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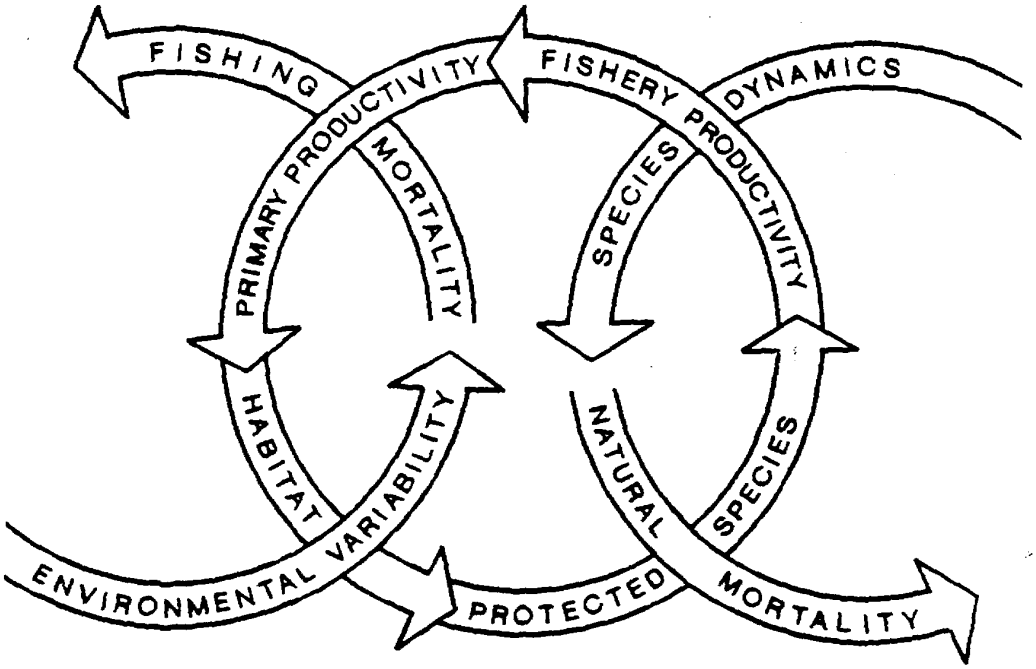
NOAA

NATIONAL MARINE FISHERIES SERVICE

PROGRAM DEVELOPMENT PLAN

FOR

ECOSYSTEMS MONITORING AND FISHERIES MANAGEMENT



DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NATIONAL MARINE FISHERIES SERVICE

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Executive Summary

All living marine organisms are part of biologically and environmentally linked species groups which comprise an interdependent system (loosely termed a marine ecosystem). Stocks within a marine ecosystem fluctuate considerably and in many cases change over periods of decades even without a commercial fishery. These fluctuations are affected by environmental processes and resulting ecological perturbations, as well as by the direct influence of a fishery, habitat alterations and pollution. Consequently, more attention needs to be focused on the fact that there are pronounced natural fluctuations in the productivity potential/recruitment success of stocks, which appear in subsequent years as variations in population abundance. These variations occur under certain environmental conditions, and usually involve a change in dominance of one species over another.

Just as most species are not harvested in isolation, they cannot be managed in isolation. The manager must understand inter-species relationships if he is to manage interrelated fisheries. This includes understanding the nature of normal variations in abundance of individual stocks. Assessment of these factors is dependent upon having a well structured and integrated research program that is directed at generating knowledge about biological, oceanographic, and economic processes associated with living marine resources. The interrelationships that exist between these processes requires that a holistic approach be taken in examining them.

A holistic approach to research, monitoring, and management of living marine resources is now feasible because of advances in technology and systems modeling methods. These technological advances along with demands for more sophisticated information to support conservation and management have made it timely for a shift in Federal living marine resource program efforts toward a multi-species/ecosystem approach.

The objective of this Ecosystem Monitoring and Fisheries Management Program initiative is to orient the NOAA living marine resource research and management program to a multi-species/ecosystem approach which provides a forecasting capability, while continuing to meet legislative mandates and the ongoing support needs of Federal regulatory processes.

Program efforts required for increasing the level of living marine resource monitoring and management to that of an ecosystem approach will be built upon the existing core NMFS program base which presently supports traditional single-species focused living marine resource management. Routine fishery monitoring and research activities within the proposed core NOAA fisheries program will continue to provide the minimum level of information necessary to meet immediate management needs. However, the core program will be adjusted so that its data products are complementary to the research proposed in this ecosystem program initiative.

Seven regional marine ecosystems (RMEs) within U.S. jurisdiction and/or containing resources of interest to the U.S. provide the conceptual and structural framework for development of the NOAA program for ecosystem monitoring and fisheries management:

- o North Atlantic Shelf
- o South Atlantic and Gulf of Mexico Shelf
- o Atlantic Oceanic
- o California Current
- o Pacific Oceanic
- o Gulf of Alaska and Bering Sea
- o Antarctic

In most instances, these RMEs are not "closed" systems with distinct boundaries. In fact, the boundaries of these systems may be constantly changing horizontally and vertically in response to short term or local natural and/or human induced perturbations in oceanographic features.

The RMEs will serve as the basic planning units for the ecosystem focused management approach. A hierarchy of objectives will be established for each regional marine ecosystem, its species groups/ecological units, and for the science program for each of these units. Consequently, the RMEs will be the basis for program development and management and the framework for reporting under the NOAA management by objectives (MBOs) system.

Program development plans (PDPs) will be developed for each ecosystem planning unit. These will identify information needs, focus program efforts, and provide a basis for managing program implementation for the various species groups/ecological units comprising each RME.

The NOAA fisheries program will utilize ecosystem models to more effectively direct research and data collection efforts toward achieving a better understanding of the physical, ecological, and human systems surrounding the Nation's fisheries. Ecosystem modeling will provide a conceptual framework for increasing our understanding of the environmental reality/complexity of the living marine resources we are mandated to manage. In addition, ecosystem based models will be used to provide the conceptual framework for focusing and integrating fisheries research and data collection efforts among the NOAA components and other Federal and state agencies and academia. Natural species groupings/ecological units will also provide the data basis for multi-species Fishery Management Plans (FMPs) developed by the Regional Fishery Managenent Councils. This will provide for consistency of management decisions with the ecosystem framework and allow full utilization of the forecasting capabilities provided by associated models and data bases. Ecosystem models will also provide the context for protected species management regimes and recovery plans.

NMFS program management and technical representives will participate in the program planning for the Climate and Global Change initiative and related activities to ensure the types of remote sensors, temporal and spatial resolution of data collection and experimental designs, and data sets and management/access systems are appropriate for ecosystem modeling and monitoring needs.

The shifting of NOAA's fisheries program focus towards an ecosystem approach to living marine resource research and conservation and management is intended to accomplish the following:

- Provide a conceptual framework for integration of the NOAA fisheries ecosystem program.
- Facilitate access to/utilization of existing and future NOAA oceanographic, atmospheric monitoring and data management capability.
- Improve the value/cost of living marine resource management information.
- Provide for pro-active management through development of a forecasting/prediction capability.
- Provide whole-system (ecologically comprehensive) approaches which provide guidance for resource managers.

The elements outlined in this program development plan (PDP) do not constitute a stand-alone program. Instead, they represent the supplementary and complementary program elements needed to effect a transition in focus and capability of the existing NOAA living marine resource science and management program. New program elements will be integrated with ongoing science and management programs to ensure continuity of existing data bases and regulatory regimes.

Existing agency planning and reporting systems will be used for documenting task level program plans and for meeting MBO and other management reporting requirements.

I. Introduction

A. Rationale/justification:

The purpose of this initiative is the orientation of the NOAA fisheries program to encompass a multi-species/ecosystem monitoring and resource management approach and provide the basis for developing a forecasting capability, while continuing to meet legislated mandates (e.g., MFCMA, MMPA, ESA, FWCA, NEPA, etc.). The central concern underlying the desire to shift the focus of NOAA fisheries programs toward one which supports ecosystem monitoring as a basis for fisheries and protected species management and for habitat conservation is the need to develop a capability to forecast changes in these ecosystems. This will permit assessment of the consequence of these changes for species of commercial, recreational, and/or social value. This ecosystem approach will raise Federal research and management efforts to a level of sophistication that will better support both habitat conservation and management of living marine resources.

All living marine organisms are part of biologically and environmentally linked species groups which comprise an interdependent system (loosely termed a marine ecosystem) from which they extract their needs and to which they in turn contribute support for other components. Fluctuations in the biomasses of these organisms is strongly influenced by both internal and external factors. Internal factors include predation, competition, and migration which affect recruitment and natural mortality rates. External factors include influences such as temperature anomalies, which affect growth rate and food uptake and thus predation rate; habitat loss and pollution, which affect reproductive success and mortality; and, fishing, which acts by removing older biomass thus affecting predation, cannibalism, recruitment, and senescent mortality.

Most traditional fisheries resources are heavily exploited. In many instances the resource base has declined. It has been assumed that overfishing was the major cause for most of these declines. Empirical data show, however, that stocks fluctuate considerably and in many cases change over periods of decades without a commercial fishery. These fluctuations are affected by environmental processes and resulting ecological perturbations, as well as by the direct influence of a fishery, habitat alterations and pollution. Consequently, more attention needs to be focused on the fact that there are pronounced natural fluctuations in the productivity potential/recruitment success of stocks, which appear in subsequent years as variations of population abundance.

Short time series of trends in fishery yields and recruitment correlated with environmental change have been developed. These relationships can change under certain environmental conditions, and usually involve a change in dominance of one species over another. The temporal and spatial scales of these fluctuations are significant in interpreting changes in the fishery catches. Fisheries reflect not only local events, but also large scale climate-ocean and solar system driven changes which induce biological responses on local event scales.

Just as most species are not harvested in isolation, they cannot be managed in isolation. The manager must understand inter-species relationships if he is to manage interrelated fisheries. Successful use and management of living marine resources requires knowledge of:

1) stock dynamics and interactions,
2) the effects of ocean environment on fish stocks,
3) the effects of fishing on living marine resources, and
4) the effects of economic factors on the amount and type of effort exerted.

Assessment of these factors is dependent upon having a well structured and integrated research program that is directed at generating knowledge about biological, oceanographic, and economic processes associated with living marine resources. The interrelationships that exist among these processes require that a holistic approach be taken in examining them. This includes understanding the nature of normal variations in abundance of individual stocks.

A holistic approach to research, monitoring, and management of living marine resources is now feasible because of advances in technology and systems modeling methods. In particular, what allows us to propose this new approach is the availability of satellite sensors which now permit the acquisition of synoptic environmental data, computer technology which permits the manipulation and analysis of large data bases, and conceptual advances in systems modeling which allows development of ecosystem modeling. Taken together these technological advances along with the demands for more sophisticated information to support conservation and management of the marine resources and environment make it timely for a shift in Federal program efforts toward a multi-species/ecosystem approach which will support a forecasting capability.

B. Scientific problem:

An ecosystem approach will encompass the activities necessary for identifying and developing an understanding of the relationships and patterns of dynamic interdependencies within the different species groups (ecosystems) of living marine organisms and their relationships to human activities. It will also include in a hierarchic fashion the physical habitat factors, e.g., current patterns, water temperature, salinity, nutrients, contaminants, etc., which define and influence the environments of these living resources. These relationships need to be understood because all ecosystem components are interlinked in the marine environment as a result of their having evolved together. Therefore, no one component can be changed without affecting other components. The ability to define and realistically model these relationships and monitor natural cycles is essential to understanding and predicting the consequences of changes, both natural and human induced, on the species within these ecological units. An understanding of the ecological context within which harvesting and/or habitat alteration activities are taking place is essential if adverse impacts from these activities are to be minimized or mitigated. The ecosystem approach will also open up new management possibilities through the expansion of existing management philosophies and methods. It is unlikely that any significant improvements in the effectivness of living marine resource management will be possible unless ecological concepts are explicitly incorporated into management approaches for living marine resouces.

Current management practices are focused on single species and assume that a sustained yield can be attained for each species, regardless of its individual biological characteristics and inter-species dependencies, if the proper regulations are promulgated. The major shortcoming with traditonal fisheries models (i.e., single species constant parameter models e.g., surplus production, yield per recruit, and age structured models) is their failure to recognize adequately that the behavior of individual exploited stocks and their population parameters, (i.e., mortality, migration, growth, reproduction and recruitment) is largely dependent upon environmental variations. This variability is not adequately described in these traditional models. Multispecies ecosystem simulations will rectify some of the shortcomings of single-species approaches. Besides determination of the equilibrium biomasses, ecosystem simulations can be useful for determining the ecosystems' responses to fishing, to habitat degradation, to management options, and to environmental changes.

II. Program Description

A. Program structure:

Seven regional marine ecosystems (RMEs) within U.S. jurisdiction and/or containing resources of interest to the U.S. provide the conceptual and structural framework for development of the NOAA program for ecosystem monitoring and fisheries management:

- o North Atlantic Shelf
- o South Atlantic and Gulf of Mexico Shelf
- o Atlantic Oceanic
- o California Current
- o Pacific Oceanic
- o Gulf of Alaska and Bering Sea
- o Antarctic

The relative locations and spatial distribution of these RMEs is illustrated in Figure 1.

The RMEs will be the basis for program development and management and the framework for reporting under the NOAA management by objectives (MBOs) system.

Regional marine ecosystems (RME) are zoogeographical areas characterized by similar oceanographic features and biological composition. These RMEs also include adjacent estuaries and riverine systems utilized during the life history of those living marine resources of concern within the ecosystem. Each RME is comprised of one or more species grouping or ecological units. These ecological units consist of populations of fish, shellfish, marine mammals/protected species and other organisms that function as a dynamic interdependent ecological unit. These species are trophically linked through food web relationships, either as predator-prey or as competitors, and their population abundance and distribution are controlled by similar oceanographic or physical habitat features. In most instances, these are not "closed" systems with distinct boundaries. In fact, the boundaries of these systems may be constantly changing horizontally and vertically in response to short term or local natural and/or human induced perturbations in oceanographic features. These RMEs may also be affected by environmental events beyond their defined boundaries and/or longer term shifts in ocean climate. Further, there is some biological exchange between ecological components as the result of food-web linkages, migrations, etc. Overlaps in these RMEs will require program coordination and collaboration within and among NOAA/NMFS regions.

Figure 1

Map illustrating general location of the seven regional marine ecosystems within U.S. jurisdiction and/or containing living marine resources of interest to the U.S.

(1) - North Atlantic Shelf

(2) - South Atlantic and Gulf of Mexico Shelf

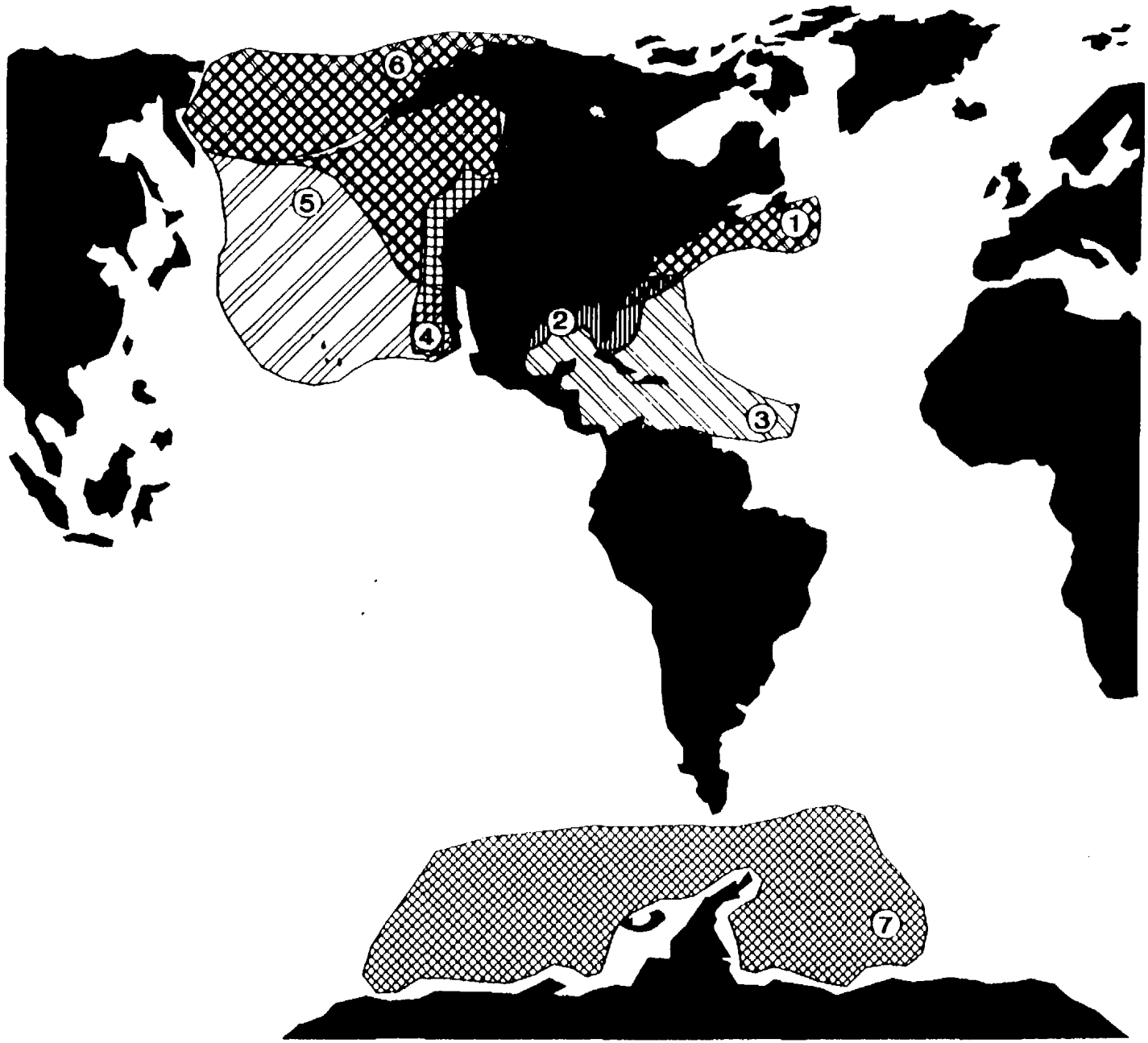
(3) - Atlantic Oceanic

(4) - California Current

(5) - Pacific Oceanic

(6) - Gulf of Alaska and Bering Sea

(7) - Antarctic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C. Program development:

1. Implementation strategy:

Program efforts required for increasing the level of living marine resource monitoring and management to that of an ecosystem approach will be built upon the existing core NMFS program base which presently supports traditional single-species focused living marine resource management. Routine fishery monitoring and research activities within the proposed core NOAA fisheries program will continue to provide the minimum level of information necessary to meet immediate management needs. However, the core program will be adjusted so that its data products are complementary to the research proposed in this ecosystem program initiative.

The basic planning units for an ecosystem focused management approach will be the seven regional marine ecosystems (RMEs) occuring within the jurisdictional waters of the U.S., or of interest to the U.S. (Section II, A, Figure 1). Program development plans (PDPs) will be developed for each ecosystem planning unit. These will identify information needs, focus program efforts, and provide a basis for managing program implementation for the various species groups/ecological units comprising each RME.

The NOAA fisheries program will utilize ecosystem models to more effectively direct research and data collection efforts toward achieving a better understanding of the p'ysical, ecological, and human systems surrounding the Nation's fisheries. Ecosystem modeling will provide a conceptual framework for increasing our understanding of the environmental reality/complexity of the living marine resources NMFS is mandated to manage. In addition, ecosystem based models will be used to provide the conceptual framework for focusing and integrating fisheries research and data collection efforts among the NOAA components and other Federal and state agencies and academia. Natural species groupings/ecological units will also provide the data basis for multi-species Fishery Management Plans (FMPs) developed by the Regional Fishery Management Councils. This will provide for consistency of management decisions with the ecosystem framework and allow full utilization of the forecasting capabilities provided by associated models and data bases. Ecosystem models will also provide the context for protected species management regimes and recovery plans.

B. Program objectives:

Program goal: To orient the NOAA living marine resource research and management program to a multi-species/ ecosystem approach which supports a forecasting capability, while continuing to meet the mandates of major living marine resource legislation and the ongoing support needs of Federal regulatory processes.

A hierarchy of objectives will be established for each regional marine ecosystem, its species group/ecological units, and for the science program for each of these units.

RME objectives will identify the general thrust of the program efforts for each ecosystem. These RME objectives will provide the basis for the planning/reporting categories within the NOAA MBO/MPR system.

Species group/ecological unit objectives will provide statements of what the Federal (NOAA/NMFS) program is attempting to accomplish relative to each of these units. These objectives will be defined in terms of the conservation or utilization of the species group and will provide the framework for development of specific program plans and milestones.

Science program objectives will be defined within the context of the species group/ecological unit programs. They will provide statements of what the science program is attempting to achieve relative to supporting actions/decisions required for attainment of a particular species group program objective.

This program objective/milestone framework will provide the basis for resource allocations, management reporting, and individual performance contracts.

The NMFS will begin its reorientation to an ecosystems perspective by building preliminary models of systems types (e.g., coastal-benthic, oceanic-pelagic, estuarine, etc.) before setting up vast data-collection schemes. This approach will avoid the two most common mistakes of systems modeling; over-sampling (i.e., more types and amounts of data than are necessary) and over modeling (building models that are unnecessarily complex). These preliminary models will include those aspects of fishing systems that are, or are suspected to be, crucial to management of a particular system-type. The structure, functioning and sensitivities of these preliminary models will then be evaluated according to previously specified criteria. This prior specification of focused objectives is critically important, if we are to avoid the problems of over-collecting and over-modeling.

Full ecosystem models will be used primarily to gain an overview of the relationships among major components of the system. These models can become very complex and much of their structure will necessarily be of a subjective/judgmental nature as many of the structural relationships among the components of the system cannot presently be verified. This type of model will be primarily a research tool and will be used to describe the probable relationships among major ecological components within the different RMEs. Additionally, these models could be used for management of the dominant species, since their resolution for these species is usually as acceptable as that of the simpler conventional models.

Environmentally-dependent multi-species models will be developed for a wide range of situations. They will be used to model individual trophic levels, to describe multispecies fisheries, to extend predator-prey and competition models and to model special situations (i.e., tuna-porpoise relationships). These models will also be largely based on statistically and experimentally derived relationships and parameters. They will also be used for factor sensitivity analysis to define which factors are dominant driving forces in a particular ecosystem. This information will then permit monitoring efforts to be focused on these driving factors. These types of models may include the same concepts described for environmentally-dependent single species models and include interspecies relationships as well.

Environmentally-dependent single species models will be developed primarily as sub-components of multi-species models and will have utility as management tools. The principal failing of the present steady-state single species models is they do not account for recruitment variability. This is particularly true with the small pelagic fishes where the incoming year class may at times be larger than the rest of the exploitable biomass. Development of environmentally-dependent single species models will be focused on the recruitment problem and will include only those factors that have been demonstrated to affect the population process of the individual species. The models will be mixtures of early life history biology, physical oceanography and population dynamics processes.

Although NMFS currently has a very limited input to the long-term monitoring of climate related environmental indices, other NOAA elements are heavily committed to this type of work. A successful NMFS ecosystem-based living marine resource management program assumes acquisition of the environmental data through an integrated NOAA effort. The meteorological data base is much more extensive and available than is the oceanographic data base. In addition, the global meteorological data gathering system is designed to produce real-time products. A comparable data gathering system does not yet exist for oceanographic data. Some semblance of a coordinated NOAA oceanographic monitoring system is a requisite for an in situ effective ecosystem monitoring and fisheries management system. Once oceanographic data products are produced on a regular, continuing basis, ecosystem models can be designed to efficiently utilize these products. The payoff from complex ecosystem models will be much reduced if environmental data time-series are not available to derive models and if near real-time environmental data are not available to operate the models.

NMFS program management and technical representives will participate in the program planning for the Climate and Global Change Initiative and related activities to ensure the types of remote sensors, temporal and spatial resolution of data collection and experimental designs, and data sets and management/access systems are appropriate for ecosystem modeling needs. This will permit the NOAA fisheries program to tap into the data flow associated with the Climate and Global Change Initiative to obtain the synoptic environmental data needed for developing and operationally supporting ecosystem models. The principal role for the other NOAA program elements is to provide the full spectrum of physical information necessary to understand and monitor the oceanic and atmospheric components of the marine ecosystems. These components define the boundaries of marine ecosystems and indicate factors which, when understood and monitored, will allow prediction of changes in these systems and their component living marine resources, and the consequences of these changes for the individual resource users and the Nation. In turn, information on biological factors will be provided to the Climate and Global Change program because most marine animals are effective integrators of their environment and may serve as effective indicators of subtle changes in the environmental factors controlling marine ecosystems.

2. Program enhancement areas:

It is widely recognized within NMFS and the scientific community in general that an ecosystem focused approach is necessary, and overdue, to bring Federal oceanic, atmospheric and living marine resource research programs into an integrated effort. This approach in necessary to understand and model the many climatic, inter-species, and human factors that regulate the size of fish stocks.

An ecosystem approach must address a wide range of research, including:

1. development and production of indices describing relevant environmental processes in the ocean;

2. analysis of the causative interactions between climatic processes, human induced factors, and subsequent ecological effects, and the population processes of individual species; and,

3. development of ecosystem models, as well as management oriented environment-dependent single-species and multispecies models.

A summary of the type of research and data needed to create a coherent environmental monitoring system that will provide the information about processes and events necessary for developing a forecasting capability is provided in Appendix A. Many of the research and data system elements outlined are beyond the existing NMFS program capabilities. The realization of programs to meet these data needs will require improved coordination with and contributions from the data collection and research activities of other NOAA elements, as well as Federal and state agencies, contract contributions from academic and private researchers, and selective enhancement of NMFS base program efforts.

The following are living marine resource program areas requiring enhancement in order to develop an effective ecosystem focused fisheries program, based on the existing core NOAA fisheries program supporting traditional management. The importance of these program areas will differ among the RMEs and their relative level of effort will be detailed in each of the regional ecosystem PDPs.

Pre-recruit Surveys: Information on late juvenile/ pre-recruit life stages of fish stocks and other living marine and estuarine resources, including protected species, has been largely unavailable from traditional survey methods. This information is needed to determine the distribution and abundance of these life stages within marine ecosystems. These surveys will also provide data on natural mortality rates and their correlation with anthropogenic and environmental factors. This information is needed for profiling the life history characteristics of the various species, developing recruitment indices, and eventually incorporating this information into ecosystem models for predicting recruitment and fishery year class strength. Additionally, the information is needed for developing estimates of mortality due to habitat alteration and pollution, and for explaining changes in protected species population levels. Funding for charter vessels and/or contracts will be needed to support pre-recruit surveys.

Fishery Oceanography: Synoptic and ecological unit specific oceanographic and climate data are needed, along with the concurrent collection of biological data to define and monitor critical changes in the physical processes within marine ecosystems. NMFS must define these environmetal data needs and work with the other NOAA program elements to ensure their data collection efforts are consistent with these needs. These data will facilitate definition of these physical processes and their impacts on and ability to serve as predictors of living marine resource productivity and future population levels. Development of ecosystem specific data sets will require access to, and translation and analysis of data from various synoptic and site specific environmental data acquisition systems, e.g., satellite remote sensors, data buoys, etc. Problem directed "at-sea" data collection will also be required to provide "ground truth" calibration and higher density sampling from selected areas. This includes sampling to understand the dynamics of specific oceanographic phenomena, e.g., river discharge plumes and associated fronts, current boundary effects, etc., which may be key factors in ecosystem dynamics. Charter vessels, as well as directed and opportunistic efforts on NOAA vessel cruises will be utilized to develop this additional data. Ecological unit based data sets, including those developed in support of the NOAA Climate and Global Change program and Estuarine Science program, will provide the environmental data needed for integration with biological and fishery information to construct predictive models.

Conservation Engineering: New and innovative sampling tools and techniques will be required for stock assessment surveys (especially for pre-recruit life stages) and ecosystem monitoring systems. This will require establishing a core in-house expertise, as well as, charter vessel and contract support to develop, evaluate, and adapt methods for collecting information currently unavailable through traditional methods. This expertise will also be needed in the future for the development of selective harvesting systems. Species selective harvesting gear (i.e., techniques and hardware which permit catching only targeted species; and/or excluding by-catch, including protected species) will need to be developed and/or evaluated for implementing management regimes to allow maximizing production under the multispecies regulation possible with ecosystem focused fisheries management.

Food-web Analysis: Information will be needed on the inter-relationships and dependencies among the various trophic levels and competitors within an ecosystem. Understanding these dynamic biological relationships is essential for the construction of predictive ecosystem models. This will require defining predator/prey relationships and the factors influencing inter- and intra-seasonal process dynamics within various ecological units. Ecosystem focused fisheries management requires a thorough understanding of the complex nature of trophic relationships. Both our ability to predict resource abundance within various trophic levels, as well as to analyze the impact of harvesting selected segments of the ecosystem on other segments, is dependent on food-web analysis.

Stock Identification: Defining the relationships and abundance of stock components within ecological unts will require the development and operational application of fish stock identification techniques (e.g., based on the genetic and/or other distinguishing characteristics of subpopulations). This information is needed to determine the impact of alternative harvesting levels and strategies on the component stocks in multi-species/stock fisheries. Implementation of management measures which do not account for discrete stocks of fish species could lead to several types of problems, including severe overfishing of some less abundant sub-components; decreases in genetic heterogeneity, etc.

Stock Component Aging: Continuous aging of individuals of a species is needed for estimating age at sexual maturity, age composition, longevity, growth, etc., which are critical elements in determining species or stock population dynamics, and in the development of appropriate conservation and management regimes. This will require the development, validation and continuous operational application of techniques for aging individuals within a population using body hard-parts (bones, teeth, fin rays, otoliths, scales, etc.). This will also require archiving hard-parts to facilitate research and historical analysis of changes in individual growth rates and population structure. This archive data will need to be cross-referenced with available stock identification information to provide a long-term stock reference.

Habitat and Productivity Relationships: Basic information for understanding ecosystems is needed on the species specific/ecological unit habitat characteristics, requirements, and use, as well as, information on the effects of habitat degradation. It will be necessary to define and quantify the relationship between habitat characteristics of the different marine ecosystems and ecological units and their influence on the productivity/abundance of living marine and estuarine resources. This will involve: expansion of estuarine and coastal research in all regions; identification of critical/limiting habitat components for individual resources and monitoring trends in these components; quantifying the forcing functions for resource productivity; modeling population effects to determine consequences of alternative changes in habitat components; and, defining human impacts on fishery production. Human impacts analysis will include monitoring coastal land use and changes in use to identify non-point source impacts on estuaries and oceanic stocks with estuarine/coastal dependent life histories. The definition of processes for the major estuarine habitat types proposed under the NOAA Estuarine Research Program will provide data on critical habitat which will be incorporated into ecosystem models. (see Appendix C for program relationships)

Catch/Effort Modeling Data: It will be necessary to upgrade stock abundance, fishing mortality and fishing operations data, as well as to improve species identification, age and sex composition, and other biological data for specific stock components and geographical areas to meet ecosystem modeling needs and for evaluating the effectivness of regulatory measures. These data are also needed for understanding fish population dynamics. This will include evaluating and implementing improved catch/landings data collection sampling designs and methods for automation of routine data collection. Methods for acquiring data on fishing effort associated with reported landings will need to be developed. Information on some non-managed species will also be needed, since some of these species are key indicators of change (cause/effect relationships) in the ecosystems. Fishing effort/discard information is needed for these non-managed species since variations in their landings are often related to economic considerations and not to changes in resource abundance/availability levels. This latter information will provide the historical trends data needed to indicate the need for and the appropriate type of management actions for stocks currently not being managed.

Recreational Catch Monitoring: It will be necessary to improve the spatial coverage and collection methods for landings data from recreational fisheries in all areas of the country. It will also be necessary to increase sampling to provide biological data,(e.g., gonads for reproductive characteristics, hard parts for aging studies, etc.) on statistically "rare event" species which have a significant recreational value. This will permit upgrading data on fishing mortality for a number of fish stocks whose primary source of fishing mortality is recreational fishing. This information is necessary to provide a full accounting of fishing mortality for analysis of ecosystem dynamics.

Recruitment Variability Causes: Efforts to analyze the causes of natural variablility in the recruitment of living marine resources will need to be expanded as a requisite to the development of ecosystem models. Biological variability is strongly influenced by environmental variability as well as variability related to human activity. Recruitment process oriented studies will be undertaken to identify the fundamental processes underlying reproductive success and recruitment variability, as well as, to define the role of environmental variables and their value as predictors. Much of the dynamics of fisheries and the difficulties in their exploitation and management histories (e.g., booms and collapses) can be inferred from the interaction of forces acting in different time scales. Variability of fishery resources occurs on nearly all time scales. There are five general categories of causes for changes in fish abundance. These categor e re l) intraspecies dynamics, which includes compensatory mechanisms such as stock-recruitment relationships, density-dependent growth, and cannibalism; 2) competition among species, which in practice is difficult to demonstrate conclusively; 3) predation, which is generally treated as natural mortality in fishery analysis; 4) fishing, or exploitation; and, 5) environmental fluctuations, particularly abiotic and lower trophic level biological factors. Defining the causes of recruitment variability will also require compiling and reviewing historical data to identify the cyclic patterns and frequency of changes in recruitment rates and their correlation with environmental factors. This will include the review of fish scale deposition patterns in bottom sediments and other types of archival/geological records. Current year data will also be needed to validate these variability patterns for ecosystem model component development.

Fishing Strategy Analysis: The economic and social impacts of natural fluctuations in resource productivity/abundance and availability, and of alternative fishery management schemes need to be defined. Analyses need to focus on changes in investment, employment, and fishing strategies for both commercial and recreational fisheries under alternative ecosystem stock composition conditions and resource allocation schemes. Baseline socio-economic data will need to be assembled for fisheries on a regional basis. This information will serve as a basis for incorporating human/ecological-impact model components into ecosystem models of the fisheries. This should include the range of alternative and probable operational and investment behavior of fishermen and processors under different levels of allowable fishing mortality. This information will allow simulation of the likely behavioral changes by participants in the fisheries component of the ecosystem and the consequences of these changes.

Forecasting Models and Systems Development: Fishery prediction and modeling centers will need to be established. These centers will be involved with advancing the state-of-the-science in stock assessment and ecosystem model development. They may be co-located at a NMFS facility or major university that has, or can assemble, the necessary expertise. These centers will provide the analytical expertise necessary for developing the mathematical models, conducting sensitivity analysis of model components, and defining ecosystem data set requirements. They will provide the source of specialized expertise needed by the NMFS science programs to design and set up systems to utilize environmental and oceanographic data in fishery management models. They will also assist the operational programs to develop, validate and support operation of regional living marine resource/ecological forecasting systems. This will include support for establishing geographic information systems to facilitate access to and manipulation of integrated physical and biological data sets.

Management Alternatives Analysis: It will be necessary to support the continued development and evaluation of alternative management approaches and regulatory regimes to expedite the implementation of improved living marine resource/fishery management techniques based on ecosystem models with forecasting capabilities. This includes continued effort to develop and evaluate methods for establishing management regimes involving conceptual features such as limited entry, stock shares, cost-benefit, optimum fleet size and composition, etc. This will help resource managers to define the range of alternative management tools possible using an ecosystem focused approach and their suitablility for different resources and conditions.

Habitat Issue Resolution: Methods for resolving habitat use conflicts within an ecosystem context will need to be developed. This will permit the use of ecosystem models for development and adoption of habitat valuation, impact evaluation and rehabilitation methodology. It will also allow analysis of alternative development proposals and mitigation measures (utilizing ecosystem models) to predict their cost/effectiveness. This will facilitate the use of ecosystem models for predicting and strengthening NOAA recommendations concerning the impacts of proposed habitat alterations, of water quality changes on living marine resource productivity and distribution, and of the effectivness of environmental management measures.

4. Relationship to other initiatives (NOAA):

Program diagrams illustrating the relationships of the Ecosystem Monitoring and Fisheries Management and the Estuarine Research Program initiatives with the core NMFS program are provided in Appendix C. The nature of these programs and related initiatives proposed by other NOAA elements are summarized as follows:

Climate and Global Change: This is a coordinated NOAA multi-line organization atmosphere and ocean monitoring and research program with an interdecadal focus. It is also coordinated with similar global change program initiatives being developed by other Federal agencies, e.g., NSF, NASA, EPA, etc. NMFS is participating in the development and management oversight of the NOAA program. The NMFS ecosystem monitoring and fisheries management program will be a major user of the atmospheric and oceanographic data produced by this initiative. The NMFS program will provide data on biological activity for species which will be used by this NOAA program as indicators of global change.

Estuarine Research Program: The NOAA Estuarine Program Office initiative will provide information on the nature of productivity processes in various types of estuarine habitats, which will complement other NMFS habitat research programs and provide habitat value and food-web information needed for species group/ecological unit model development.

Cooperative Recruitment Program (CORE): The CORE program is a proposed research initiative developed cooperatively by NMFS and Sea Grant to advance understanding of fishery recruitment processes. This research initiative will include recruitment process studies and analysis of environmental effects on early life stages. It includes long-term (climatic) change effects and species replacement phenomena as related to recruitment. Environmental monitoring and advanced technology applications as related to assessment and prediction of pre-recruits is also included. This program provides more specific guidance for the types of recruitment research needed to support the NMFS ecosystem initiative and is directly complementary to this initiative.

Fishery Oceanography Program: The objectives of this OAR developed initiative are to isolate and describe the causal environmental mechanisms resulting in variations in fish and shellfish population size and distribution, and to develop efficient means of monitoring key environmental factors. The program will focus on upwelling systems, estuarine frontal systems and eastern continental shelf convergent current systems. It includes an expansion of the existing FOCI program and would involve cooperative work with NMFS. This program would be directly complementary to the types of fishery oceanography needed to support the NMFS ecosystem initiative.

Strategic Research Initiative: This is a Sea Grant university committee-developed initiative which identifies the types of recruitment and fishery oceanography research these universities could contribute. It is directly related to the types of research proposed in the CORE and Fishery Oceanography Program initiatives, and is supportive of the information needs defined in the NMFS ecosystem initiative. This initiative is contingent on new Sea Grant reauthorization legislation which includes authorization for funding strategic research. Fishery oceanography is identified for expansion as a strategic research area.

III. Program Management

A. Management objectives:

The NMFS Directorate intends to achieve the following through shifting Agency program focus towards an ecosystem approach to living marine resource research, conservation, and management.

o - Provide a conceptual framework for integration of the NOAA fisheries ecosystem program

The shift to an ecosystem focus for the NOAA fisheries program requires that research be more effectively organized to produce information needed for a better understanding of the physical, ecological and human systems surrounding the Nation's fisheries. It will provide the conceptual framework to integrate research and data collection efforts within the NMFS and among the NOAA service components and other Federal and state agencies and academia. The expansion of research and management programs beyond their current single species focus to encompass multi-species/ ecosystem concepts is also necessary in order to better achieve conservation and management objectives.

o - Facilitate access to/utilization of existing and future NOAA oceanographic, atmospheric monitoring and data management capability

The principal role for NOAA is to provide a full spectrum of physical and biological information necessary to understand the oceanic and atmospheric components of the marine ecosystems. The fisheries forecasting program will need to tap into the data flow associated with the Climate and Global Change Initiative and other related NOAA activities/initiatives. This should provide much of the synoptic environmental monitoring data needed for developing and supporting living marine resource ecosystem/species group forecasting models. These environmental factors define the physical limits of marine ecosystems and are indicators that, when understood and monitored, will allow prediction of ecosystem changes and of their component living marine resources. Of particular concern is the acquisition of data on subsurface phenomena and for polar areas which are not well represented in normal data collection efforts. NMFS will need to define its environmental data needs for understanding and monitoring each of the RMEs and work with other NOAA elements to ensure their data collection and data base development is consistent with these needs. NOAA will then be better able to determine the consequences of these ecosystem changes for individual resource users and the Nation.

o - Improve the value/cost of living marine resource management information

Development of ecosystem models will permit sensitivity analyses which will identify the principal factors driving changes in the various ecosystem components. Monitoring efforts can then be focused on these essential factors, thereby improving the efficacy of monitoring and survey activities. An ecosystem-oriented approach has the potential to shift the information cost/benefit curve to the right, rather than just follow the curve. This will increase the information value obtained at a given cost.

o - Provide for pro-active management through development of a forecasting/prediction capability

An ecosystem focused approach will enable NOAA to become pro-active (i.e., to anticipate and take actions which avoid/minimize problems) in its conservation and management efforts through the use of ecosystem models which will provide multi-species population abundance and habitat alteration impact forecasting capabilities. This is in contrast to present reactive methods which are largely projections of trends from hindcasting for single species which frequently allow for identifying and reacting to situations only after they approach crisis proportions. The relevance of the ecosystem approach to management of multispecies fisheries is clearly illustrated by the constant changes in catch composition that occur temporally and spatially. Each species has specific requirements and interactions within the ecosystem. The physical environment which influences and helps to define these ecosystems varies continuously. Defining relationships within an ecosystem and monitoring appropriate environmental, biological, and human influences will permit forecasting displacements and adjustments in the ecological balance. Using current methods, these adjustments can be observed only after the fact as changes in catch age-size structure, etc., which are difficult to interpret in isolation.

o - Provide whole-system (ecologically comprehensive) approaches which provide guidance for resource managers

A better understanding of the ways that marine ecosystems work is clearly needed. Full cognizance of the biological characteristics of the individual species within an ecosystem should make it possible to determine which species are legitimate candidates for stock stabilization management efforts and which stocks are inherently variable. To accomplish this it will be necessary to develop whole-system approaches (i.e., species group/ecological unit) that also meet the criteria of providing qualitative and quantitative guidelines for living marine resource managers. The ability to provide even roughly accurate forecasts of living resource dynamics will significantly improve our management tools. This will also improve constituent confidence in the Federal living marine resource conservation and management process.

B. Management strategy

The elements outlined in this program development plan (PDP) do not constitute a stand-alone program. Instead, they represent the supplementary and complementary program elements needed to effect a transition in focus and capability of the existing NOAA living marine resource science and management program. This initiative will move the NOAA program from one concerned primarily with single species to one that considers the inter-dependencies among living marine resources and their environment. This transition will be done in such a way that existing base program efforts, while continuing to meet ongoing management needs, will be refocused and enhanced to provide the data for creating species group/ecological unit focused and geographically organized data bases. New program elements will be integrated with ongoing science and management programs to ensure continuity of existing data bases and regulatory regimes. These new elements will provide the requisite ecosystem monitoring and fisheries management capabilities and will lead to the development of a forecasting capability for the major resources within the various ecosystems considered.

Within each RME, natural species groups/ecological units will be defined as the units for operational program planning and management. NMFS RME program objectives will be articulated and a program development plan (PDP) prepared for each ecosystem. These RME PDPs will address program requirements for research and monitoring needed to support the protection, conservation, management, restoration and development of all the significant resources within the ecological unit, including fisheries, protected species and their habitats.

Ecosystem PDPs will be the basis for updating the NMFS and Regional strategic planning documents. They will also be the basis for developing future year NOAA fisheries program budget justifications.

Allocations of current year resources and proposed program accomplishment milestones will be reported by species group/ecological unit through the NMFS Current Year Operating Plans (CYOPs). Adjustments in field program task structure may be required to focus and facilitate program support for meeting ecosystem program needs.

NMFS will work with the Regional Fisheries Management Councils to ensure the ecosystem focused research and data collection efforts support the needs of the councils for development of fishery management plans (FMPs) for the fisheries utilizing/impacting the natural species groupings within these ecosystems. These ecosystem units will also provide the data base for developing protected species management regimes and recovery plans. These PDPs will also identify industry assistance/participation required for potential resource development and maintenance/adjustment of traditional industries in response to changes in stock abundance/distribution expected to be associated with forecasted changes in the ecosystem.

C. Management structure:

NMFS Regional Directors will be responsible to the Deputy Director for developing and implementing an ecosystem focused research and management program for the regional marine ecosystems-RMEs (and their living marine resources) associated with their "geo-political" region, consistent with planning guidance and regional conditions and program needs. (Lead for Antarctic ecosystem planning is the Director, Office of Protected Resources.) This includes; working with the Center Directors to coordinate the development of species group/ecological unit programs, as appropriate for the RMEs involved; coordination of planning and program implementation with the Regional Councils and constituents; and providing milestone reports.

NMFS Center Directors will be responsible for defining research objectives in cooperation with the lead Director for the ecosystems for which they have program involvement. This includes defining information needs and research/monitoring program requirements.

Office of Research and Environmental Information; Predictions, Analysis, and Monitoring Division will have the headquarters lead for coordinating development and implementation of the NMFS ecosystem program. This planning will be coordinated with the Office of Protected Resources. This will involve providing staff recommendations to the Deputy Director, through the Executive Director, relative to inter-region consistency of PDPs with planning guidance requirements and technical adequacy. This will include assisting the Regional Directors with the coordination of information and data exchange needs and access requirements with other NOAA line organizations at the headquarters level.

Office of Protected Resources will be responsible to the Deputy Director for developing an ecosystem focused program development plan for the Antarctic Ecosystem. The Conservation Science Division will have the lead responsibility for defining NMFS Antarctic research program requirements and coordinating the preparation of the Antarctic ecsoystem PDP with headquarters and field program elements. This Office will also review protected species and habitat components of all seven regional marine ecosystem PDPs for consistency.

Management and Budget Office will prepare program planning and reporting guidance and related budget justification materials, as directed by the Executive Director, in cooperation with the Office of Research and Environmental Information and the Office of Protected Resources. This will include coordinating MBO objective development and milestone reporting.

D. Planning and reporting requirements:

Regional Marine Ecosystem PDPs will be developed which define system components, program objectives, organizational participants, technical requirements, fiscal resource allocations and implementation schedules and milestones. These plans will be incorporated into the regional strategic plans, during subsequent update of the NMFS Strategic Plan.

Existing agency planning and reporting systems will be used for documenting task level program plans and for meeting MBO and other management reporting requirements.

E. Coordination:

The spatial scope of the regional marine ecosystems and their monitoring and management program requirements will require extensive intra-NMFS, intra-NOAA, inter-agency, and international coordination.

Intra-NMFS; Extensive coordination among NMFS regions and program elements will be required because of the overlap in regional marine ecosystems.

Intra-NOAA; A number of NOAA program elements will be providing systems monitoring, data management, and related support services within the Climate and Global Change program context which will be utilized by NMFS ecosystem focused programs. Other NOAA program initiatives, noted in Section II.C.4., are also directly related and/or supportive of the NMFS ecosystem initiative. Coordination will be required at both the headquarters and field levels to ensure data products meet NMFS program needs.

Inter-Agency; Access to data from the global change programs of other Federal agencies, (e.g., NASA, NSF, EPA, DOE, etc.) will be coordinated through the NOAA Climate and Global Change Program. The extension of these regional marine ecosystems into waters of adjacent nations will also require coordination with the Department of State relative to NMFS research and conservation programs.

International; The scope of regional marine ecosystems results in their extension into the waters of adjacent nations,(e.g., Canada, Mexico, Caribbean Islands, U.S.S.R., Chile, Argentina, etc.). An effective ecosystem focused program will require the cooperation and/or participation of these nations in monitoring, research, and conservation programs.

Outline of Ecosystem Research and Data Needs

I. Descriptions of Habitat (Ecosystem/Ecological Unit) Boundaries

A. Zoogeographic distributions
B. Population identification and discrimination studies
C. Physical habitat characterizations
D. Identification of major perturbations and influences

II. Identification of Needed Monitoring Programs

A. Physical data
1. climate information, climatology
a. local wind fields
b. seasonal rainfall
c. remote wind driven effects, i.e., current, swell, upstream upwelling, etc.
d. riverine, estuarine influences
2. physical oceanographic information, climatology
a. local processes and patterns, i.e., upwelling, eddy and circulation structures, tidal and swell characteristics
b. thermal and nutrient related physical structure(s)
c. larger system influences, one to two scales beyond local influences, i.e., major currents, hemispheric and oceanwide
d. seasonal thermo-haline properties, in particular those having direct effects on physiological and behavioral processes

B. Biological data
1. species distributions
2. habitat requirements of life stages of important species
3. reproduction patterns within species
4. population structure and behavioral differentiations, iee., migrations, dispersion patterns, and related behaviors
5. interspecies relationships, i.e., who eats whom
6. underlying productivity patterns, related to A. (above)
7. biological rates
a. hard part aging studies
b. age-length based distribution studies, by sex
c. reproduction patterns, i.e., egg production by size-time
d. mortality patterns, related to B.5, A.2.b,and c
e. individual and population growth
f. emigration/immigration, region/population interchange rates

C. Fishery data
   1. catch/landings by species, size and sex
   2. locations of catches in time and space
   3. fishing parameters related to search and catching
      a. gear employed, type and amount
      b. vessel characteristics; age, speed, fuel comsumption, range, etc.
      c. catch capacities; total hold, processing limitations, etc.
      d. fish location techniques employed; sonar, birds, visual, etc.
      e. time spent in transit, search, and fishing activities
   4. Crew characteristics, i.e., experience, relative efficiencies

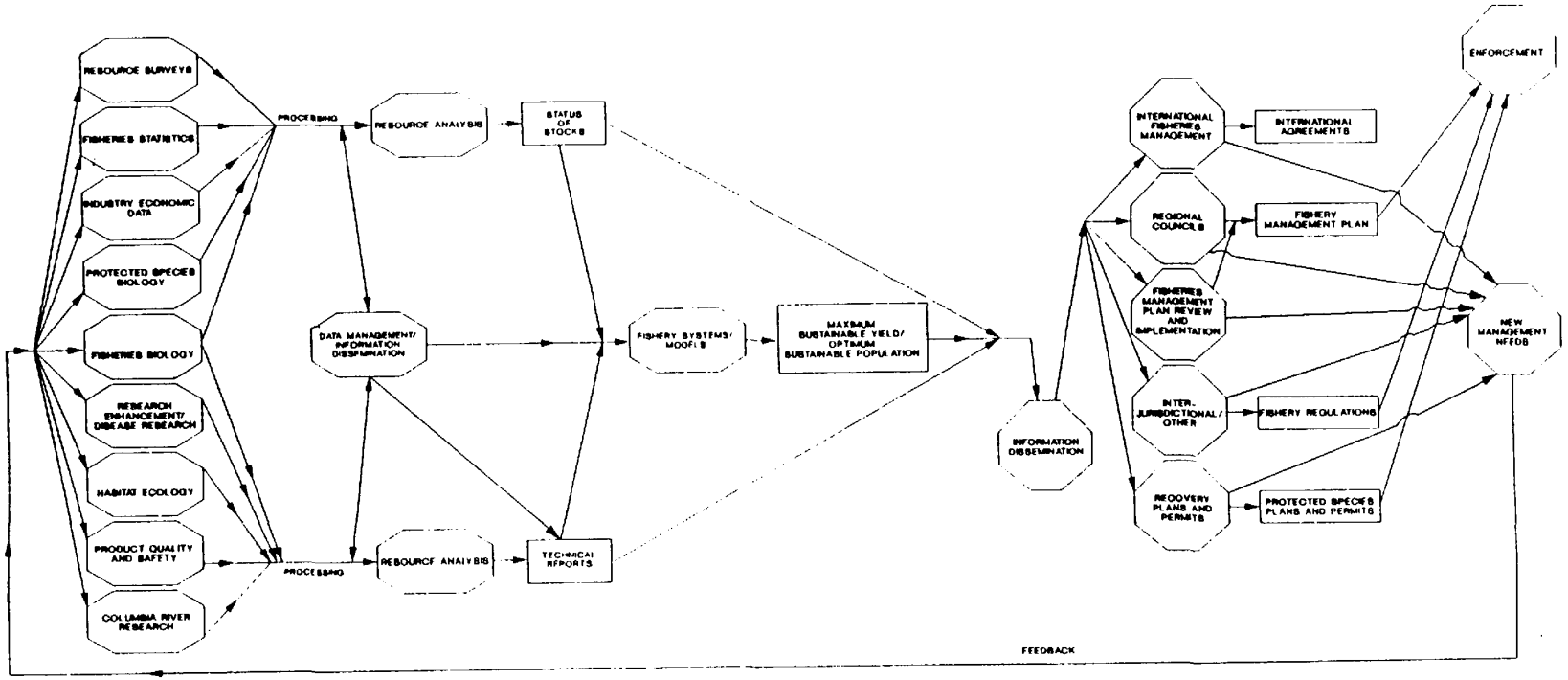
D. Habitat changes and perturbation considerations
   1. pelagic contexts
   2. demersal and/or reef contexts
   3. estuaries, inland waterways and river deltas
   4. critical human population pressure areas
      a. habitat reclamation or destruction effects, i.e., landfill, etc.
      b. pollution, i.e., thermal, biological, chemical, etc.
      c. multiple user problems, i.e., power boats/manatees, etc.
      e. environmental manipulations, i.e., artificial reefs, etc.

E. Socioeconomic data
   1. market place(s)/landing port(s)
   2. price paid for landings
   3. rates of delivery related to pricing
   4. sharing policies for payments received
   5. product processing and distribution: local/ national/export
      a. local fresh fish market
      b. remote fresh fish markets
      c. frozen fish products for primary consumption
      d. frosen fish products for shipping to processors
      e. processed products, canning, smoking, etc.
      f. reduction to fish meal, oil, etc.
   6. processing costs
   7. distribution, transport and storage costs
   8. vessel costs: replacement, maintenance, running, gear, etc.
   9. consumer prices, and related market capacities
   10. resource monitoring and management costs (relative to resource)
   11. methods of obtaining support for 10 (above)
   12. recreational values: option values, consumer surplus, etc.
   13. societal values; estetics, employment, cultural, preservation, etc.

F. Ecosystem similarities for aggregation(s) of approaches
   1. species characteristics, i.e., eastern boundary currents, etc.
   2. cultural affinities, i.e., sportsfishing dominated catches
   3. tractability, i.e., oceanic species vs estuarine species
   4. habitat characteristics, i.e., proportion of estuarine habitats per unit area of coast line, presence of major rivers, degree of habitat degradation, types of substrata, e.g., bottom vs reef and rock pile distributions w/r productivity
   5. fishing gear, i.e., trawling, trolling, trapping, seining, etc.
   6. climate zones and coastal characteristics, i.e., estuarine, rocky cliffs, sandy beaches, broad and narrow shelf, etc.

G. Management techniques
   1. conventional models
      a. single species, environment-free, production or size-age based, generally a posteriori assessments
      b. catch monitoring, i.e., quotas, seasons, sizes,
      c. a priori effort restrictions, regardless of catch
   2. ecological system bases
      a. multiple species by gear and season, with generally annual, more recently with long term perspectives, c.f., J.G. Pope and Laevastu/Bax efforts
      b. climate-ocean forecasting driven ecosystem approach to effort allocations, versatility and responsiveness stressed
      c. transition zone monitoring/forecasts, including thermocline and frontal fluctuations, as means for stratifying catches, as well as interpretation of changes in effort efficiencies, and changes in system general zoogeographic patterns
   3. habitat function models; to quantify interrelationships among factors mediating productivity (primary and secondary) within major habitats of concern for use in predicting population change due to man's effects on such habitats
   4. protected species legislation; Marine Mammal Protection Act, ect., already mandate ecosystem approaches

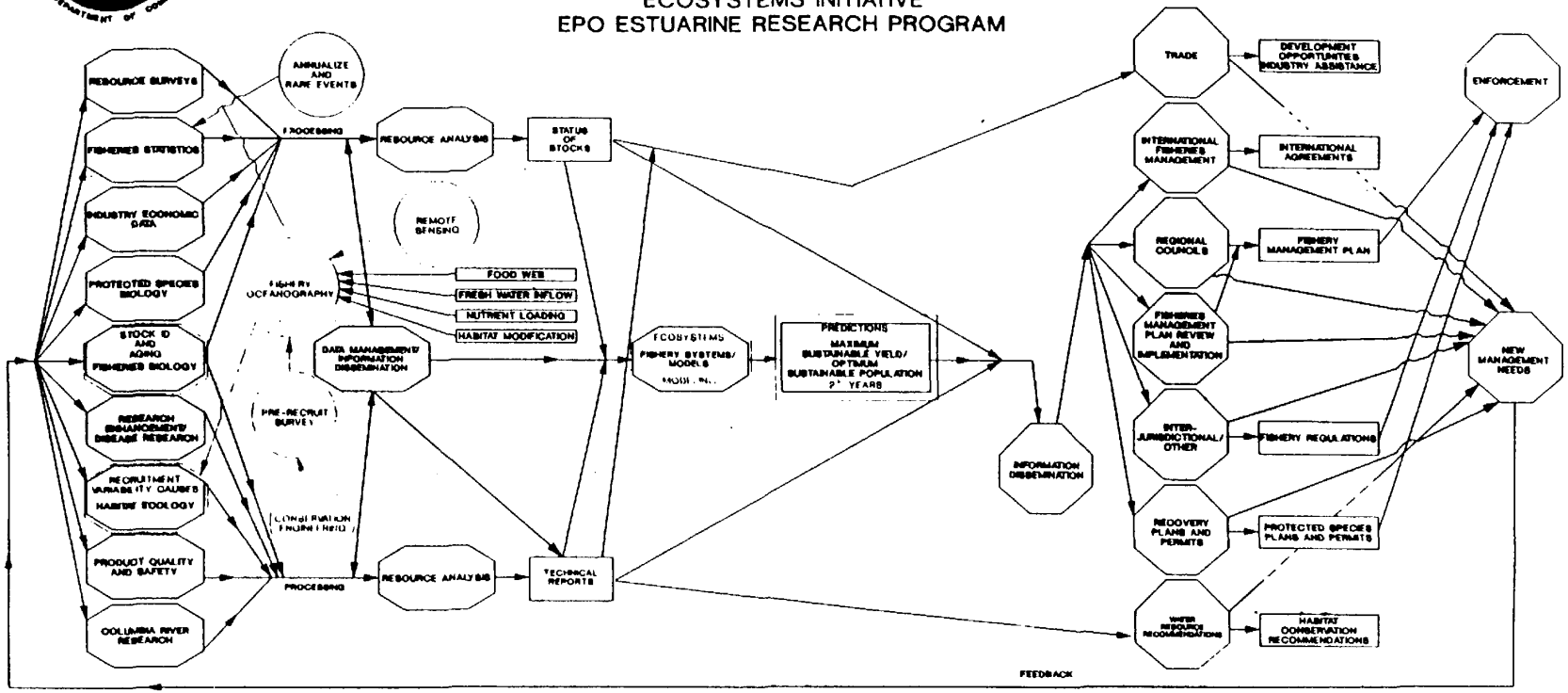
LIVING MARINE RESOURCES



LIVING MARINE RESOURCES

ECOSYSTEMS INITIATIVE

EPO ESTUARINE RESEARCH PROGRAM



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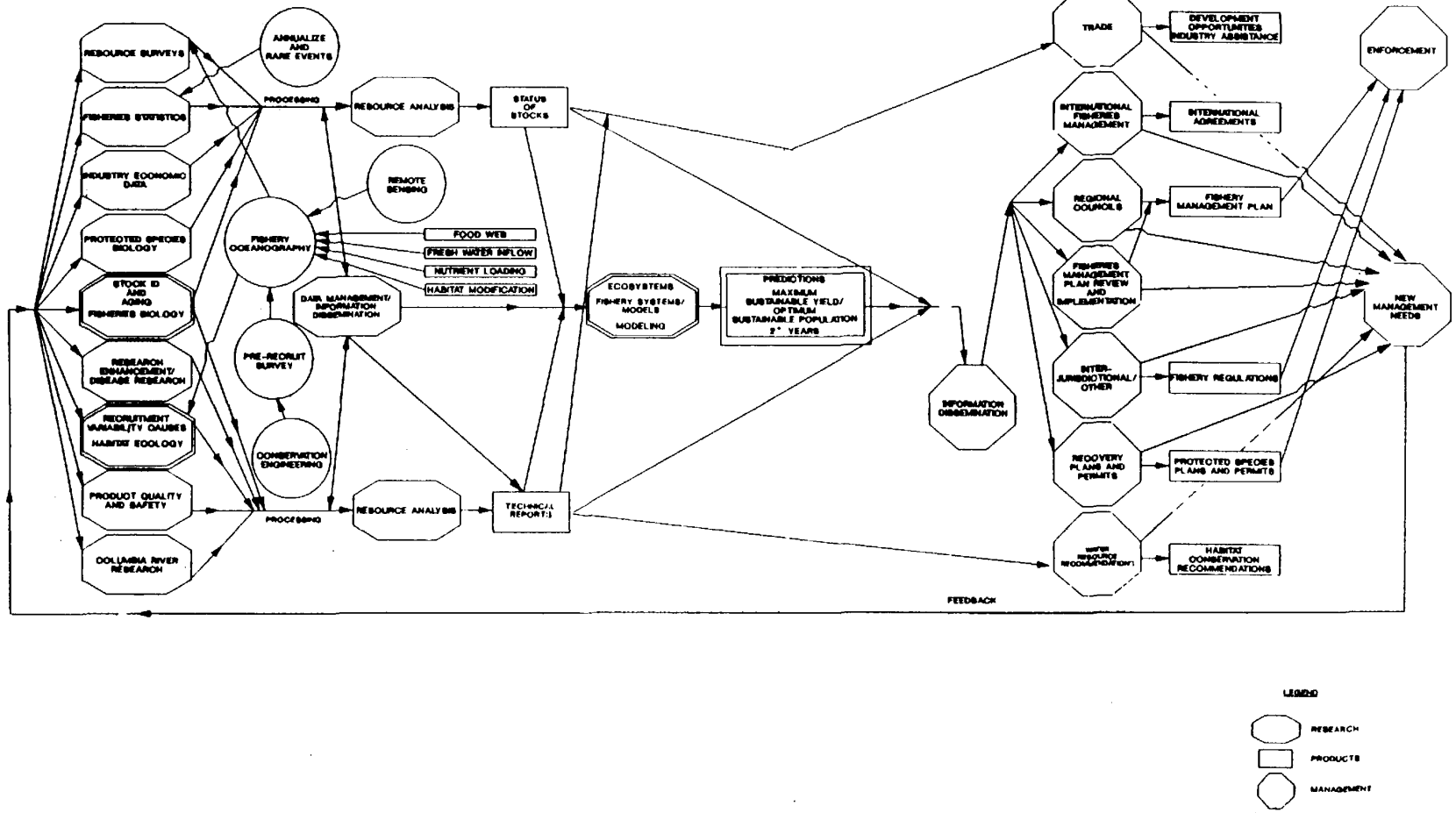
WATER RESOURCE RECOMMENDATIONS



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TRADE