 females to males.

The plan commented that increased exploitation would reduce available supply of anchovies as forage for predator species of fish, birds and mammals, with the greatest impact at the centers of the fishery. The OY formula was designed to reduce exploitation impact when the biomass is low and to protect the long term productivity of the resource.

For the central subpopulation of northern anchovies, the following formula was adopted for OY;

1. When the estimated spawning biomass is less than 100,000 tons, OY is 0;

2. When the estimated spawning biomass is between 100,000 and 1 million tons, OY is 18,000 tons for the non-reduction fishery catch; and

3. When estimated spawning biomass is 1 million tons or more, OY for the combined reduction and non-reduction fisheries is 18,000 tons or 1/3 of the biomass above 1 million tons, whichever is greater.

Because 70% of the central subpopulation is found in the U.S. FCZ, optimum yield within the FCZ was set at 70% of the OY for the central subpopulation as a whole.

Under this formula OY at a biomass of 1.8 million tons spawning biomass would be 267,000 tons, considerably less than the MSY figure of 484,000 tons at the same biomass. OY for a spawning biomass of 3.6 million tons, the estimated population for 1976, would be 870,000 tons, much greater than the 1976 harvest of about 200,000 tons.

The maximum carrying capacity of the area was estimated at 3.9 million tons spawning biomass of anchovies. The average spawning biomass 1951 to 1975 has been 1.95 million tons. Under the proposed harvest quota, the spawning biomass would average 2.55 million tons, a level greater than equilibrium biomass. Spawning biomass would fluctuate around this average and would be expected to fall below 1 million tons during 19% of the years.

Pre-spawning anchovies of ages 0 and 1 will be protected for the most part by closure of the 3 mile inshore area by the state of California and by the 5 inch minimum size limit. These young fish contribute mostly to the recreational fishery as forage and live bait.

Review: The OY formula provides for a fishery that is less intense than managing for MSY, but more intense than recent harvesting.

Maintenance of an anchovy population sufficient to sustain adequate predator stocks was one of the management objectives of this plan. However, no apparent attempt was made to define quantitatively what "adequate" levels of predators would be. Determining a quantitative or operational definition of "adequate levels," or of OSP for mammals as defined conceptually in the MMPA, would be a very difficult task. However, the question of OSP levels should have been raised, even if considered not answerable at present.

The dependence of predators on anchovies was discussed in the plan, but not the existence of potential impact on alternative prey. Anchovies have been estimated to make up 45% of the average biomass and 50% of the production of small schooling fish (Green, 1978). The plan concluded that benefit to the nation does exist when fish are left in the water because they support commercially and recreationally valuable fish and squid as well as "non-valued birds and mammals." OY levels as formulated, considerably less than MSY, would contribute to leaving fish in the water and maintaining predator stocks.

The question of whether predator populations would be supported sufficiently was not addressed in detail in the plan. The analysis of predator needs and interactions in the plan was confined to the observation that during 1951-1961 when spawning biomass was below 2 million tons (as opposed to the present 3 to 4 million tons), predators did not appear to decline. However, no information on marine mammal populations is available to support or refute that assumption. The plan concluded that long term average anchovy biomass in excess of 2 million tons should not have a severe adverse effect on predators. Under the OY formula, spawning biomass was anticipated to average 2.5 million tons. It was expected to fluctuate around this average and to fall below 1 million tons for one year in five.

The relationship of natural populations of predators to fluctuations in their prey is a complex one and not well worked out theoretically at the present state of the art of ecology. Populations of long lived predators such as mammals may not respond quickly to changes in prey abundance. The crucial parameter of survival of young to sexual maturity may respond over one to several years to such changes in abundance. However, because of the late age of sexual maturity, it would take a longer time for the impact of several years of low juvenile survival to become apparent in the overall population size (Green, 1977). The question of time lags in predator prey relationships is a classic one, and merits more consideration in multi-species fishery management (May, et al., 1979). For some predators, reproductive success may respond to a threshold value of prey availability, such as a minimum required prey density, so that the relationship of predator abundance to prey abundance is not simple. Even though relationships are not known precisely, it is still clear that a significant reduction in food availability causes a reduction in the carrying capacity of an ecosystem for predators.

Another important aspect of the effects of a fishery on ecosystem carrying capacity is the potential use of alternative prey species, in this case other forage or small schooling fish, by predators. Whether alternative prey are available depends in part on the specialized food requirements of a predator with respect to season, spatial distribution, density, and behavior (such as schooling) of prey. If alternate prey are available, then the impact on those populations of more intensive predation (increased natural mortality) should be considered, particularly if those populations are also harvested.

Compared to detailed social and economic considerations in the plan, predator prey relationships received a fairly broad brush treatment. With the information on anchovy populations in the plan, some analysis of the impact of the proposed catch levels on predators could have been made.

<u>Ecosystem perspective example</u>: One way to look at the impact of a fishery on an ecosystem is to estimate the loss of forage to predators other than the fishery. Traditional fishery calculations include estimates for rates of fishing mortality (F) and natural mortality (M). Natural mortality results largely from predation in a healthy ecosystem, so can be used to estimate the amount that the predators are eating. On an annual total weight basis, fishing mortality displaces some of the natural mortality, although the combination of fishing and natural mortality exceeds natural mortality alone. The difference in estimated total annual natural mortality of a fish stock with and without a fishery can provide some indication of the short term impact of a fishery on forage availability. To get a handle on longer term changes in availability of forage, the aspect of average spawning biomass or average standing stock must also be taken into consideration.

As an example, estimates of changes in natural mortality anticipated in association with the proposed northern anchovy fishery are presented here. The following analysis applies to a fishery in which both natural and fishing mortality occur concurrently (Ricker, 1975). The formulas used for estimating biomass consumed by predators in this example are standard ones for the assumptions used for gain and loss rates. It is the emphasis on predator forage and the use of the formulas to estimate changes in predator intake that are unusual. F is the instantaneous rate of fishing mortality; M is the instantaneous rate of natural mortality; G is the somatic growth rate.

Fish stock biomass is decreased by death and increased by growth, so the rate of biomass change (decrease) is F + M - G. The biomass of the fish stock at the beginning of the year is B_O or initial biomass, or spawning biomass for anchovies. That biomass decreases at the rate F + M - G. The average biomass during the year, $\bar{B}$, is:

$$\bar{B} = B_O \times (1 - e^{-(F+M-G)}) / (F+M-G) \quad (1)$$

Then the estimated weight of fish that die naturally, or forage available to predators, is $M\bar{B}$.

Without a fishery there is no fishing mortality. In that case, the estimate of predation of natural mortality is derived in the same way as the previous case, except that there is no fishing mortality, so F = 0. Then estimated predation is $M\bar{B}$ where:

$$\bar{B} = B_O \times (1 - e^{-(M-G)}) / (M-G) \quad (2)$$

The difference in the two estimates of $M\bar{B}$, or total annual natural mortality, in the cases with and without a fishery, is the hypothetical loss of forage due to the fishery. Values for M and G are the same in both cases. The value for F is a variable, being greater than zero in the case with a fishery, and zero in the case without a fishery. Values for B_O are the same for considering short term changes in forage, and different for considering long term changes when variation in average spawning biomass becomes a factor.

Calculations of total annual natural mortality with various levels of B_O and F for the northern anchovy fishery are summarized in Table F-2. The short term loss of forage available to predators, under the proposed fishery level based on the OY formula, for years with a high spawning biomass (e.g., 3.6 million tons in 1976) is estimated at 420,000 tons. Similarly, for years with a low spawning biomass, short term loss is estimated as 160,000 tons. Since there is considerable natural variation in the anchovy population, and consequently in available forage from year to year, these values may not be significant. Of greater importance is the change in forage resulting from the long term decrease in anchovy density or average spawning stock that is expected to result from the proposed fishery, case C in Table F-2. On the basis of expected median population values with and without the proposed

Table F-2. Calculations of total annual natural mortality for the central subpopulation of northern anchovies at various levels of spawning biomass and fishery mortality.

Case	B_o (tons)	Q (tons)	E	F	(F+M-G)	$\bar{B}$ (tons)	$M\bar{B}$ (tons)
without a fishery:							
A	3.6×10^6	0	0	0	0.8	2.48×10^6	2.63×10^6
B	2.0×10^6	0	0	0	0.8	1.38×10^6	1.46×10^6
median C	3.35×10^6	0	0	0	0.8	2.31×10^6	2.44×10^6
with an "ideal" fishery (catch sex ratio 1:1):							
A'	3.6×10^6	867×10^3	0.241	0.417	1.217	2.08×10^6	2.21×10^6
B'	2.0×10^6	333×10^3	0.167	0.272	1.072	1.23×10^6	1.3×10^6
median C'	2.05×10^6	350×10^3	0.171	0.279	1.079	1.25×10^6	1.33×10^6
with actual fishery (catch sex ratio 1.73:1 F:M):							
A"				same as A'			
B"				same as B'			
median C"	1.84×10^6	280×10^3	0.152	0.245	1.045	1.14×10^6	1.21×10^6

Short term losses in forage ($M\bar{B}$):

for spawning biomass 3.6×10^6 tons, $A - A' = 420 \times 10^3$ tons

2.0×10^6 tons, $B - B' = 160 \times 10^3$ tons

Long term losses in forage ($M\bar{B}$):

for median biomass, ideal fishery $C - C' = 1.11 \times 10^6$ tons

actual fishery $C - C'' = 1.23 \times 10^6$ tons

Table F-2, continued:

Symbols:

B_o - initial spawning biomass

Q - quota, from OY formula: $Q = 0.333 \times (B_o - 10^6)$

E - exploitation rate ($E = Q/B_o$)

F - fishing mortality rate, iterative solution: $E = \frac{F}{F+M-G} \times (1 - e^{-(F+M-G)})$

M - natural mortality rate: $M = 1.06$

G - somatic growth rate: $G = 0.26$

$\overline{B}$ - average or mean biomass: $\overline{B} = B_o \times (1 - e^{-(F+M-G)}) / (F+M-G)$

$M\overline{B}$ - quantity of fish consumed by predators, or forage fishery of several hundred thousand tons annually, estimated available forage is expected to decrease on the order of 1.23 million tons annually, or about half of the amount consumed by predators in the absence of a fishery.

While the anchovy management plan did allow for forage for predators, the question remains of whether it allowed enough. Had such calculations been incorporated in the plan, the OY selected might have been different.

The northern anchovy plan contained a reference to an endangered species, the brown pelican, which depends on anchovies for food. A link between anchovy abundance and reproductive success of the brown pelican is suspected. High anchovy abundance may be required for successful reproduction, although definitive data are not yet available. The Pacific Fishery Management Council became aware of this relationship after the plan had been drafted when comments were made through the NEPA review process. A Section 7 consultation was held as required by the ESA. While no specific action was taken in the final plan, monitoring for impacts of the anchovy fishery on the pelicans was recommended. Such monitoring is not a Council responsibility, however, and funding for it is not guaranteed. Critical habitat for the pelican under the ESA has not yet been officially designated.

Summary: The northern anchovy plan provides a good example of beginning the shift of fishery management techniques from the single species orientation to an ecosystem perspective. MSY was calculated as required under the FCMA, but OY was reduced substantially from MSY on the basis of ecosystem level considerations, namely the role of anchovies as forage fish and the need to support predator populations in the ecosystem. An endangered species was considered explicitly in the plan. The intents of environmental legislation were recognized and acted upon in the plan, although more could have been done with the available data to gain an ecosystem level perspective on impacts of proposed fishing levels. Rough quantitative estimates of the impact of proposed fishing levels on predators, based on present ecological theory and on data in the plan, could also have been incorporated in the plan.

Draft Squid Plan, 1978

The Mid-Atlantic Fishery Management Council developed a management plan for squid in the northwest Atlantic in 1978. These comments apply to the August 1978 draft.

Species: longfinned squid, *Loligo* sp.; shortfinned squid, *Illex* sp.

Distribution: Longfinned squid range over the continental shelf from Nova Scotia to the Gulf of Mexico. Primary commercial concentrations occur from Georges Bank to Cape Hatteras. Summer or shortfinned squid extend from Greenland to Florida, but are most abundant between Nova Scotia and New Jersey. They are most abundant in the summer in the Gulf of Maine and Newfoundland region. Squid move offshore in late fall.

Management objectives adopted in the plan were to:

1. Achieve and maintain optimum stocks for future recruitment;

2. Prevent destructive exploitation of squid species;

3. Minimize capture of nontarget species;

4. Achieve efficiency in harvesting and use;

5. Maintain adequate food supply for predator species, recognizing that squid are also predators;

6. Minimize user conflicts;

7. Improve understanding of the condition of the stocks; and,

8. Encourage increased American participation in the squid fishery.

Ecological relationships: Overexploitation of squid could result in decrease of other marine species which compete with fisheries for squid. Substantial increases in squid numbers might threaten fish species that are preyed upon during early life stages by squid. Some 54 species of fish have been identified as predators of adult squid. The largest predator reported is the pilot whale (*Globicephala melaena*) which feeds almost exclusively on squid, mainly *Illex*. Off Newfoundland these whales subsist on *Illex* about 6 months a year. The plan recognized that years of *Illex* scarcity could significantly impact pilot whale populations in the Newfoundland area. While no data are available from the Atlantic, it can be inferred from Pacific data that squid are also a significant part of porpoise diet. Billfishes, a valuable commercial and recreational group, use squid heavily for food. It has been postulated that an apparent increase in squid abundance may have occurred in response to declining abundance of finfish, but the actual relationship remains unclear.

History: Gear for squid includes pound nets, otter trawls, floating traps, and rarely haul seines.

Foreign fishing began in 1975 with an incidental catch. Mean squid catch for 1972-1976 for all countries except the U.S. was 50,000 tons, peaking in 1973 at 56,768 metric tons. Foreign landings are currently about 95% of all squid landings. Squid are taken as a bycatch for silver hake, red hake, other groundfish, herring, mackerel and some other pelagic and finfish.

Status: Squid are short lived and fluctuate widely in abundance. Preliminary data analysis indicated that *Loligo* numbers in 1977 in the southern New England mid-Atlantic area were 18% greater than in 1976, but 23% less than in 1975. The plan concluded that even on conservative estimates, this would be adequate to support an OY of 44,000 tons for *Loligo*. For *Illex*, abundance has increased sharply from 1974 to 1976. Catches as high as 20,000 tons have not had an apparent impact on production when the population has been large. The USSR estimated minimum biomass of *Illex* on Georges Bank as 100,000, 58,000, 197,000 and 258,000 tons for the summers of 1971, 1972, 1975, and 1976 respectively.

MSY estimated for *Loligo* in the plan was 44,000 tons based on recruitment of 1.5 billion individuals to the population annually. A preliminary estimate of MSY for *Illex* was 40,000 tons. The plan indicated that the Council chose conservative values for MSY.

OY set in the plan restricted the harvests of *Illex* to 30,000 metric tons and *Loligo* to 44,000 metric tons. Foreign harvests were limited to 20,000 metric tons and 30,000 metric tons respectively for 1979.

OYs were set at conservative levels of estimated MSY for *Loligo* and at 75% of the estimated MSY for *Illex* to allow for incomplete data.

Review: The plan contained no explicit mention of the MMPA. However, the potential impact of several years of scarce squid on habitat for pilot whales and possibly other marine mammals was recognized. Optimum carrying capacity and OSP for pilot whales were not addressed in the plan, nor were any impacts on the habitat or ecosystem extrapolated from proposed catch levels.

The combined OY of 74,000 metric tons was the same as recent ICNAF quotas, but higher than recent catches. Squid are fish food. There has been some concern among fishermen that these quotas may be too high, not leaving enough left over as forage for tuna and other species.

In setting the OY for *Illex*, a safety factor was incorporated to allow for incomplete data, in line with conservation principles (Holt and Talbot, 1978).

U.S. mid-Atlantic squid catch in 1976 was 901 metric tons, on the order of 1% of OY. U.S. fishery capacity was estimated at 24,000 metric tons. There was considerable room in the plan for increasing the ecological safety margin by reducing OY without affecting domestic fisheries.

The plan implied that because of their short life span, squid which are not harvested are wasted. The implicit attitude that nonconsumptive uses of a fishery are not valuable is contrary to the conservation definition in the FCMA, the intent of ecological legislation, and good management practice.

Summary: The potential impacts of an intense squid fishery on squid prey and predators, including marine mammals, were recognized in the plan. No quantitative estimates of the impacts of various harvesting levels on the ecosystem, e.g., food available to predators, were attempted, although rough calculations along the lines of the anchovy example (discussed earlier in this appendix) were possible given the data in the plan. For one species OY was set below MSY to allow for deficiencies in data used in MSY estimation, reflecting one aspect of the conservation intent of the FCMA.

Draft Spiny Lobster Plan, 1978

The Western Pacific Council is developing a plan for spiny lobster. These comments apply to the draft version of May 1978.

Species: Spiny lobster, *Palinurus* sp.

Distribution: Depth range of 1 to 200 meters; commonly associated with coral reefs or rock bottom, around islands.

Management objectives adopted in the plan were to:

1. Maintain the reproductive potential of spiny lobster stocks;

2. Permit expansion and continuation of economically viable spiny lobster fisheries:

3. Minimize environmental and ecological impacts of the fisheries, particularly on the endangered Hawaiian monk seal; and,

4. Acquire additional information on the resources and fisheries for use in refining management measures as necessary.

For all areas other than the northwestern Hawaiian Islands, the main plan objective was to promote acquisition and review of information, since fisheries are little developed and little documented. There is a small fishery with a definite potential for growth in the northwestern Hawaiian Islands. An objective of the management plan was to institute conservation measures sufficient to safeguard the stock against serious loss of productivity and to protect other elements of the environment, while placing minimum obstacles to further development of the fishery.

Ecological interactions: Lobsters feed mainly on small invertebrates and detritus, and are eaten by octopuses, reef fish, monk seals and tiger sharks.

While monk seals are known to prey on lobsters, the importance of lobsters in their diet is not known and may vary with the area. Lobsters are significant food items for seals around Laysan. However, they are assumed not to be significant elsewhere.

The Hawaiian monk seal is an endangered species. The same habitat is used by the green sea turtle, proposed as a threatened species. The NMFS may at some future time declare waters around some of the Hawaiian Islands to be critical habitat for the monk seal.

Anticipated environmental impacts included in the plan were the expected long term maintenance of the reproductive capacity of the stock, a continuing but unknown degree of competition with lobster predators such as Hawaiian monk seals, and some minimal risk of entrapping the seals in lobster traps. Prohibition of trapping in shallow water and establishment of a refuge around Laysan Island were expected to provide additional protection for lobster populations and to mitigate interactions with monk seals.

Status: Spiny lobster stocks were considered to be in a healthy condition. None have been severely overfished or adversely affected by other human activities.

Present exploitation: Harvest is by diving, grabbing, or spearing for recreation or subsistence, and a small commercial fishery with tangle nets; some incidental catch in fish traps.

MSY was estimated in the plan at 552,000 to 690,000 lobsters, based more on extrapolation from other lobster fishing regions than on the sparse data from Hawaii.

Conservation measures: No OY or Total Allowable Catch figures were established in the plan. The fishery was regulated by gear, area, and size restrictions instead. Conservation measures would prohibit fishing within 20 miles of Laysan Island for five years, would place size restrictions on males and females taken, and would prohibit landing of females with eggs or lobsters with swimmerettes removed. Measures also would prohibit fishing methods other than trapping or hand catching, specifically tangle nets, traps with triggered closures, and spearing. Fishing would be prohibited in water shallower than 10 fathoms except around Midway and Kure (to allow recreational fishing by military personnel) in order to protect lobster spawning stock to some extent, and also to protect the fringing reef area inhabited by monk seals and to minimize interactions between the seals and fishermen.

Laysan Island would be established as a refuge for monk seals to allow a comparison of the effects of fishing and not fishing on monk seal populations around an island. Extensive observation of monk seals was recommended both to check on population trends and to try to assess food habits.

Review: The plan rested on the assumptions that regulations of no fishing above 10 fathoms and a sanctuary around Laysan Island would serve as protection to the monk seals, and that either lobsters were not a significant food item for monk seals, or that the potential reduction in lobster abundance due to the fishery would not be serious for the seals.

The fishery before 1978 consisted of three boats, fishing six months a year and landing about 60,000 lobsters. Because Hawaiian lobsters are a relatively unexploited stock, the possibility for high short term profits by rapid overexploitation exists. Very few boats could potentially accomplish that. A large jump in harvesting levels, on the order of a tenfold increase, could result from the recommended catch regulations. Such a rapid jump would not allow much of a margin of safety for anticipated or unanticipated ecological impacts of the fishery.

The management plan acknowledged that the MMPA and ESA completely protect Hawaiian monk seals which are listed as an endangered species. The need for monitoring the seal population was recognized. However, the responsibility for such monitoring would not rest with the council. While lobsters were shown to be a significant part of the diet of monk seals around Laysan, the plan simply assumed that not to be the case for the rest of the area. The MMPA and ESA issues were recognized, but the only action taken with respect to them in the plan was inclusion of gear regulations intended to prevent incidental catch of seals.

The council assumed that it did not have responsibility for demonstrating plan compliance with the MMPA and ESA, but instead that other agencies must document that the plan does not comply before the council needed to take action responding to the MMPA or ESA.

The spiny lobster plan illustrated the problem of resource management with insufficient data. In this case the best available scientific information is not sufficient to indicate the importance of spiny lobsters in Hawaiian monk seal diet, or the extent to which local lobster stocks depend on spawning around other islands. Both of these unknown relationships influence the impact of a lobster fishery on monk seals. The plan recommendation to increase fishery levels and try to monitor the impacts on monk seals through observations of their population dynamics implied that resource exploitation should continue until an adverse impact on monk seals was demonstrable, at which time the ESA and MMPA protection of the seals would require changes in the fishery. However, because monk seals are long lived, it is quite possible that by the time a decline in total population numbers could be observed and documented, severe reductions in population numbers would be unavoidable. The council has acted on the premise that because a risk to monk seals of greatly intensified lobster fishing has not been demonstrated by an agency such as the Marine Mammal Commission, that increased harvesting should proceed. The council could have chosen to delay greatly increased harvesting until such time as its safety, that is a low risk of impact to monk seals, could be documented. One possible alternative approach, with a greater ecological safety margin, would have been to increase fishing intensity gradually and only when a low risk of affecting monk seal populations could be demonstrated. The latter approach would shift the burden of proving that a particular level of resource utilization is compatible with the ecosystem conservation intent of environmental legislation onto the exploiters of the resource. The risk of adverse impact on seals could have been reduced through measures designed to allow only a very slow growth of the fishery.

Summary: While the spiny lobster plan recognized the application of the ESA and MMPA as well as the FCMA, recommended lobster catch regulations reflected concern with direct interaction between fishermen and seals, but not with assuring low risk of adverse impacts on seal populations. Analysis of this plan illustrates that different management approaches can be based on interpretation of the same best available scientific information.

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APPENDIX G

FISHERY YIELD CONCEPTS

Maximum Sustainable Yield (MSY) is defined as "the greatest harvest that can be taken from a self-regenerating stock of animals year after year while maintaining constant average size of the stock" (Holt and Talbot, 1978). Important elements of this definition include the concept of sustainability, i.e., a level of harvest that can be maintained year after year because it does not affect the average abundance of the resource, and the concept of maximization, i.e., conditions that produce the greatest sustainable yield. The MSY concept applies only to stocks that are self-renewing. In practice this means that management for MSY should cover all or almost all of a breeding population.

The MSY concept is derived from hypotheses supported to some extent by observation. The fundamental assumption is that an animal population increases rapidly when the initial population size is small, but that the rate of increase slows as the population size increases, until a point is reached at which the rate of increase is zero and the population size remains steady. The graph of such a population size against time is an S-shaped or sigmoid growth curve. When the population size ceases to grow, births and deaths still occur, but losses from the population are exactly replaced by additions to it.

Another assumption associated with MSY calculation is that the population size at which birth and death rates balance in an unexploited population is the carrying capacity, or the population size which the environment can support. Populations which have never been exploited are assumed to be at carrying capacity. Since it depends on the condition of the habitat, carrying capacity can change over time in response to environmental changes such as climate variation, pollution, etc. When exploitation begins the average standing stock of a resource population will be reduced and will fall below the carrying capacity level.

The relationship of birth and survival rates to population size is assumed to be a density dependent one. This means that birth and/or survival rates are higher when total population is lower. Higher birth or survival rates may result from more favorable conditions due to less crowding, from behavioral responses, or from increased food availability in proportion to number of individuals in the population. (A given amount of food divided ten ways provides a larger individual portion than if it were divided among a hundred members of a population).

A population of a given size can have either few births and deaths (low turnover), or many births and deaths (high turnover). The turnover rate is a replacement rate for a population. A high turnover rate generally implies more production available to the ecosystem of which the population is a part, since most deaths are due to predation and provide food for other elements of the ecosystem.

The density of a stock is its standing population size per unit area. When the density of a population falls below carrying capacity, according to the theory underlying MSY, birth rate (not necessarily the total number of births) and survival rate increase and exceed the death rate. The rate at which new individuals in a population enter a given age class (e.g., 2 year olds or adults) or size class (e.g., longer than 10 cm.) is called recruitment to that class and depends on the combination of birth rate and rate of survival to the given age or size. When recruits outnumber losses for an age or size class, either the surplus can be removed by harvesting and the population level will remain below carrying capacity, or the surplus will increase standing population size until recruitment and death rates are once again in balance. If harvesting removes exactly the surplus of recruits over deaths, then the average population size will not change, the surplus will be the same the following year, and that level of harvest can be sustained. The population level at which the surplus of recruits over deaths for the total population is greatest, is the population level producing MSY. This approach assumes that environmental conditions remain constant.

When the size of a population is not changing, it is in equilibrium with the combination of environmental conditions and harvesting pressure. Equilibrium yield (EY), also known as replacement yield, is the level of harvesting that removes the surplus of births over deaths without changing population size. Depending on the size of the population, EY can be greater than, less than, or equal to MSY. EY is sustainable yield for the population at a particular abundance level; EY varies with time because population size varies with time. MSY is achieved at only one of a possible range of population sizes, and, conceptually, is constant for a given carrying capacity.

Using highly simplified birth, survival and death rate assumptions, the MSY population for "r selected" species is estimated to be half of carrying capacity. Frequently the MSY level is assumed to be between 40% and 60% of carrying capacity (Holt and Talbot, 1978.) The relative size of MSY level and carrying capacity appears to vary with the species being harvested. For marine mammals, for which simplified sigmoid population growth curve assumptions are not appropriate, MSY population levels have been estimated to be higher than 60% of carrying capacity (Fowler, et al., 1978). When enough information is available on the biological characteristics of a population to make more realistic assumptions about its growth rate, then MSY can be determined more accurately.

Assumptions underlying MSY calculations are that:

1. the stock is self-contained;

2. the stock was at carrying capacity before exploitation began;

3. there are no significant changes in carrying capacity during the period of exploitation:

4. the kind of density dependence of reproduction, growth and/or natural mortality, and any time lags in the stock's response to exploitation, will not cause fluctuations of large amplitude in the stocks; and

5. the process of reducing the 'initial' stock by exploitation is reversible.

These assumptions are very difficult to test and overly simplistic (Holt and Talbot, 1978).

Methods for calculating sustainable yields from a population of a single species are well developed. The method used in a particular case depends on which assumptions are applicable for the patterns of recruitment, growth, natural mortality, fishing mortality, and fishing effort (Ricker, 1975).

Data for estimating rates of natural and fishing mortality come from mark-recapture experiments, size or age composition of fishery catch, or the relation of fishery success to effort (catch per unit effort). Estimates of recruitment or growth rate are derived similarly, and may have additional information from life history or physiology of the species, e.g., how many eggs a gravid female produces. It is important to note that most of the data on which fishery yield calculations are based come from fishing. When exploitation of a population stops, there is no longer as much information on the condition of the stock.

If data are not sufficient to base MSY calculations on various population models with well defined assumptions about growth and mortality rates, then sustainable yield levels are estimated through a process of educated guessing and experience. Yield estimates can be based on the apparent effects, or lack of them, on a stock of recent or historic catches. This is dangerous since "effects" may not be apparent if substantial time lags are involved. Yield estimates might also be based on information about the life history of the target species, or on the basis of experience with similar species, or the same species in a different area.

Traditional yield calculations are very much single species oriented. They depend on the assumptions that the environment remains constant and that natural mortality rate (M) also remains constant. Natural mortality rate is that from all causes except fishing. Natural mortality results from predation, disease, old age, pollution, etc. In a healthy ecosystem, predation is such a large component of natural mortality that M can be used as an estimate of predation rate. In MSY calculations M is assumed to remain constant. This implies that predation rate is independent of predator abundance, an unrealistic assumption. However, even if M does remain constant, the total food available to predators may vary. M is a rate analogous to interest rate on a savings account. While the interest rate may remain constant, accumulated interest for a year very much depends on the amount of principal in the account. Half the principal earns half the interest with the same interest rate. Similarly, even if mortality rate remains constant for a fished population, the fact that the fishery usually reduces the average standing stock of the population means that the annual total consumed by predators may be likewise reduced. With reduced food the predator population may shift to other prey or become reduced in size.

Another problem with the constant M assumption is that it does not take into account the time required for a predator population to adjust to changes in density of its prey. Marine mammals, for example, might respond to a long term reduction in available food through lower survival of pups and/or other age classes, older age of first reproduction, longer intervals between births for adult females, and eventually a lower overall population size. Such population responses are slow, not immediate as assumed in the MSY concept. The time required for adjustment to changed environmental conditions is called a time lag. During the adjustment process, the relatively overabundant predators can put unusual stress on prey populations. For long lived predators such as marine mammals, consideration of adjustment time lags is essential for realistic management (May, et al., 1979).

The assumptions underlying MSY are particularly strained when more than one stock is fished in a given area. Stock recruitment relationships are affected both by the changes in the environment and by fishing on other stocks in the same ecosystem (Gulland, 1978).

Ecological problems with MSY derive from its concentration on only the stock, excluding the factors of competition or relationships between trophic levels, the impacts of symbiotic or commensal relationships, and environmental changes such as climate, pollution, or other human influences which affect changes in carrying capacity (Holt and Talbot, 1978).

The concept of MSY as a function of stock size alone was developed to provide an approximate description of the response of a stock to exploitation. It has been useful as a teaching aid and in providing a very preliminary conservation criterion for avoiding or correcting overexploitation. The MSY concept has been a useful simplified model for understanding wild populations. However, it has become institutionalized and is playing a more absolute role than is justified. It was never intended as the sole conceptual basis for management. Unfortunately, MSY has become an obstacle to accepting concepts derived from more detailed ecological information that could provide a more adequate management basis. In particular, a more adequate basis is necessary when human impacts on the biosphere are increasing and diversifying (Holt and Talbot, 1978).

The MSY concept has shortcomings, but it has focused management on long term and sustainable yields, considering the future, as well as on an exploitation level that definitely cannot be exceeded without depleting the resource stock. The MSY concept is not applicable in situations of harvesting both predator and prey. In such cases time scales and trophic interactions become very important (May, et al., 1979).

If enough assumptions are made about population dynamics, recruitment and mortality rates, and fishing effort on a stock, then population models exist which provide formulas for the calculation of sustainable yields (MSY or EY) Ricker, 1975). However, maintenance of existing population sizes or highest sustainable yields may not always be appropriate management objectives.

Acceptable Biological Catch (ABC) may be greater or less than MSY on the basis of biological considerations such as fluctuating recruitment in stock or allowing depleted stocks to increase. ABC estimates depend on scientific or managerial judgement in addition to formulated calculations.

MSY is a single species management concept. One problem that has been apparent with MSY is the difficulty of estimating and attaining it in practice. Such difficulty has arisen in part from incomplete data, in part from the tendency of fisheries to become overcapitalized and hence reluctant to remain at specified catch levels, and in part from failure of the oversimplified assumptions underlying MSY calculations. However, there are conceptual as well as practical problems with MSY. In a multi-species fishery situation with various ecological interactions among resource populations to be taken into account, MSY for each species is no longer an appropriate management goal.

Replacement of MSY as a management concept will not be simple. Sustainable yield calculations that incorporate impacts of a fishery on the ecosystem as well as on the stock itself, and that allow for the impacts on alternate prey of a shift in predation pressure, will be more complicated than MSY calculations because they will involve more variables. More realistic treatment of natural mortality is a good starting place for departure from present MSY theory. New theories should incorporate the effects of a fishery on predators, as well as the effects of predators on a changing fishery stock. Incorporation of more realistic predator prey interactions will be a step toward whole ecosystem considerations in fisheries management.

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APPENDIX H

MARINE MAMMALS IN THE U. S. FCZ

Provisional List of Common, Rare, and Threatened or Endangered Species of Marine Mammals by Council Area

(In many cases the distribution, biology, ecology, and population status of marine mammals are poorly known. It is likely that this list should be modified and enlarged.)

Relatively Common Species	Relatively Rare Species	Threatened or Endangered Species
	NORTH PACIFIC COUNCIL	
minke whale	Baird's beaked whale	bowhead whale
killer whale	common dolphin	sei whale
belukha whale	short-finned pilot whale	blue whale
Pacific white-sided dolphin	Risso's dolphin	fin whale
harbor porpoise	bottlenose whale	gray whale
Dall's porpoise	northern right whale dolphin	right whale
bottlenose dolphin	Stejneger's beaked whale	humpback whale
northern fur seal	narwhal	sperm whale
bearded seal	false killer whale	
Steller sea lion	striped dolphin	
walrus	Cuvier's beaked whale	
ribbon seal	hooded seal	
ringed seal	northern elephant seal	
larga seal		
harbor seal		
sea otter		
polar bear		

Relatively Common Species	Relatively Rare Species	Threatened or Endangered Species

PACIFIC COUNCIL

Relatively Common Species	Relatively Rare Species	Threatened or Endangered Species
minke whale	Bryde's whale	sei whale
killer whale	Baird's beaked whale	blue whale
common dolphin	pygmy killer whale	fin whale
short-finned pilot whale	Risso's dolphin	gray whale
long-finned pilot whale	dwarf sperm whale	right whale
Pacific white-sided dolphin	shortsnouted dolphin	humpback whale
northern right whale dolphin	Hubb's beaked whale	sperm whale
harbor porpoise	dense-beaked whale	Guadalupe fur seal
Dall's porpoise	ginkgo-toothed whale	sea otter
bottlenose dolphin	Stejneger's beaked whale	
Cuvier's beaked whale	false killer whale	
northern fur seal	spinner dolphin	
Steller sea lion	bridled dolphin	
northern elephant seal	striped dolphin	
harbor seal	spotted dolphin	
California sea lion	rough-toothed dolphin	

CARIBBEAN COUNCIL

Relatively Common Species	Relatively Rare Species	Threatened or Endangered Species
minke whale	pygmy killer whale	sei whale
killer whale	pygmy sperm whale	blue whale
common dolphin	dense-beaked whale	fin whale
short-finned pilot whale	false killer whale	right whale
Risso's dolphin	spinner dolphin	humpback whale
harbor porpoise	bridled dolphin	sperm whale
bottlenose dolphin	striped dolphin	West Indian manatee
Cuvier's beaked whale	spotted dolphin	
	rough-toothed dolphin	

Relatively Common Species	Relatively Rare Species	Threatened or Endangered Species

NEW ENGLAND COUNCIL

minke whale	short-finned pilot whale	sei whale
killer whale	bottlenose whale	blue whale
common dolphin	pygmy sperm whale	fin whale
long-finned pilot whale	dwarf sperm whale	right whale
Risso's dolphin	Atlantic white-sided dolphin	humpback whale
harbor porpoise	white-beaked dolphin	sperm whale
bottlenose dolphin	Sowerby's beaked whale	
grey seal	dense-beaked whale	
harbor seal	True's beaked whale	
	false killer whale	
	bridled dolphin	
	striped dolphin	
	Cuvier's beaked whale	
	hooded seal	
	harp seal	

MID-ATLANTIC COUNCIL

minke whale	Bryde's whale	sei whale
killer whale	pygmy killer whale	blue whale
common dolphin	long-finned pilot whale	fin whale
short-finned pilot whale	pygmy sperm whale	right whale
Risso's dolphin	dwarf sperm whale	humpback whale
harbor porpoise	Atlantic white-sided dolphin	sperm whale
bottlenose dolphin	dense-beaked whale	
Cuvier's beaked whale	Gervais' beaked whale	
harbor seal	True's beaked whale	
	false killer whale	
	spinner dolphin	
	bridled dolphin	
	striped dolphin	
	spotted dolphin	
	rough-toothed dolphin	
	hooded seal	
	gray seal	
	harp seal	

Relatively Common Species	Relatively Rare Species	Threatened or Endangered Species
SOUTH ATLANTIC COUNCIL		
minke whale	Bryde's whale	sei whale
killer whale	pygmy killer whale	blue whale
common dolphin	long-finned pilot whale	fin whale
short-finned pilot whale	Risso's dolphin	right whale
harbor porpoise	pygmy sperm whale	humpback whale
spotted dolphin	dense-beaked whale	sperm whale
bottlenose dolphin	Gervais' beaked whale	West Indian manatee
Cuvier's beaked whale	True's beaked whale	
harbor seal	false killer whale	
	spinner dolphin	
	bridled dolphin	
	striped dolphin	
	rough-toothed dolphin	
	hooded seal	
GULF OF MEXICO COUNCIL		
minke whale	Bryde's whale	sei whale
killer whale	pygmy killer whale	blue whale
common dolphin	Risso's dolphin	fin whale
short-finned pilot whale	dwarf sperm whale	right whale
pygmy sperm whale	dense-beaked whale	humpback whale
harbor porpoise	Gervais' beaked whale	sperm whale
spotted dolphin	false killer whale	West Indian manatee
bottlenose dolphin	spinner dolphin	
Cuvier's beaked whale	bridled dolphin	
	striped dolphin	
	rough-toothed dolphin	

Relatively Common Species	Relatively Rare Species	Threatened or Endangered Species
	WESTERN PACIFIC COUNCIL	
minke whale	Baird's beaked whale	sei whale
killer whale	belukha whale	blue whale
common dolphin	pygmy killer whale	fin whale
short-finned pilot whale	Risso's dolphin	right whale
harbor porpoise	pygmy sperm whale	humpback whale
bottlenose dolphin	dwarf sperm whale	sperm whale
Cuvier's beaked whale	shortsnouted dolphin	Hawaiian monk seal
northern fur seal	northern right whale dolphin	dugong
	dense-beaked whale	
	false killer whale	
	spinner dolphin	
	bridled dolphin	
	striped dolphin	
	rough-toothed dolphin	

Descriptive Information for Marine Mammals in the U. S. Fishery Conservation Zone

Species	Distribution	Councils	Food Items	Relative Abundance	References
LARGE CETACEANS					
Balaena mysticetus bowhead whale	Arctic, Chukchi, Bering, Beaufort Seas	NP	copepods and amphipods	endangered	3,4,13,18
Balaenoptera acutorostrata minke whale	oceanic	all	euphausiids, cod, copepods, sardines, sandlance, pollock, mackerel, saury and squid	common some areas	8,9,11,12, 13,14
Balaenoptera borealis sei whale	oceanic	all	calanus, euphausiids, small schooling fish	endangered	5,8,9,11,12 13,14,18
Balaenoptera edeni Bryde's whale	tropical Atlantic and Pacific	PA,MA,SA, GM			8,11,14,16
Balaenoptera musculus blue whale	oceanic	all	small euphausiids, occasional small fish	endangered	5,7,8,9,11, 12,14,17,18
Balaenoptera physalus fin whale,	oceanic	all	lanternfish, squid, euphausiids, herring, copepods, small pelagic fish	endangered	3,5,7,8,9, 11,12,14,17, 18

Species	Distribution	Councils	Food Items	Relative Abundance	References
Eschrichtius robustus gray whale	eastern Pacific	PA,NP	copepods, small schooling fish, herring eggs, sea cucumbers	endangered	3,5,7,8,12 18
Eubalaena glacialis right whale black right whale northern right whale	oceanic	all	copepods, euphasiids	endangered	3,7,8,9,11, 14,18
Megaptera novaeangliae humpback whale	oceanic	all	planktonic crustaceans, some cod	endangered	3,5,7,8,9, 11,12,13,14, 18
Orcinus orca killer whale	oceanic	all	flatfish, sardine, salmon, squid, cod, large fish, whales, dolphins, tuna, seals	common most areas	2,7,8,9,11, 12,13,14,17
Physeter catodon sperm whale	all oceans except Polar ice fields	all	cephalopods, midwater and benthic fish	endangered	2,3,5,7,8, 9,11,12,13, 14,18
SMALL CETACEANS					
Berardius bairdii Baird's beaked whale North Pacific giant bottle-nosed whale	offshore, Bering Sea to S. California	NP,PA,WP	benthic and midwater fish and cephalopods, occasional benthic animals	not very abundant	7,8,11,12, 14

Species	Distribution	Councils	Food Items	Relative Abundance	References
Delphinus delphis common dolphin white-bellied porpoise saddleback dolphin	Atlantic and Pacific, warm temperate climate; pelagic	all	schools of migrating fish, herring, hake, sardines, lanternfish, anchovies, squid	Atlantic 30,000	8,9,11,12, 14,17
Delphinapterus leucas beluga whale belukha whale white whale	Arctic ocean south to 50°N	NP,NE	halibut, flounder, cephalopods, squid, other fish, shrimp, crab	several thousand	3,4,5,7,9, 12
Feresa attenuata pygmy killer whale	tropical and warm temperate, Atlantic and Pacific	PA,WP,MA, SA,GM,CA	probably squid	rare	8,11,12,14, 17
Globicephala macrórhynchus short-finned pilot whale pilot whale	Pacific and Atlantic, tropical and warm temperate, inshore and offshore	all	squid and schooling fish	common Florida, Caribbean	8,9,11,12, 14,17
Globicephala melaena long-finned pilot whale	cool temperate, N. Atlantic; Pacific West Coast	PA,NE,MA SA	squid *(Illex)*, cod, turbot	common north of Cape Hatteras; Newfoundland Stock 50,000	9,11,14
Grampus griseus Risso's dolphin gray grampus	shelf, Gulf of Alaska; all temperate and tropical seas	all	small squid	rare; regularly seen east coast in summer	7,8.9.11, 12,14

Species	Distribution	Councils	Food Items	Relative Abundance	References
Hyperoodon ampullatus northern bottlenose whale; north Atlantic bottlenose whale; bottlenose whale	Bering Sea, N. Atlantic	NP,NE	squid; wide variety; fish, benthos	occasional; common north of Nova Scotia	9,11,12,14
Kogia breviceps pygmy sperm whale	Florida to Massachusetts, Gulf of Mexico	NE,MA,WP, GM,SA,CA	squid, crabs, and shrimp	rare; common Texas coast	9,11,12,14, 17
Kogia simus dwarf sperm whale	Hawaii, California, eastern U.S.	PA,WP,NE, MA,GM		rare	8,9,11,14, 17
Lagenodelphis hosei shortsnouted white-bellied dolphin; Fraser's dolphin	eastern tropical Pacific	PA,WP		common some areas	11,14
Lagenorhynchus acutus Atlantic white-sided dolphin	offshore, New England	NE,MA	squid, herring, silver hake, smelt	variable	9,11,14
Lagenorhynchus albirostris white-beaked dolphin	Cape Cod north; Gulf of Maine	NE	squid, cod, capelin, herring, pelagic and bottom fish, small crustaceans		9

Species	Distribution	Councils	Food Items	Relative Abundance	References
Lagenorhynchus obliquidens Pacific white-sided dolphin	coastal, Alaska to Baja, Calif.	NP,PA,WP	midwater fish, sardines, squid, anchovy, saury	abundant, California current	7,8,11,12, 14
Lissodelphis borealis northern right whale dolphin	shelf, Gulf of Alaska, north Pacific, Kurils to California and British Columbia	NP,PA,WP	squid and pelagic fish	abundant off California; rare Oregon, and Washington	7,8,11,12, 14
Mesoplodon bidens Sowerby's beaked whale, North Sea beaked whale	Massachusetts east	NE		rare	9,11,14
Mesoplodon carlhubbsi Hubb's beaked whale arch-beaked whale	offshore, Calif. to British Columbia	PA		rare	8,11,14
Mesoplodon densirostris Blainville's beaked whale dense-beaked whale	tropical and warm temperate, all oceans	PA,WP,NE, MA,SA,GM, CA		rare	8,9,11,14
Mesoplodon europaeus Gervais' beaked whale Gulf stream beaked whale	New York to Gulf of Mexico	MA,GM,SA		occasional stranding	9,11,14,17

Species	Distribution	Councils	Food Items	Relative Abundance	References
Mesoplodon ginkgodens ginkgo-toothed whale	California current	PA		rare	8
Mesoplodon mirus True's beaked whale	Florida north	NE,MA,SA		some strandings	9,11,14
Mesoplodon stejnegeri Stejneger's beaked whale Bering Sea beaked whale saber toothed whale	Bering Sea to Oregon	NP,PA		rare	3,7,8,11,14
Monodon monoceros narwhal	Arctic ocean	NP	flounder, rockfish, squid, cod, shrimp, crab	rare	12,13
Phocoena phocoena harbor porpoise	coastal north Atlantic, north Pacific	all	herring, cod, sole, crustaceans, squid	common	2,3,7,8,9, 11,12,14
Phocoenoides dalli Dall's porpoise	Alaska to Baja, California, just offshore	NP,PA	squid, schooling fish	frequent California; abundant Bering Sea	3,7,8,11,12, 14
Pseudorca crassidens false killer whale	all temperate and tropical seas	all	squid, large fish		8,11,12,14, 17

Species	Distribution	Councils	Food Items	Relative Abundance	References
Stenella attenuata bridled dolphin	tropical Atlantic and Pacific	PA,WP,MA, SA,GM,CA			11,14
Stenella clymene	Texas coast	GM		rare	17
Stenella coeruleoalba striped dolphin streaker porpoise	Atlantic and Pacific	all	squid *(Loligo)* lanternfish		8,9,11,12 14
Stenella longirostris long-snouted dolphin Spinner dolphin	tropical Atlantic and Pacific, inshore and offshore	PA,WP,MA, SA,GM,CA			11,14,17
Stenella plagiodon spotted dolphin	warm temperate Atlantic and Pacific	PA,MA,SA, GM,CA	flying fish, herring, anchovies, squid	common Florida and Gulf of Mexico	9,11,14,17
Steno bredanensis rough-toothed dolphin	all tropical warm temperate seas	PA,WP,MA, SA,GM,CA		rare	8,9,11,14
Tursiops truncatus bottlenose dolphin	wide	all	fish,squid, shrimp, trash fish	common	8,9,11,12, 14,17

Species	Distribution	Councils	Food Items	Relative Abundance	References
Ziphius cavirostris Cuvier's beaked whale goose-beaked whale	all temperate and tropical seas; deepwater	all	available fish, cephalopods, benthic crustaceans	most abundant beaked whale	3,7,8,9,11, 14,17
PINNIPEDS					
Arctocephalus townsendi Guadalupe fur seal	Cedros, San Miguel, Guadalupe Islands (California)	PA	probably fish, squid, crustaceans	less than 2000; endangered	1,11,14
Callorhinus ursinus northern fur seal fur seal	Alaska to California breeding; northern Pacific winter and spring	NP,PA,WP	pollock, salmon, cod, herring, other fish, squid	1,300,000	1,3,5,7,12
Cystophora cristata hooded seal bladder nose seal	Alaska; occasionally Maine to Florida	NP,NE,MA, SA		rare	9,13
Erignathus barbatus bearded seal	Bering, Beaufort, Chukchi	NP	shrimp, crabs, clams, octopus, fish, snails, amphipods, isopods	300,000 U.S. and U.S.S.R	3,5,13
Eumetopias jubatus Steller sea lion northern sea lion	Alaska to California	NP,PA	pelagic fish, squid	100,000	1,5,7,11,12, 13,14

Species	Distribution	Councils	Food Items	Relative Abundance	References
Halichoerus grypus gray seal	New Jersey north	NE,MA	available fish, pollock, haddock, flounder, mussels	80 in Maine waters, 12-17 at Nantucket	9,12
Mirounga angustirostris northern elephant seal	Gulf of Alaska to Baja, Calif.	NP,PA	neritic and demersal fish, squid; dives deeply	50,000 to 60,000	1,11,12,14
Monachus schauinslandi Hawaiian monk seal Laysan monk seal	Hawaiian archipelago	WP	lobsters, other benthos	endangered	11,12,14,18
Odobenus rosmarus walrus	Bering, Chukchi Seas, Bay of Fundy	NP	benthic mollusks. shellfish, mussels	200,000	3,9,12,13
Phoca fasciata ribbon seal	Bering, Chukchi Seas	NP	squid ?	90,000 to 100,000 Alaska	3,5,12,13
Phoca groenlandica harp seal	New England coast to Virginia	NE,MA	fish, larger plankton	rare	9,12,13
Phoca hispida ringed seal	Bering, Chukchi, Beaufort Seas	NP	Arctic cod, small fish, euphausiids, amphipods	250,000 to 1,500,000 Alaska	3,5,12,13
Phoca largha larga seal spotted seal	Chukchi, Beaufort, Bering Seas	NP	fish, snails, squid, octopus, crustaceans	200,000 Alaska	2,3,5,11,12, 13,14

Species	Distribution	Councils	Food Items	Relative Abundance	References
Phoca vitulina harbor seal	Alaska to Baja, California; Labrador to Long Island; occasional further south	NP,PA,NE, MA,SA	hake, pollock, herring other fish, squid, bivalves, crustaceans	7,000 Gulf of Maine; 270,000 Alaska; 7,500 Washington to Baja, California	1,3,5,6,7,9, 16
Zalophus californianus California sea lion	British Columbia to Baja, California	PA	squid, fish, octopus, benthic fish, hake, anchovy, herring, salmon, mackerel	80,000 to 125,000	1,12
CARNIVORA					
Enhydra lutris sea otter	Baja, Calif. to Aleutians, Pribilofs	NP,PA	benthic mollusks, echinoderms, demersal fish, mussels, clams, oysters, octopus	threatened in California 100,000 to 150,000 Alaska	3,5,10,11, 14,16,18
Ursus maritimus polar bears	Beaufort, Chukchi Seas, Bering Strait	NP		9,500 Arctic 3,000 Alaska	5,13
SIRENIA					
Trichechus manatus West Indian manatee	Greater Antilles, Bahamas, Florida Keys to Beaufort, N.C,; Gulf of Mexico to Rio Grande	SA,GM,CA	sea grass	endangered	11,14,16,18

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APPENDIX I

GLOSSARY OF TERMS

Acceptable biological catch (ABC):

seasonally determined catch that may differ from MSY for biological reasons. It may be lower or higher than MSY in some years for species with fluctuating recruitment. It may be set lower than MSY in order to rebuild overfished stocks. (North Pacific Council, 1978 DEIS/FMP Groundfish Fishery in the Bering Sea/Aleutian Island Area, p. 5)

Carrying capacity:

population size at which death rate is balanced by recruitment (for an undisturbed population); initial size of a renewable resource population before exploitation by man. (Holt and Talbot, 1971, p. 22.)

upper asymptote of the sigmoid growth curve (simple logistic model); where N = population size number; r = intrinsic rate of increase; k = carrying capacity; t = time then

$$\frac{dN}{dt} = rN(1 - N/k)$$

(Odum, 1971, p, 183)

Conservation:

wise use, including keeping for future use. (Holt and Talbot, 1978, p. 7)

(1) insuring the preservation of a quality environment that considers esthetic and recreational as well as product needs, and (2) insuring a continuous yield of useful plants, animals, and materials by establishing a balanced cycle of harvest and renewal. (Odum, 1971, p. 408)

Conservation and management:

all of the rules, regulations, conditions, methods, and other measures (a) which are required to rebuild, restore, or maintain, and which are useful in rebuilding, restoring, or maintaining any fishery resource and the marine environment; and (b) which are designed to assure that:

(i) a supply of food and other products may be taken and that recreational benefits may be obtained on a continuing basis;

(ii) a irreversible or long-term adverse effects on fishery resources and the marine environment are avoided; and

(iii) there will be a multiplicity of options available with respect to future uses of these resources. (Fishery Conservation and Management Act, 1976)

Conservation principles:

The privilege of utilizing a resource carries with it the obligation to adhere to the following four general principles:

1. The ecosystem should be maintained in a desirable state such that
   a) consumptive and non consumptive values could be maximized on a continuing basis,
   b) present and future options are ensured, and
   c) risk of irreversible change or long-term adverse effects as a result of use is minimized.
2. Management decisions should include a safety factor to allow for the facts that knowledge is limited and institutions are imperfect.
3. Measures to conserve a wild living resource should be formulated and applied so as to avoid wasteful use of other resources.
4. Survey or monitoring, analysis, and assessment should precede planned use and accompany actual use of wild living resources. The results should be made available promptly for critical public review. (Holt and Talbot, 1978, p. 14 - 15)

Equilibrium yield (EY):

the yield in weight taken from a fish stock when it is in equilibrium with fishing of a given intensity, and (apart from effects of environmental variation) its biomass is not changing from one year to the next. (Ricker, 1975, p. 3)

the annual or seasonal harvest which allows the stock to be maintained at approximately the same level of abundance (apart from the effects of environmental variation) in succeeding seasons or years. (North Pacific Council, 1978 DEIS/FMP Groundfish Fishery in the Bering Sea/Aleutian Island Area, p. 5)

Maximum net productivity (MNP):

the greatest net annual increment in population numbers or biomass resulting from additions to the population due to reproduction and/or growth less losses due to natural mortality. (NMFS operational definition, 50 CFR 216.3)

Maximum sustainable yield (MSY):

the largest average catch or yield that can continuously be taken from a stock under existing environmental conditions. (Ricker, 1975, p. 4)

the greatest harvest that can be taken from a self-regenerating stock of animals year after year while still maintaining a constant average size of the stock. (Holt and Talbot, 1978, p. 22)

Natural mortality:

deaths from all causes except man's fishing, including predation, senility, epidemics, pollution, etc. (Ricker, 1975, p. 5)

Optimum carrying capacity:

the ability of a given habitat to support the optimum sustainable population of a species or population stock in a healthy state without diminishing the ability of the habitat to continue that function. (Marine Mammal Protection Act, 1972)

Optimum sustainable population (OSP):

the number of animals which will result in the maximum productivity of the population or the species, keeping in mind the optimum carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element. (Marine Mammal Protection Act, 1972)

range of population levels with the upper limit being the average carrying capacity of the habitat and the lower limit at the MSY level. (At present this appears to best satisfy MMPA criteria of maximum productivity, healthy state, health and stability of the ecosystem, and maintenance of populations as significant functioning elements within the ecosystem. With more information, the range could be narrowed.) (Marine Mammal Commission, 1976, p. 7)

a population size which falls within a range from the population level of a given species or stock which is the largest supportable within the ecosystem to the population level that results in maximum net productivity. (NMFS operational definition 50 CFR 216.3)

Optimum yield:

the amount of fish (a) which will provide the greatest overall benefit to the nation with particular reference to production and recreational opportunities, and (b) which is prescribed as such on the basis of maximum sustainable yield from such fishery as modified by any relevant

Optimum yield continued:

economic, social, or ecological factor. (Fishery Conservation and Management Act, 1976)

a plus or minus deviation from ABC for purposes of promoting economic, social, or ecological objectives as established by law and public participation processes. Ecological objectives, where they primarily relate to biological purposes and factors, are included in the determination of ABC. Where biological objectives relate to resolving conflicts and accommodating competing uses and values, they are included as appropriate with economic and/or social objectives. (North Pacific Council, 1978 DEIS/FMP Groundfish Fishery in the Bering Sea/Aleutian Island Area, p. 5 - 6).

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APPENDIX J

GLOSSARY OF ACRONYMS AND SYMBOLS

Legislation:

ESA - Endangered Species Act
FCMA - Fishery Conservation and Management Act
MMPA - Marine Mammal Protection Act
NEPA - National Environmental Policy Act

Agencies:

CEQ - Council on Environmental Quality
EPA - Environmental Protection Agency
ICNAF - International Commission on North Atlantic Fisheries
IWC - International Whaling Commission
NMFS - National Marine Fisheries Service
NOAA - National Oceanic and Atmospheric Administration

Terms:

ABC - Acceptable Biological Catch
DYNUMES - Dynamic Numerical Marine Ecosystem Model
EIS - Environmental Impact Statement
EY - Equilibrium Yield
FCZ - Fishery Conservation Zone
FMP - Fishery Management Plan
MNP - Maximum Net Productivity
MSY - Maximum Sustainable Yield
OSP - Optimum Sustainable Population
OY - Optimum Yield
PMP - Preliminary Management Plan
SSC - Scientific and Statistical Committee
TALFF - Total Allowable Level of Foreign Fishing

Symbols:

B_o - initial biomass

$\bar{B}$ - average biomass

F - fishing mortality rate

G - somatic growth rate

M - natural mortality rate

APPENDIX K

SUGGESTED REVISIONS OF NMFS GUIDELINES FOR DEVELOPMENT OF FISHERY MANAGEMENT PLANS

These suggested revisions apply to NMFS Guidelines (42 FR 34588, July 5, 1977). Suggested additions are underlined. No deletions are suggested.

602.2.d.3. *Interrelationship of species/habitat.* The broad, long term goal of the several plans developed by each Council should be to optimize the benefits from the total weight of all forms of marine animal and plant life, <u>including both target and nontarget species and the health of the ecosystem</u>, within the Council area of authority.

602.3.b.5.iii. *Ecological relationships.* Describe the relationship of the stocks <u>with marine mammals, endangered species, and significant nontarget fish, animals, or plants of commercial, aesthetic, recreational, or ecosystem health value</u>, including discussions of relevant food chain and predator prey relationships. <u>The description shall include, where applicable</u>:

(A) <u>diagrams of food web interactions and/or other important ecological interactions</u>;

(B) <u>a quantitative analysis of significant predator prey interactions and likely responses to changes in densities of predators or prey</u>;

(C) <u>an evaluation of the status of marine mammal populations in relation to optimum carrying capacity and maximum productivity, or an indication of the information required to make such an evaluation if not presently possible</u>;

(D) <u>a description of the relationship of the fishery to endangered species population status and recovery plans, or an indication of the information required for such a description if not now possible</u>; <u>and</u>

(E) <u>an assessment of the health of the marine ecosystem, including diversity, stability, and resilience, with respect to the combined impacts of all harvesting, pollution, and other significant impacts such as other human activities or climate variations</u>.

602.3.b.12.ii *Description of alternatives.* Describe the alternative optimum yields considered and their advantages and disadvantages to marine mammals, endangered species, and other significant nontarget species, as well as to target species and the fishing industry.

602.3.b.12.iii. *Analysis of beneficial and adverse impacts of potential management options.* In considering various conservation and management measures in order to determine which are necessary and appropriate for the conservation of the fishery resource, management of the fishery, and to achieve the optimum yield, the beneficial and adverse impacts of such measures, along with an assessment of the associated probability of those impacts, must be analyzed. These impacts should be identified and described, to the extent possible in summary form.

602.3.b.12.iv. *Tradeoffs between the beneficial and adverse impacts of the preferred or optimal management options.* Conservation and management measures shall be identified which are deemed by the Council to be the preferred or optimal means of achieving optimum yield. Such measures will, in all likelihood, contain or represent trade-offs between the specific management objectives identified in the plan. It may not be feasible or possible to optimize each management objective as some may contain unavoidable conflicting aspects. The trade-offs between the beneficial and adverse ecological, social and economic impacts of the preferred or optimal management options and an evaluation of the acceptability of the level of risk of adverse impacts should be described in summary form.