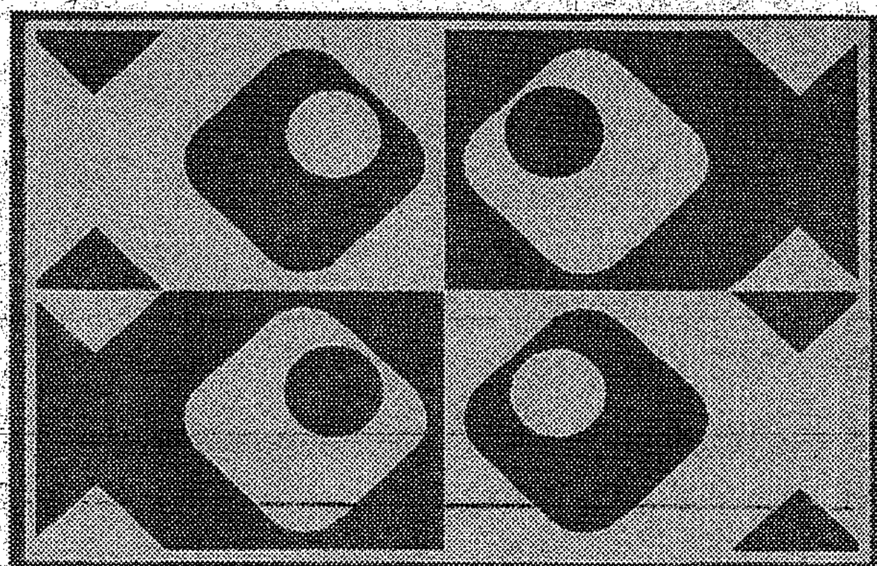
NMFS

MEDS INFORMATION MANAGEMENT STRATEGIC PLAN



Prepared by
Office Of Research and
Environmental Information
Data Management Division

DRAFT

National Marine Fisheries Service

Marine Ecological Data System (MEDS) Information Management Strategic Plan

June 1, 1992

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Prepared by
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EXECUTIVE SUMMARY

The National Marine Fisheries Services (NMFS) has prepared this Marine Ecological Data System (MEDS) Information Management Strategic Plan as a part of its efforts to define and plan for the critical information needs it will face in the coming decade.

The Information Strategy Planning methodology developed by James Martin and described in his book *Information Engineering, Book II, Planning & Analysis*, was used in the development of this plan. This methodology begins with an examination of the (1) mission; (2) functional organization; and (3) strategic goals and objectives of the enterprise. Critical success factors (what must go right if the enterprise is to succeed) are then identified. Potential future technology impacts and a strategic systems vision (what the future might hold in store for the enterprise) are also examined. From this analysis, critical information needs are identified and a strategic plan to support the mission, and strategic goals and objectives of the enterprise are formulated.

The following NMFS information management strategic goals and objectives were identified as the focus for the future MEDS:

- *The commitment to reduce scientific uncertainty in the science used in its decision-making process.*
- *The intent to move to an ecosystems-based management of living marine resources.*
- *The goal of becoming a NOAA data center for biological data for which it has stewardship.*

This plan calls for the development of a marine ecological data base and decision support system to address these goals and objectives. To support the MEDS goals, NMFS will build an information system based on:

- *Distributed architecture.*
- *Open Systems.*
- *Wide use of standards.*
- *An ecosystems perspective.*

A five year summary of the funding being sought under the ESDIM Program for this effort has been included. The detailed FY 1993 proposals being submitted are attached under separate cover as Appendix A. These projects start the implementation of the MEDS plan.

SECTION I. BACKGROUND

INTRODUCTION

This section describes the purpose, outputs, methodology, and background for the Marine Ecological Data System (MEDS) Information Management Strategic Plan.

PURPOSE

The purpose of this MEDS plan is to describe the results of a strategic planning process that focused on the data management and information needs for the National Marine Fishery Service over the next ten years. MEDS will build upon its predecessor, the IT-95 System, which uses a common suite of hardware and software in a distributed architecture.

The long-term motivation for the planning was to be responsive to NOAA's goals as articulated by Dr. Knauss for expanding the agency's focus on ecosystems based management of living marine resources. This focus is also reflected in the NMFS Strategic Plan as Goal #3 (see Section IV.) which addresses ecosystems and improving NMFS fishery forecasts.

The initial outputs of the strategic data management planning process, in support of overall NOAA and NMFS strategic planning, include (1) this MEDS plan; (2) a package of funding proposals for the FY 93 ESDIM program (see Appendix A); and (3) the beginning of an integrated system-wide program planning effort to better integrate the various NMFS "islands of data" as we expand ecosystem-based management of living marine resources. The re-orientation of the existing data management program currently underway, will result in better support of the major agency programs goals and objectives. In NMFS, the data management program does not stand alone with a separate agenda - - it cuts across and supports all agency program areas.

METHODOLOGY

In order to develop the MEDS concept and plan within the available time and budget constraints, NMFS adopted a methodology that combined the strategic information engineering approach reflected in the James Martin trilogy and the strategic business planning approach reflected in such texts as George Steiner's book on Strategic Planning (see bibliography). The methodology relied heavily on guidance from senior data management staff in headquarters as well as each of the five NMFS regions, literature reviews, brainstorming sessions, and interviews with key program management staff at various levels throughout the agency.

Much information was also collected from a bottom-up approach which involved soliciting feedback on various issues. In spite of efforts to involve as many people in the various planning and review cycles, everybody could not be contacted and additional comments which will contribute to this plan are solicited. We will continue to seek additional input for this plan as we move to the more detailed program specific data management planning that necessarily must follow this strategic definition of needs.

BACKGROUND DETAILS

The National Marine Fisheries Service's predecessor, the U.S. Commission of Fish and Fisheries was founded by an act of Congress in 1871. Today, NMFS is a part of the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA). Its mission is the stewardship of the Nations's living marine resources. Never has this mission been as critical and urgent as it is today. Mounting problems threaten U.S. fisheries, and living marine resources and the habitat upon which they depend. At the same time this mission has grown more complex as a result of the more than 100 legislative acts and international treaties enacted in the last 20 years; and the greatly increased number of organizations with which NMFS now interacts. (See Section II.)

With its five Regional Offices and 29 principal research facilities, distributed along the Nation's coastal borders, NMFS believes it has in place the nucleus of the organization necessary to meet these challenges and has set forth an aggressive strategic plan that will allow it to meet its mission through the current decade. (See Section III.)

The NMFS Strategic Plan lays out a strategy which calls for reducing the risk to living marine resources by making decisions that err toward conservation, not overfishing, in the face of uncertainty. It further commits to reducing that uncertainty by expanding the scientific information upon which these decisions are based to enhance the economic well being of fisheries. The plan lists eight major goals for which it must achieve if it is to fulfill its mission. These are:

- Rebuild overfished marine fisheries.
- Maintain currently productive fisheries.
- Advance fishery forecasts and ecosystem models.
- Integrate conservation of protected species and fisheries management.
- Improve seafood safety.
- Protect living marine resource habitat.
- Improve the effectiveness of international fisheries relationships.
- Reduce impediments to U.S. aquaculture.

Each of these goals is further defined by a number of specific objectives and a group of planned actions to accomplish them. (See Section IV.)

The central thrust of the NMFS information managment strategy described in this document is the reduction of that uncertainty which surrounds so many of the critical decisions. NMFS, in its role both as a regulatory agency and as the steward of the Nations' living marine resources, makes those decisions on a day-by-day basis. Many of these decisions will have a major impact on the future:

- Abundance of this critical food supply.

- Survival of the Nations's living marine resources.

- Economic well-being of a major sector in coastal and regional economies and the individuals within it.

In developing this information strategy, a number of investigations and activities have already been initiated using a combination of NMFS base funds and NOAA ESDIM prior year funding..

- The first being the identification of the data which NMFS presently collects, and for which it has stewardship. This census is planned for completion by the end of FY 92. Efforts are currently underway to develop meta data for those data bases as well as to rescue critical data in danger of being lost. Additionally, all data is being examined to ensure it is of "science quality" and where necessary efforts are being planned to raise its quality to this level. (See Section V.)

- A second effort is the evaluation of the scientific effort and information requirements necessary to achieve Goal #3 *Advance fishery forecasts and ecosystem models*. This goal is a key element in meeting NMFS's commitment to reducing uncertainty in the future. (See Section VI.)

- The third effort involves the identification of the critical success factors involved in removing uncertainty relative to achievement of the goals described in the NMFS strategic plan. (See Section VII.)

These investigations have made it clear that the current NMFS information and decision support systems will not meet the needs of these critical goals, nor will they satisfy the NMFS's requirement to support major NOAA-wide programs and other external users with the biological and environmental data for which it has stewardship. A new information strategy is required that builds on the strength of the existing system, but has the flexibility to evolve and meet the more complex mission requirements of the future. Additionally, this information strategy will have to address two major issues:

1. Support of a Virtual Environmental and Biological Data Center
The requirement for a virtual environmental and biological data center built on a distributed architecture and linked through an open systems model is rooted in the decentralized nature of the NMFS organization and the resulting distributed nature of its biological and environmental data bases. The NMFS philosophy concerning the stewardship of this data is in concert with that of the National Academy of Sciences's National Research Council which in a report entitled *Solving the Global Change Puzzle - A U.S. Strategy for Managing Data and Information* makes the following observations:

> "The prime function of any data and information management system is the stewardship of the data and information, with all of its ramifications."
>
> "Successful data systems or centers are those that combine data management with scientific use of the data"
>
> "A successful system involves the scientific community at all stages of development and operation."
>
> "We envision a 'virtual system' which, as described below, implies that the user sees a uniform and coherent structure. In actuality, the system will be built by many participating organizations out of many different parts on different computers using different software. An additional layer of software and/or hardware will be used to tie together the pieces, so that the user can navigate through the entire system virtually *as if it were a single entity."*

2. Ecosystems Based Management of Living Marine Resources
Today, answers to increasingly complex questions are required in almost every area of scientific investigation and decision-making. This continues to be true for ecosystems-based management of living marine resources. Our data management system must have the design flexibility to integrate various types of data over different time and space scales to support unknown but more complex analyses in

the future. This requires a capability to share and integrate scientific information on a scale beyond anything ever attempted before. NMFS, as custodian of a large and critical portion of the Nation's biological and environmental data bases, must fulfill its role of stewardship by making this data available. Additionally it will become increasing dependent in the years ahead on having access to data from other organizations. To this end, the resulting information system must adhere to the international standards for such data and its access; and provide for the exchange of data with scientists and decision-makers throughout the world. The National Research Council report mentioned above contains a statement "Some important fields that will be involved in global change research do not have established data centers. For example, there are no recognized national data centers for ecological, biological, and geological data. These gaps must be filled if an effective global change data management system is to be established." NMFS is committed to responding to this issue by enhancing access to its biological and related ecological data bases and making them available on a national and international basis.

The road map to implement the MEDS concept is described briefly in Section XI and in detail in Appendix A. The costs to accomplish this will far exceed the funding possible from NMFS's base line budget. This means that achieving the goals set forth in this document is dependent on receiving funding from NOAA-wide, cross-cutting programs for the required research and data management activities. NMFS is requesting funding under the Earth System Data and Information Management Program initiative for the data management proposals contained in Appendix A of this document. NMFS has made a major commitment to achieving the goals set forth in this document and is now asking for ESDIM's support and commitment to make it a reality.

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SECTION II. NMFS MISSION

INTRODUCTION

This section briefly describes the NMFS mission and history, and the increasingly complex and critical nature of its mission. Also discussed are the growing number of strategic partnerships and the critical role that data management plays in supporting the mission.

MISSION

The mission of the National Marine Fisheries Service is the stewardship of the Nation's living marine resources.

BACKGROUND

It has long been recognized that conservation and wise use of living marine resources requires a sound scientific basis. In 1871, the United States Congress established the U. S. Commission of Fish and Fisheries, predecessor of the National Marine Fisheries Service, "... to investigate the reasons for the decline in coastal fish stocks off southern New England and to recommend corrective measures . . ."

The National Marine Fisheries Service today is a part of the National Oceanic and Atmospheric Administration (NOAA), America's "Earth System Agency". NOAA's fundamental mission is to observe, describe and predict the natural variability of the global earth system (the ocean, the atmosphere, and features of the solid earth and near space environment) and to identify any changes in the earth system caused by natural events or human activity. Living marine resources are part of the earth system and the NOAA Strategic Plan assigns responsibility for their research and their conservation to the National Marine Fisheries Service.

The National Marine Fisheries Service thus carries on a 120 year tradition in its mission of stewardship of the Nation's living marine resources.

INCREASINGLY CRITICAL NATURE AND URGENCY OF THE MISSION

The need for NMFS to fulfill it's mission has never been more urgent or critical. There are mounting problems that threaten U. S. fisheries, and living marine resources and the habitat upon which they depend. Since 1977, when the U. S. extended its jurisdiction seaward to 200 miles, domestic fisheries have expanded to almost entirely displace once dominant foreign fleets. The replacement of foreign fleets has not, however, eliminated overfishing. Continued expansion of domestic fishing capacity not only adds to the stress on living marine resources, it also undermines the economic well being of some fisheries. One manifestation of the expansion of fishing capacity and overfishing is the conflicts between user groups, which ultimately must be addressed through difficult allocation decisions. Options for allocation are often limited by the non-selective nature of many types of fishing gear. In addition, the U. S. is now fishing more species than ever before; however, scientific information on many of these species is lacking.

The relationship between fisheries and marine mammals and endangered species is also problematic. As populations of some marine mammals and endangered species recover, they are more frequently taken incidentally in fishing operations. It is also possible that fisheries contribute to the failure to recover of some other marine mammal and endangered species. In some cases, efforts to protect marine mammals and endangered species may require valuable fisheries to be terminated.

There are other serious threats, as well. Habitat degradation continues to threaten some living marine resources and growing concerns for the health risk from seafood threaten the industry.

INCREASING COMPLEXITY OF THE MISSION

Meeting these critical issues has grown increasing complex. In the last 20 years NMFS' responsibilities have increased exponentially as a result of more than 100 legislative acts and international conventions and treaties. NMFS now has management responsibility for most U. S. living marine resources.

Most of its responsibilities emanate from the following six statutes plus their recent amendments.

- The Magnuson Fishery Conservation and Management Act of 1976, which regulates fisheries within the U. S. Exclusive Economic Zone.
- The Endangered Species Act, which protects species determined to be threatened or endangered.
- The Marine Mammal Protection Act, which regulates taking or importing marine mammals.
- The Lacey Act, which prohibits fishery transactions that violate state, Federal, American Indian or foreign laws.
- The Fish and Wildlife Coordination Act, which authorizes NMFS to collect fisheries data and to advise other government agencies on environmental decisions which affect living marine resources.
- The Agricultural Marketing Act, which authorizes a voluntary seafood inspection program.

The complex nature of the various issues includes a jurisdictional reality; living marine resources often cross one or more political boundaries (state, Federal, and/or international). No single political entity has full jurisdiction, in these situations, and co-operative domestic and international efforts in data collection, research, planning, and resource management are required.

INCREASING NUMBER OF PARTNERS IN FULFILLING ITS MISSION

NMFS works closely with other NOAA line offices, especially in emerging NOAA-wide research efforts, such as the Coastal Ocean, Climate and Global Change, and Earth Science Data Information Management Programs, as well as the Marine Resources and Ocean Sciences 2000 Program.

Eight Regional Fishery Management Council (established under the Magnuson Act) are partners with NMFS in the management of the Nation's fisheries. These bodies are made up of representatives of state governments, commercial and recreational fisheries, environmental and consumer groups and other interests. They prepare Fishery Management Plans defining how fisheries should be regulated in view of biological, social and economic factors, for consideration by the Secretary of Commerce. These plans contain objectives for each fishery and appropriate management measures. NMFS ensures that these plans comply with legal and policy requirements, and, with the cooperation of the Coast Guard and state governments, implements the plans.

NMFS has also entered into agreements and relationships with numerous state, interstate, Federal, and international organizations to fulfill its legal mandates. For example, it has agreements and relationships with interstate Marine Fisheries Commissions for management of inter-jurisdictional fisheries; the U. S. Fish and Wildlife Service for protection of endangered and threatened sea turtles; most coastal states for enforcement under provisions of the Lacey Act; the Army Corps of Engineers for fulfillment of the provisions of the Fish and Wildlife Coordination Act; the Departments of Defense and Agriculture for voluntary seafood inspection; the U.S. - Canada Pacific Salmon Commission for conservation of Pacific salmon; and the International Whaling Commission for conservation of whales. Others include the International Convention for the Conservation of Atlantic Tuna (ICCAT) and Inter-American Tropical Tuna Commission (IATTC) for international tuna management, and the Organization of Eastern Caribbean States (OECS) for research coordination

NMFS prepares many specialized scientific reports (about 800 in 1990) in support of these Federal management responsibilities and its scientific mission. The various analyses, stock and landings forecasts, identification and evaluation of management alternatives all depend at various stages on the data management system.

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1. National Marine Fisheries Service, *Our Living Oceans, The First Annual Report On The Status Of U.S. Living Marine Resources*, 1991.

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SECTION III. NMFS ORGANIZATION

INTRODUCTION

This section presents an overview of the streamlined distributed organization for NMFS with the science and management operations integrated by geographical region. Important regional issues and species are also identified since they impact the data management system design.

NMFS ORGANIZATIONAL OVERVIEW

The National Marine Fisheries Service administers its monitoring, research and management responsibilities through its headquarters organization located in Silver Spring, Maryland, and five Regional headquarters across the continental U. S. and Alaska. There are approximately 1800 career staff employees representing a spectrum of skills including, but not limited to: wildlife or natural resource management; fisheries biology; oceanography; mathematics; statistics; chemistry; economics; computer science; sociology; law enforcement; business; and finance.

Living marine resource management is directed from these five regional headquarters. Monitoring and research programs to support this are carried out at 29 principal research facilities. This distributed reality with the scientists, managers and their data closely located to the fisheries and related living marine resources, is a key design requirement for the distributed architecture of MEDS.

A high level organization chart depicting senior management of NMFS is shown in Figure III-1. In the following sections each of the regional headquarters is decomposed to reflect the associated research facilities, their geographic locations, and functions. The diagrams do not include all subordinate levels or administrative offices.

HEADQUARTERS OPERATIONS

The National Marine Fisheries Service administers NOAA's program to manage living marine resources for commercial and recreational use. The program provides services and products to support fisheries management operations; international fisheries affairs; fishery development, trade, and industry assistance activities; protected and habitat conservation operations; and the scientific and technical aspects of NOAA's marine fisheries resources programs. A brief description of the functions and responsibilities of each of the headquarters groups is given below.

OFFICE OF THE ASSISTANT ADMINISTRATOR

The Office of the Assistant Administrator manages the National Marine Fisheries Service and coordinates the marine fisheries programs throughout NOAA to ensure the compatibility and effectiveness of all of NOAA's marine fisheries activities. The Office implements programs to assist the U.S.

fishing industry to enhance production and marketing; develops positions on international fisheries issues; assesses and provides guidance on conservation and protection of marine mammals, their habitats, and matters related to the environmental impact of human activities on living marine resources; coordinates aquaculture research; and contributes advice on the socioeconomic condition of fisheries and their product quality, safety, and use. The Office coordinates with and receives support from other Assistant Administrators including the provision of ship operational support and assessment of the effects of energy and mineral extraction, ocean dumping and coastal zone development on living marine resources. It maintains cognizance of marine related activities of the National Weather Service and the National Environmental Satellite, Data, and Information Service. The Office coordinates research programs with the Office of Oceanic and Atmospheric Research to avoid duplication of effort among NOAA research activities and to ensure that research results are utilized fully in planning programs and providing services.

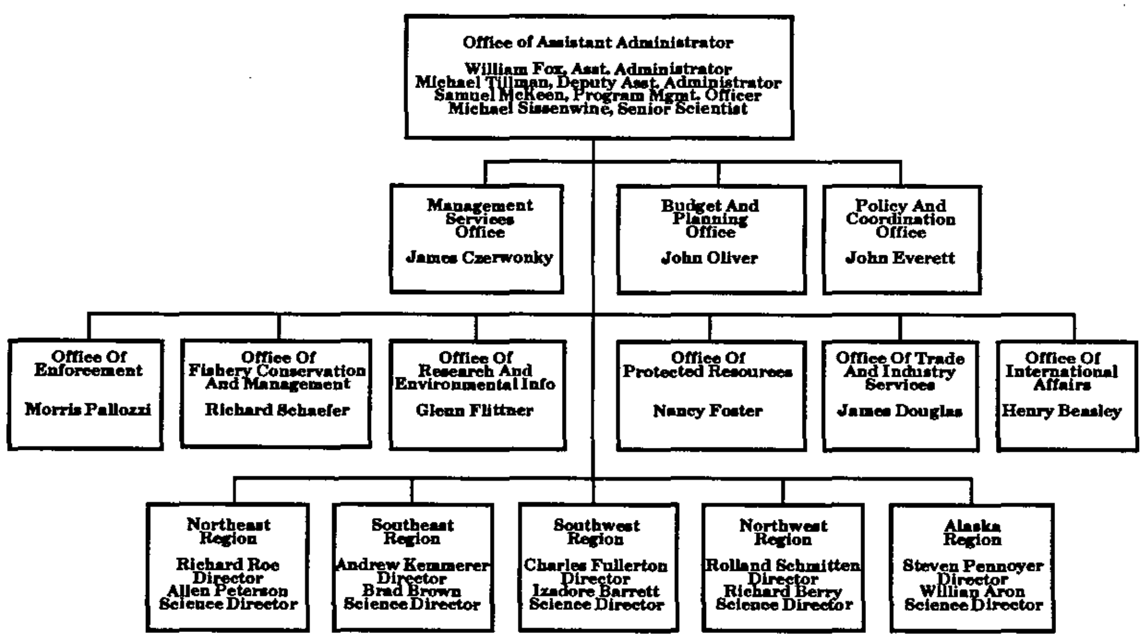

Figure III-1
NMFS Organization Chart

MANAGEMENT SERVICES OFFICE

The Management Services Office advises on the selection of NMFS-wide administrative and management goals, objectives, and measures of accomplishment and productivity. The Office coordinates agency review of Inspector General and General Accounting Office audits; monitors implementation of audit recommendations; coordinates agency internal control assessments and the identification and selection of Internal Control Review candidates. The Office provides management and technical oversight of the Scientific Publications Staff located in Seattle, Washington. The Office monitors the staffing and organization of NMFS and conducts management and organization studies to ensure the optimum utilization of human and material resources. It coordinates the NMFS Information Collection Budget program and agency compliance with the Paperwork Reduction Act. The Office provides ADP support and services to NMFS headquarters components. It coordinates the implementation, operation and integration of Departmental, NOAA and NMFS administrative systems; coordinates and monitors NMFS-wide EEO/AAP activities; coordinates NMFS privatization and A-76 activities; provides foreign travel processing services for NMFS; and provides program support for NMFS headquarters elements.

BUDGET AND PLANNING OFFICE

The Budget and Planning Office advises on the selection and priority of NMFS-wide programs goals, objectives, and measure of accomplishment. The Office monitors the utilization of resources and advises on the most efficient distribution among the Financial Management Centers. It manages the NMFS-wide development of the NMFS Strategic Plan and other plans to meet objectives; provides staff support for NMFS budget formulation and budget execution activities; and functions as the focus for management of NMFS financial resources. The Office develops Congressional budget hearing testimony and presentation materials. It advises on resource alternatives and identifies the management impact of resource allocation, retrenchments, and reprogramming. The Office advises on the selection of long-range program alternatives and recommends program emphasis/ initiatives. It monitors overall program accomplishments and coordinates NMFS-wide reporting on program status.

POLICY AND COORDINATION OFFICE

The Policy and Coordination Office advises on the status and need for revision of current policies and the development of new ones. The Office develops and coordinates legislative initiatives within NMFS and across NOAA and prepares the legislative agenda. It provides for inter-agency coordination of programs and is the primary NMFS liaison with the NOAA program office for climate and global change. It prepares testimony and speeches. Its staff provides the focus for NMFS Sea Grant coordination and conduct program evaluations to assess the cost effectiveness, accomplishments, and direction of NMFS programs. The Office oversees the preparation of Internal Control Reviews.

OFFICE OF ENFORCEMENT

The Office of Enforcement enforces all Federal statutes and regulations under the jurisdiction of NOAA regarding the protection of fisheries, marine sanctuaries, marine mammals, endangered species, and other ocean resources. The Office is the principal source of advice and guidance to NOAA on enforcement matters. It plans, organizes, and implements law enforcement activities to enforce laws, including, but not limited to: the Magnuson Fishery Conservation and Management Act of 1976; the Marine Mammal Protection Act of 1972; the Endangered Species Act of 1973; and the Lacey Act. The Office investigates alleged criminal and civil violations of Federal statutes and assists U.S. Attorneys in prosecuting violators. It participates with and trains U.S. Coast Guard, U.S. Customs Service, and state law enforcement agencies in patrol and inspection activities to enforce statutes within the exclusive economic zone. The Office coordinates NOAA's enforcement policies and programs with other enforcement agencies including: state enforcement agencies; the U.S. Coast Guard; U.S. Customs Service; Drug Enforcement Agency; Food and Drug Administration; Department of Justice; and the National Narcotics Border Interdiction System.

OFFICE OF FISHERY CONSERVATION AND MANAGEMENT

The Office of Fisheries Conservation and Management provides the principal source of advice and guidance on fishery management responsibilities. The Office develops national standards, policies, and operational guidelines for fisheries management programs. It reviews and recommends action on fishery management plans and prepares regulations to be implemented, as necessary. The Office processes applications and issues fishing permits. It coordinates all administrative support required by the Regional Fishery Management Councils.

OFFICE OF RESEARCH AND ENVIRONMENTAL INFORMATION

The Office of Research and Environmental Information provides oversight for and serves as the principal source of advice and guidance on the scientific and technical aspects of NOAA's programs that gather information and data needed to predict future stock sizes and the effects of environmental perturbations or different fishing levels on the continued production of resource populations. The Office provides advice on matters related to the collection of basic statistics (environmental, biological, economic and sociological) in domestic and foreign fisheries, and the management of data from NOAA's marine fisheries resources programs. It assists in development and operation of a program for application of integrated environmental and fisheries data to predict the potential of future fisheries; develops policy and guidelines and provides national coordination for the planning, development and execution of multi-disciplinary ecological research programs relating to recruitment in large marine ecosystems. The Office is responsible for the collection of basic fisheries and environmental data. It coordinates the review and evaluation or research programs and scientific activities related to monitoring, assessment and prediction in the marine environment. The Office publishes the U.S. Fishery Statistics and manages the Scientific Publications unit.

OFFICE OF PROTECTED RESOURCES

The Office of Protected Resources provides advice and guidance on the conservation and protection of those marine mammals and endangered species under the jurisdiction of the Secretary of Commerce; on the conservation, restoration and enhancement of living marine resources and their habitats; develops national guidelines and policies for relevant research programs; provides oversight, advice and guidance on scientific aspects of managing protected species, marine protected areas and habitats; and manages specific projects as assigned by the Assistant Administrator. The Office, for protected species, prepares regulations and public notices; conducts public meetings and hearings; prepares and reviews management, recovery plans and environmental impact analyses; processes Section 7 Consultations under the Endangered Species Act; coordinates national level projects; issues permits; assists the Office of Enforcement in coordinating pertinent programs; provides technical support for international programs and negotiations; provides policy guidance on national research programs; acts as liaison with the Marine Mammal Commission, National Environmental Organizations, industry and other Federal agencies; and maintains program oversight for fur seal management and research. For habitat conservation, the Office develops national program policies, plans, and budget justifications; initiates, in cooperation with regions, national level efforts focused on habitat concerns in accordance with legislative authorities; reviews and advances NMFS positions on proposed Federal projects, permits, leases, and licenses which have national significance; reviews the adequacy of NMFS comments on Environmental Impact Statements of other agencies and Federal proposals to explore and develop outer continental shelf oil and gas resources; develops NMFS positions on proposed policies, programs and regulations of other agencies, as well as legislation of importance to habitat conservation; and serves as principal liaison with other Federal agencies and environmental organizations on habitat issues.

OFFICE OF TRADE AND INDUSTRY SERVICES

The Office of Trade and Industry Services provides the principal source of advice and guidance on NOAA's programs designed to improve the competitiveness of the U.S. fishing industry in domestic and world markets and enhance the safety and quality of U.S. seafood products. The Office develops policies, guidelines, and procedures for industry service programs administered by headquarters and/or regional offices, including programs for: (1) identification of U.S. industry trade issues and problems and advising U.S. trade agencies on fisheries trade matters and promotion activities; (2) financial assistance in the form of loan guarantees, insurance programs, a capital construction fund and research and development grants; (3) administration of fisheries marketing councils; (4) advising the

Department of Agriculture on the use of its surplus commodity purchase and export financing programs for fishery products; (5) administration of fisheries products inspection and grading and product standards programs; (6) research and development on product safety, quality and use; (7) developing and maintaining channels of communication with all fishing industry sectors on policy and program issues; (8) allocation of U.S. fishing resources to foreign countries; (9) foreign fishing and joint venture permits and foreign fishing fees; and (10) preparation of industry/market review and outlook reports. The Office has direct line authority for four financial services field offices located in Gloucester, MA.; St. Petersburg, FL.; Seattle, WA.; and Terminal Island, CA.; for three inspection services field offices located in Gloucester, MA.; St. Petersburg, FL.; and Bell, CA.; and for one inspection laboratory in Pascagoula, MS.

OFFICE OF INTERNATIONAL AFFAIRS

The Office of International Affairs serves as the principal source of advice on international issues relating to living marine resources. The Office develops policy positions on international marine resources; acquires information and provides analyses regarding foreign activities and governmental attitudes and policies regarding marine resources. It participates in negotiations within, and operations of, international forums, commissions, and agreements. The Office manages NOAA's international fisheries training program, and monitors and coordinates activities with regard to U.S. overseas diplomatic posts.

NORTHEAST REGION

The Northeast Region is headquartered in Gloucester, Massachusetts. The geographic territory of the Northeast Region includes ten Atlantic coast states (Maine through Virginia), seven Great Lake states, two landlocked states (West Virginia and Vermont), and the District of Columbia. An organization chart for the Northeast Region is shown in Figure III-2.

The Northeast Region serves as the regional representatives of the Assistant Administrator for Fisheries (NOAA) with state conservation agencies, recreational interests, the fishing industry, other constituencies, and the general public. The Region is responsible for planning, organizing, and implementing fishery management and conservation programs (including regulatory requirements under fishery management plans), fishery development, recreational fisheries programs, and providing assistance to the industry throughout the range of NMFS programs.

The Regional Director is supported by the Northeast Fisheries Science Center at Woods Hole, Massachusetts. The Northeast Fisheries Science Director oversees the Science Center and seven Regional research facilities.

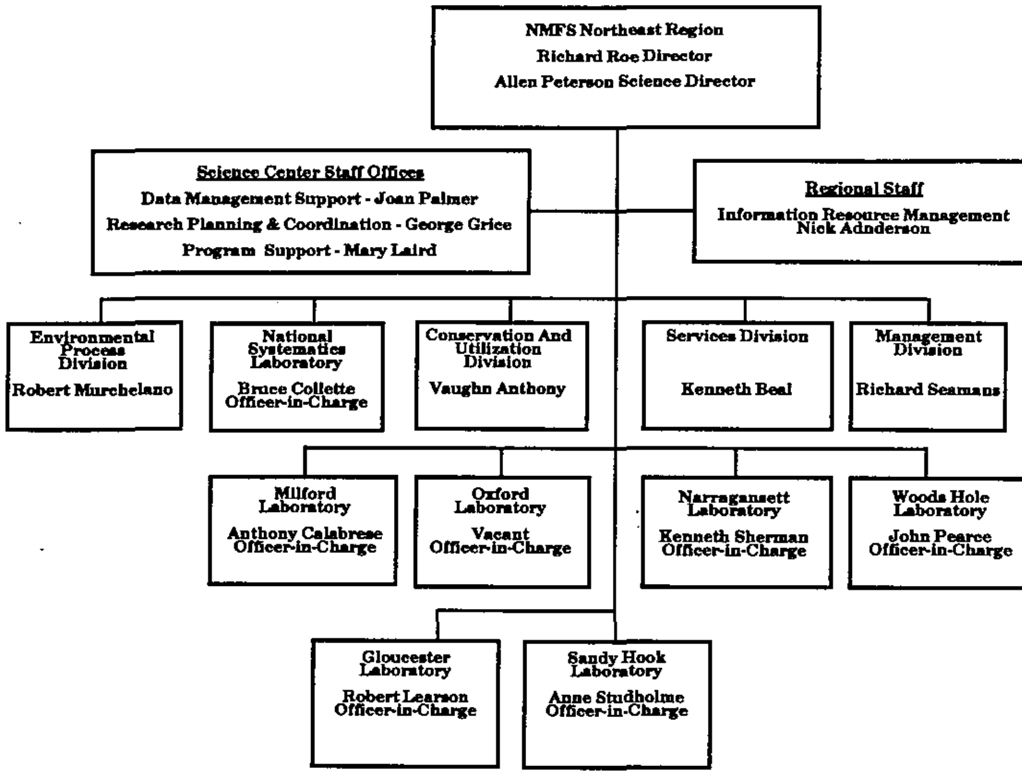

Figure III-2
NMFS Northeast Region Organization Chart

Important regional issues and concerns being addressed at these research facilities include the monitoring of severely depleted New England groundfish stocks; ocean pollution; habitat degradation and loss, and the impact on marine life and abundance; seafood product quality and safety; marine mammal interactions; and recovery of endangered species. Specific areas of concentration or specialization for the individual research centers is shown below.

MILFORD, CONNECTICUT
The Milford research facility concentrates on physiology, biochemistry, immunology, and genetics to determine effects of pollution or natural environmental factors on life functions (reproduction, growth, recruitment, etc.) of marine fish and invertebrates.

OXFORD, MARYLAND
The Oxford research facility specializes in disease agents (both infectious organisms and non-infectious contaminants) affecting molluscan and crustacean shellfish, tracking location and disease levels, developing diagnostic techniques, and pre-importation shellfish surveys.

NARRAGANSETT, RHODE ISLAND
The Narragansett research facility specializes in the study of oceanographic systems (ocean circulation), nutrient growth and location, temperature fluctuations, and fish populations as related to life cycles.

WOODS HOLE, MASSACHUSETTS
The Woods Hole research facility emphasizes population dynamics, population biology, fisheries statistics, and economics. Major activities are directed at stock assessments for fishery management plans. The Northeast Fisheries Science Center is collocated at the facility.

GLOUCESTER, MASSACHUSETTS
The Gloucester research facility specializes in chemistry investigations based on biochemical (isoelectric focusing) and immunological (monoclonal antibodies) techniques; seafood technology; and seafood quality, safety and nutritional value.

SANDY HOOK, NEW JERSEY
The Sandy Hook research facility concentrates on environmental assessments, ecosystem dynamics, and chemical processes.

SMITHSONIAN (NATIONAL SYSTEMATICS LAB, WASHINGTON D. C.
The National Systematics Laboratory focuses on species identification of crustaceans, squids and fishes.

These research facilities provide the scientific support for the agency's conservation and management responsibilities, including the regulatory activities, with respect to the Nations living marine resources and their marine and estuarine habitats. They also provide scientific advice to the New England and Mid-Atlantic Fishery Management Councils.

A partial listing of the important species in the region include:

Lobsters and sea scallops
Cod, haddock, red hake, pollock, flounders, white hake
Squid, mackerel and butterfish
Surf clams and ocean quahogs
Blue fish, river herring
Striped bass, Atlantic salmon
Sharks, tunas, swordfish
Right whales, dolphins

SOUTHEAST REGION
The Southeast Region is headquartered in St. Petersburg, Florida. The geographic territory of the Southeast Region includes four Atlantic coast states (North Carolina, South Carolina, Georga, and Florida), five Gulf coast states (Florida, Alabama,

Mississippi, Louisiana and Texas), nine landlocked states (Kentucky, Tennessee, Missouri, Arkansas, Iowa, Nebraska, Oklahoma, and New Mexico), Puerto Rico, and the U. S. Virgin Islands. An organization chart for the Southeast Region is shown in Figure III-3.

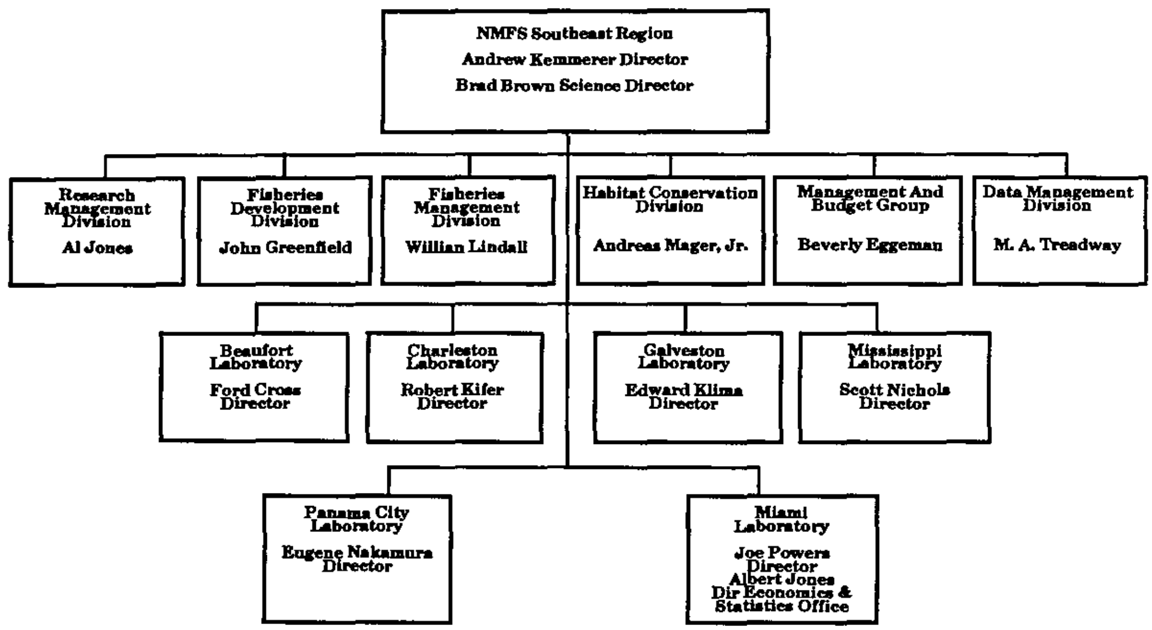

Figure III-3
NMFS Southeast Region Organization Chart

The Southeast Region serves as the regional representatives of the Assistant Administrator for Fisheries (NOAA) with state conservation agencies, recreational interests, the fishing industry, other constituencies, and the general public. The Region is responsible for planning, organizing, and implementing fishery management and conservation programs (including regulatory requirements under fishery management plans), fishery development, recreational fisheries programs, and providing assistance to the industry throughout the range of NMFS programs.

The Regional Director is supported by the Southeast Fisheries Science Center located in Miami, Florida. The Southeast Fisheries Science Director oversees the Science Center and six Regional research facilities. An additional laboratory in

Lafayette, Louisana is under development and is expected to be operational in FY 1995. The focus will be wetlands research.

Important regional issues and concerns being addressed at these research facilities include bycatch, especially the effect of shrimping on endangered sea turtles and juvenile fish; recovery of endangered sea turtles; habitat degradation and loss and the impact on marine life and abundance; Atlantic and Gulf pollution (including oil spills) and the impact on marine life and abundance; overfishing and marine mammal interactions; issues and factors influencing the recruitment process of commercial and recreational fishery stocks. Specific areas of concentration or specialization for the individual research centers is shown below.

BEAUFORT, NORTH CAROLINA
The Beaufort research facility concentrates on population dynamics; population biology of menhaden, king and Spanish mackerel, and reef fish; investigations of the distribution and contribution of natural and created estuarine and coastal habitats to the survival of estuarine-dependent fisheries; and oceanographic processes affecting growth and survival of larvae and juveniles for ocean spawning estuarine dependent species.

CHARLESTON, SOUTH CAROLINA
The Charleston research facility focuses on use of traditional and underutilized commercial and recreational fishery resources; omega-3 fatty acids (fish oil); seafood product quality and safety issues; and autopsies and marine forensic studies.

GALVESTON TEXAS
The Galveston research facility specializes in shrimp population dynamics; sea-turtle biology and physiology; habitat conservation and enhancement; and rearing tagging, and releasing of Kemps Ridley sea turtles.

MISSISSIPPI LABORATORY
The Mississppi Laboratory comprises two facilities located within 65 miles of each other, one at Pascagoula, Miss. and one at the Stennis Space Center, Miss. The Laboratory manages the Latent Resource Program and provides at-sea vessel support for all other SEFC programs. The facility provides docking for two NOAA vessels, the Oregon II and the Chapman. The Laboratory manages the Southeastern Area Monitoring and Assessment Program (SEAMAP) that involves state and federal cooperation to collect, manage and distribute fishery independent data. The laboratory conducts gear research to achieve conservation objectives. The Trawl Efficiency Device (TED) was developoed at the laboratory to eliminate capture of sea turtles in shrimp trawls. Engineering research and development activities, along with applications of satellite remote sensing are carried out at the Stennis Space Center facility.

PANAMA CITY, FLORIDA
The Panama City research facility studies stock distribution and abundance; movements and migrations; stock identification; predator-prey relationships; age and growth, reproductive biology, early life history and recruitment of coastal pelagic and coastal demersal fishes; and the biology and ecology of sea turtles and billfishes.

MIAMI, FLORIDA
The Miami research facility emphasizes population dynamics; fisheries biology; and population assessments for fish, marine mammals and sea turtles. The laboratory manages the Cooperative Tagging Program to collect life-cycle history information. The Southeast Fisheries Science Center is collocated at the facility.

These research facilities provide the scientific support for the agency's conservation and management responsibilities, including regulatory activities with respect to the Nations living marine resources and their marine and estuarine habitats. They also provide scientific advice to support the South Atlantic, Caribbean and Gulf of Mexico Fishery Management Councils.

A partial listing of the important species in the region include:

Menhaden
Reef fish complex (snappers, groupers, wreckfish, etc.)
Swordfish and billfishes (marlin, sailfish)
Spiny lobster, stone crab
Shrimp (pink, white, brown)
King and Spanish mackerel, dolphin, cobia
Red drum
Coral and coral reefs
Porpoise, sea turtles, whales (sperm, humpback, right, minke)
Sharks, tunas

SOUTHWEST REGION
The Southwest Region is headquartered in Long Beach, California. The geographic territory of the Southwest Region includes two coastal states (California and Hawaii), two landlocked states (Arizona and Nevada), American Samoa, Guam, and the North Mariana Islands. An organization chart for the Southwest Region is shown in Figure III-4.

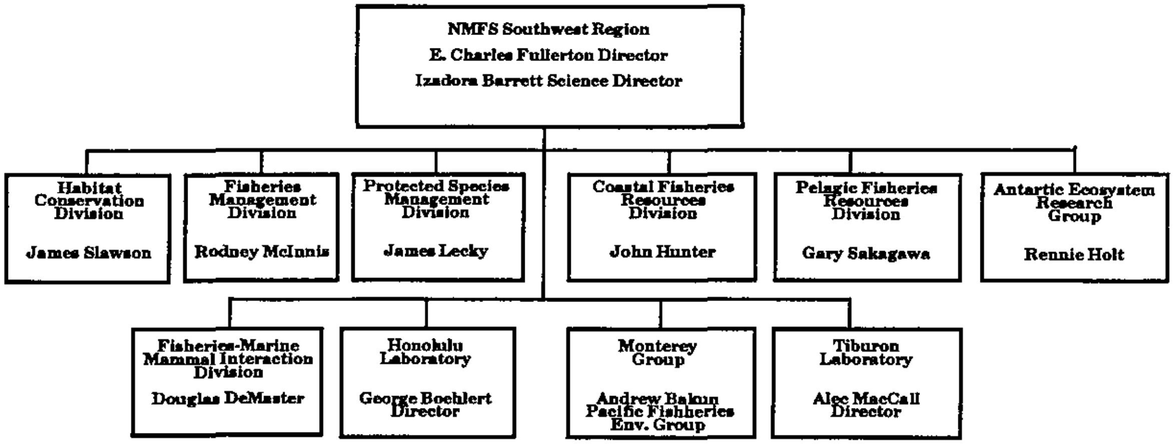

Figure III-4
NMFS Southwest Region Organization Chart

The Southwest Region serves as the regional representatives of the Assistant Administrator for Fisheries (NOAA) with state conservation agencies, recreational interests, the fishing industry, other constituencies, and the general public. The Region is responsible for planning, organizing, and implementing fishery management and conservation programs (including regulatory requirements under fishery management plans), fishery development, recreational fisheries programs, and providing assistance to the industry throughout the range of NMFS programs.

The regional director is supported by the Southwest Fisheries Science Center located in La Jolla, California. The Southwest Fisheries Science Director oversees the Science Center and four Regional research facilities.

Important regional issues and concerns being addressed at the research facilities include porpoise bycatch in the tuna fishery, recovery of the Hawaiian monk seal and other endangered species, ocean pollution, habitat degradation and loss and the impact on marine life and abundance, marine debris (including driftnets) and the impact on marine life and abundance, and marine mammal interactions. Specific areas of concentration or specialization for the individual research centers is shown below.

HONOLULU, HAWAII
The Honolulu research facility studies insular, pelagic and seamount resources; fishery enhancement and dynamics; ecology of fish and shellfish resources for island-associated ecosystems and the effects of ocean

environment on abundance; the pelagic ecosystem and physiology of tropical tunas; and marine mammals and endangered species.

LA JOLLA, CALIFORNIA
The La Jolla research facility focuses on stock assessments, tuna/large pelagics; fishery/marine mammal interactions (including tuna/porpoise); North Pacific albacore; coastal pelagic fishes and groundfish. Stock assessments are also done in the Antarctic region. The Southwest Fisheries Science Center is collocated at the facility.

MONTEREY, CALIFORNIA
The Monterey Pacific Fisheries Environmental Group located in Monterey specializes in mathematical modeling and data processing; fishery environmental linkages; and physical oceanography.

TIBURON, CALIFORNIA
The Tiburon research facility concentrates on groundfish physiology and ecology; groundfish stock assessments; Klamath and Sacramento River salmon; and habitat issues affecting San Francisco Bay and the Gulf of Farallones.

These research facilities provide the scientific support for the agency's conservation and management responsibilities, including the regulatory activities, with respect to the Nations living marine resources and their marine and estuarine habitats. They also provide scientific advice to the Pacific and Western Pacific Fishery Management Councils.

A partial listing of the important species in the region include:

- Salmon
- West Coast groundfish (rockfish, perch, sole, whiting, and sablefish)
- Northern anchovy
- Striped bass
- Spiny and slipper lobsters
- Corals
- Hawaiian and Western Pacific groundfish and seamount resources
- Billfish, tunas and sharks
- Whales (gray, humpback), harbor monk and elephant seals, harbor porpoise and other porpoises

NORTHWEST REGION
The Northwest Region is headquartered in Seattle (Sand Point), Washington. The geographic territory of the Northwest Region includes two coastal states (Washington and Oregon), and seven landlocked states (Idaho, Montana, North Dakota, South Dakota, Wyoming, Utah, and Colorado). An organization chart for the Northwest Region is shown in Figure III-5.

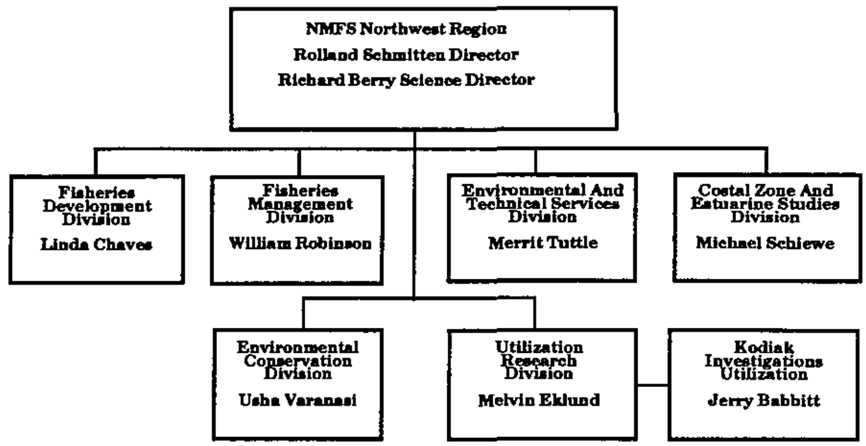

Figure III-5
NMFS Northwest Region Organization Chart

The Northwest Region serves as the regional representatives of the Assistant Administrator for Fisheries (NOAA) with state conservation agencies, recreational interests, the fishing industry, other constituencies, and the general public. The Region is responsible for planning, organizing, and implementing fishery management and conservation programs (including regulatory requirements under fishery management plans), fishery development, recreational fisheries programs, and providing assistance to the industry throughout the range of NMFS programs.

The Regional Director is supported by the Northwest Fisheries Science Center located in Seattle (Montlake), Washington. The Northwest Fisheries Science Director oversees the Science Center and seven Regional research facilities.

Important regional issues and concerns being addressed at these research facilities include the potential endangered species listing of some salmon stocks; Columbia River hatchery production and survival of smolts; ocean pollution; marine debris (including driftnets); habitat degradation and loss and the impact on marine life and abundance; and conflicts between marine mammals and fisheries. Specific areas of concentration or specialization for the individual research facilities is shown below.

MONTLAKE, WASHINGTON
The Montlake research facility concentrates on the aquatic resources of the Columbia River drainage system and Puget Sound; fish passage problems

associated with dams; habitat issues; enhancement of salmon and steelhead runs; effects of contaminants on life processes; and seafood product quality and safety issues.

MANCHESTER, WASHINGTON
The Manchester research facility specializes in hatchery techniques to produce quality smolts and increase their survival, and in genetic identification of Pacific salmon stocks in mixed ocean fisheries.

MUKILTEO, WASHINGTON
The Mukilteo research facility focuses on long-term effects of exposure to polluted estuaries on juvenile salmon, flat fish, and other marine species; and development and use of toxicity bioassays for marine sediments and water.

NEWPORT, OREGON
The Newport research facility studies fish behavior, i.e., how various physical and biological factors affect survival and distribution of marine resources (sablefish, walleye pollock, coho and chum salmon).

POINT ADAMS, HAMMOND, OREGON
The Point Adams research facility concentrates on fisheries habitat enhancement and protection; dredging and dredge disposal impact; and white sturgeon and Dungeness crab life histories (i.e., abundance, size class structure, and distribution).

PASCO, WASHINGTON
The Pasco research facility specializes in the ecological effects of dams and other water resource developments relating to anadromous species migrations in the Columbia River basin.

KODIAK, ALASKA
The Kodiak, Alaska research facility is part ofthe Utilization Research Division and specializes in product quality and product safety issues. There is also a fish technology pilot plant at Gibson Cove associated with this facility.

These facilities provide the scientific support for the agency's conservation and management responsibilities, including the regulatory activities, with respect to the Nations living marine resources and their marine and estuarine habitats. They also provide scientific advice to the Pacific and North Pacific Fishery Management Councils.

A partial listing of important species in the region include:

Salmon (coho chinook, chum, steelhead)
West Coast groundfish (rockfish, perch, sole, sablefish)

Sturgeon, Dungeness crab
Harbor porpoise and seals, Dals porpoise, stellar and California sea lions
Whales (gray, humpback, killer, minke)

ALASKA REGION
The Alaska Region is headquartered in Juneau, Alaska. The geographic territory of the Alaska Region is the state of Alaska. An organization chart for the Alaska Region is shown in Figure III-6.

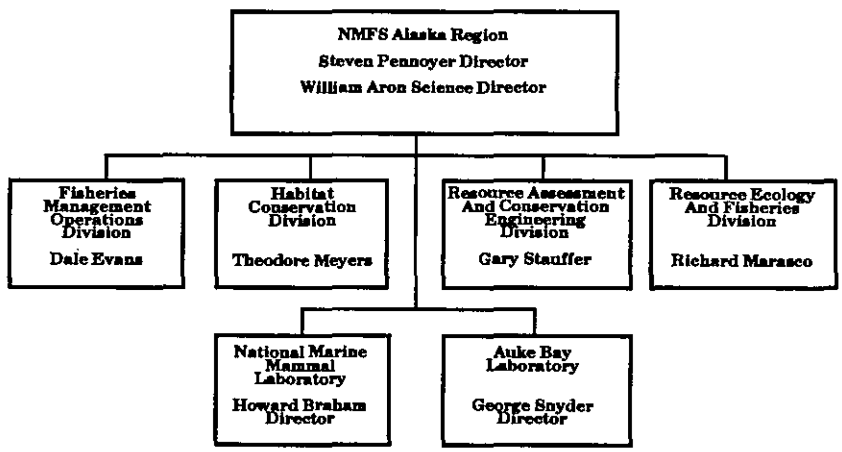

Figure III-6
NMFS Alaska Region Organization Chart

The Alaska Region serves as the regional representatives of the Assistant Administrator for Fisheries (NOAA) with state conservation agencies, recreational interests, the fishing industry, other constituencies, and the general public. The Region is responsible for planning, organizing, and implementing fishery management and conservation programs (including regulatory requirements under fishery management plans), fishery development, recreational fisheries programs, and providing assistance to the industry throughout the range of NMFS programs.

The Regional Director is supported by the Alaska Fisheries Science Center located in Seattle, Washington. The Alaska Fisheries Science Director oversees the Science Center and four Regional research facilities.

Important regional issues and concerns being addressed at the research facilities include assessment of oil spills; international issues including driftnet and salmon interceptions; increased fishing pressure on Alaska groundfish stocks; ocean pollution; marine debris (including driftnets); habitat degradation and loss and the impact on marine life and abundance; salmon enhancement; marine mammal interactions; and recovery of endangered species. Specific areas of concentration or specialization for the individual research centers is shown below.

SAND POINT, SEATTLE, WASHINGTON
The Sand Point research facility concentrates on resource surveys and stock assessments for groundfish and crab stocks off Alaska and the Pacific Northwest coast; population dynamics; fish pathology and recruitment processes; conservation engineering; depleted and recovering species of large whales, dolphins, seals and sea lions (including bowhead and humpback whales, northern fur seals, stellar sea lions, and Dalls porpoise). The Marine Entanglement Research Program is also conducted from Sand Point to address ocean-wide marine debris and gear entanglement issues. The Alaska Fisheries Science Center is collocated at the facility.

AUKE BAY, ALASKA
The Auke Bay research facility specializes in salmon stock assessment and enhancement; high seas squid resources; marine resource ecology; and the effect of natural and man-made environmental change on fishery resources. The Auke Bay laboratory also includes a large support facility in Juneau for docking NOAA vessels and staging resource surveys.

LITTLE PORT WALTER, ALASKA
The Little Port Walter research facility specializes in salmon enhancement.

KODIAK, ALASKA
The Kodiak research facility concentrates on resource survey support and population dynamics.

These facilities provide the scientific support for the agency's conservation and management responsibilities, including the regulatory activities, with respect to the Nations living marine resources and their marine and estuarine habitats. They also provide scientific advice to the North Pacific Fishery Management Council.

A partial listing of the important species in the region include:

Salmon (chinook, coho, pink, sockeye, chum)
King and tanner crabs
Squid

Bering Sea groundfish (pollock, sablefish, sole, flounders, Pacific cod, Pacific ocean perch, other flatfish, and rockfishes)
Gulf of Alaska groundfish (pollock, flounders, sablefish, rockfish, Pacific cod)
Whales (bowhead, humpback, gray, beluga), Dalls porpoise, harbor porpoise, seals, northern fur seals, stellar sea lions

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SECTION IV. NMFS STRATEGIC PLAN

INTRODUCTION

This section summarizes the NMFS strategic program goals and objectives that must be supported by the NMFS MEDS information management plan. The section closes with a discussion of goal implementation.

STRATEGIC PLAN OVERVIEW

The NMFS Strategic Plan sets forth a basic strategy and eight major goals. Their achievement is considered critical to NMFS's ability to continue to meet its mission and effectively respond to the increasingly urgent issues and complex role and relationships that have evolved. Each of these goals is divided into several objectives and a number of planned actions necessary to accomplish them.

STRATEGY

The NMFS strategy articulated in this plan represents a fundamental departure from past approaches. It states that in the face of uncertainty, NMFS will reduce the risk to living marine resources by making decisions that err toward conservation, not overfishing. Recognizing that such a strategy carries with it the responsibility to reduce these uncertainties, the plan goes on to state that NMFS will reduce uncertainty by greatly expanding the scientific information upon which decisions are based and will advocate management practices that enhance the economic well being of fisheries. Each of the goals have objectives and planned actions addressing the implementation of this strategy.

GOALS AND OBJECTIVES

NMFS has formulated eight strategic goals for the coming years. Each goal has several objectives. These are not mutually exclusive; many objectives serve more than one goal. There are also embedded issues, which are not stated explicitly, but which are necessary to fulfill these goals and objectives. For example NMFS must maintain and improve its human resources as a prerequisite for achieving any of its goals and objectives. The MEDS plan must address how to re-orient the data management system to support the strategic plan.

The future as well as the current NMFS data management system must support all agency goals and objectives and help reduce uncertainty. This is the number one system design requirement.

GOAL #1 REBUILD OVERFISHED MARINE FISHERIES

Overfishing is a national problem, although it is most severe along the Atlantic Coast and in the Gulf of Mexico. Fisheries are overfished when fishing pressure exceeds a sustainable level and when abundance has been reduced so that production is much lower than the potential.

OBJECTIVES TO ACHIEVE THIS GOAL

- Reduce fishing effort on overfished stocks.
- Implement Magnuson Act 602 Guidelines for Prevention of Overfishing.
- Reduce bycatch of overfished stocks.

PLANNED ACTIONS TO ACCOMPLISH THESE OBJECTIVES

- Conduct a national evaluation to determine which resources are overfished, including non Fishery Management Plan fisheries.
- Work with Regional Fishery Management Councils and interstate Marine Fisheries Commissions to implement effective Fishery Management Plans, and with the Coast Guard and states to ensure compliance.
- Determine the short-term loss of benefits that will accompany rebuilding of overfished stocks, and identify options to minimize adverse effects.
- Determine the magnitude of bycatch of overfished stocks and options to reduce it.

GOAL #2 MAINTAIN CURRENTLY PRODUCTIVE FISHERIES

It is better to prevent overfishing than to suffer the losses necessary to reverse it. The Nation still has many productive fisheries, including Alaska pollock, Mid-Atlantic surf clams, Gulf of Mexico butterfish, Pacific salmon and most Pacific coast rockfish.

OBJECTIVES TO ACHIEVE THIS GOAL

- Reduce the risk of over fishing.
- Reduce uncertainty in stock assessments.
- Improve compliance with fisheries management regulations.
- Advocate conversion from open access to fisheries to controlled access.
- Correct ineffective elements of the management processes.

PLANNED ACTIONS TO ACCOMPLISH THESE OBJECTIVES

- Critically evaluate Fishery Management Plans to determine if they are working, and if not, why.
- Improve communication between scientists and fishery managers.
- Obtain authority to charge user fees for access to fisheries.
- Improve knowledge of stock structure and migrations.
- Increase the precision and accuracy of resource surveys.
- Develop efficient regional fisheries data collection and data management programs, integrating state activities as appropriate.
- Conduct biological and ecological research on living marine resources that integrates appropriate state research activities, for example, growth and mortality rates, reproductive rates, and habitat requirements.
- Employ state-of-the-art technology and stock assessment methods to improve accuracy and precision of scientific information.

- Assess the degree of compliance with fisheries management regulations, evaluate the factors that have contributed to non-compliance, and correct problems.

GOAL #3 ADVANCE FISHERY FORECASTS AND ECOSYSTEM MODELS

Accurate and precise fishery forecasts and ecosystem models will allow resource management and business decisions to be more proactive and comprehensive, and enhance wise use.

OBJECTIVES TO ACHIEVE THIS GOAL

- Describe functional relationships and processes that control fishery systems.
- Develop higher-order forecasting models for living marine resource populations, ecosystems, and fishery systems.
- Maximize participation in NOAA wide programs.

PLANNED ACTIONS TO ACCOMPLISH THESE OBJECTIVES

- Conduct research on predator-prey interactions among living marine resources.
- Reduce uncertainty in fishery management associated with recruitment of young fish to the fishery.
- Apply non-traditional scientific disciplines to fishery science.
- Evaluate the applicability of adaptive management to fisheries as a means to improve understanding of fishery systems.
- Encourage collection of long time-series of data, and subject data to state-of-the-art analysis.
- Co-chair the elements of NOAA's Coastal Ocean Program involving Coastal Fisheries Ecosystems; Toxins; and Estuarine Habitats.
- Lead the Ecosystem Dynamics Research project of the NOAA Climate and Global Change Program.
- Develop a program prospectus for modernizing NOAA marine programs.
- Form cooperative arrangement with universities and state agencies.

GOAL #4 INTEGRATE CONSERVATION OF PROTECTED SPECIES AND FISHERIES MANAGEMENT

NMFS has legislative mandates to conserve, manage, and protect both fishery resources and protected species. These responsibilities, and the activities that support them, must be integrated to be effective.

OBJECTIVES TO ACHIEVE THIS GOAL

- Identify and resolve conflicts between Marine Mammal Protection Act, Endangered Species Act and fisheries.
- Determine the status of protected species.
- Monitor marine mammal "take" by fisheries and assess its significance.

- Implement Endangered Species Recovery Plans. This is a requirement of the Endangered Species Act for species listed as endangered.
- Reduce fishery and passive viewing impacts on protected species.

PLANNED ACTIONS TO ACCOMPLISH THESE OBJECTIVES

- Expand protected species population assessments.
- Improve knowledge of population biology and ecology of protected species.
- Establish Endangered Species Recovery Teams.
- Conduct at-sea observer programs for fisheries that "take" protected species.
- Monitor stranding of protected species and conduct scientific studies on stranded animals to provide information of their population biology and species interactions.
- Develop a scientific consensus on criteria to define "species", relative to the Endangered Species Act.

GOAL #5 IMPROVE SEAFOOD SAFETY

Most seafood is safe, wholesome, and of high quality. Improper handling and contaminants, however, can lessen the quality and threaten human health. The perception of human health risks can cause significant economic loss.

OBJECTIVES TO ACHIEVE THIS GOAL

- Implement a seafood inspection program, with emphasis on reducing health risks from microbial, biotoxin, and chemical sources, and on providing consumer information about quality.
- Evaluate options and establish mechanisms other than inspection to reduce human health risk.

PLANNED ACTIONS TO ACCOMPLISH THESE OBJECTIVES

- Establish agreements with other Federal agencies and states to implement effective seafood inspection.
- Conduct risk assessments and calculate benefit-cost ratios to determine priorities for seafood inspection.
- Develop statistically rigorous designs for inspection programs that consider contaminant type and the risk to human health; species and tissue; location, season, and year; and scale of patchiness.
- Evaluate health risks that are not controlled by seafood inspection.
- Educate the public about seafood safety, and what consumers can do to reduce the risk.
- Evaluate the legal authority to restrict fishing in order to protect human health.

- Improve techniques to detect biotoxin, microbial, and chemical contaminants.
- Conduct research on the sources and distribution of contaminants, and their bioaccumulation.

GOAL #6 PROTECT LIVING MARINE RESOURCE HABITAT

The long-term viability of living marine resources depends on protection of their habitat and current legislation requires it be considered as a part of any plans or proposed actions.

OBJECTIVES TO ACHIEVE THIS GOAL

- Use authority of the Fish and Wildlife Coordination Act, Magnuson Act, Marine Mammal Protection Act, Endangered Species Act, Oil Pollution Act, Superfund, and other legislation to implement a cohesive strategy to protect and restore habitat of living marine resources.
- Quantify the effects of habitat modifications and contaminants on populations of living marine resources.
- Determine if artificial or restored habitat fulfills essential habitat needs of living marine resources.
- Restore depleted stocks that have been adversely impacted by habitat modifications.

PLANNED ACTIONS TO ACCOMPLISH THESE OBJECTIVES

- Review, revise and implement arrangements with regulatory and development agencies, and states, to increase the effectiveness of NMFS' advice on habitat decisions.
- Fully implement habitat conservation provisions of the Magnuson Act in order to elevate the stature of NMFS' habitat advice.
- Prepare scientific syntheses of information on important habitat issues.
- Expand research on the biological effects of habitat modification and contaminants.
- Conduct research to determine the critical habitat requirements that limit population size of living marine resources.
- Take advantage of opportunities to conduct research cooperatively with regulatory and development agencies when the research supports living marine resources habitat protection.
- Develop implementation plans to apply Oil Pollution Act and Superfund settlements to habitat restoration.

GOAL #7 IMPROVE THE EFFECTIVENESS OF INTERNATIONAL FISHERIES RELATIONSHIPS

Conservation, fishery research, and seafood trade require effective international relationships. The fishery management and protected species jurisdiction of the U.S. is not wide enough to unilaterally conserve all living marine resources important to the Nation.

OBJECTIVES TO ACHIEVE THIS GOAL

- Use international agreements to conserve living marine resources and their habitat.
- Establish and improve international agreements to promote scientific research and communication.
- Influence international trade negotiations to achieve a more competitive position for U. S. seafood products.

PLANNED ACTIONS TO ACCOMPLISH THESE OBJECTIVES

- Monitor the effectiveness of international agreements.
- Develop mechanisms to coordinate Fishery Management Council Plans with international management agreements.
- Examine the effectiveness of the agency's organization for handling international research, management and enforcement needs.
- Improve international systems to collect and/or obtain access to living marine resource data.
- Provide more scientific resources to support international agreements.
- Collect information which will facilitate U. S. competitiveness of fishery products in global markets.
- Work with others to implement scientific activities under the North Pacific Marine Science Organization.

GOAL #8 REDUCE IMPEDIMENTS TO U.S. AQUACULTURE

The importance of aquaculture, both in the U. S. and throughout the world, is widely recognized. In many countries, aquaculture is progressing more rapidly than in the U. S. due to concerns that it might adversely affect habitat quality and wild stocks. NMFS has the scientific expertise that can help to reduce these and other impediments to U. S. aquaculture development.

OBJECTIVES TO ACHIEVE THIS GOAL:

- Determine the impacts of aquaculture on habitat and wild populations, and how to reduce adverse effects.
- Develop means to permit cultured products in the marketplace without jeopardizing conservation of wild stocks.
- Determine the potential for aquaculture to enhance recovery of protected species and depleted fisheries.
- Re-evaluate NMFS's role in U. S. aquaculture.

PLANNED ACTIONS TO ACCOMPLISH THESE OBJECTIVES

- Conduct research and provide information on the effects of aquaculture on habitat, and encourage environmentally safe alternatives.
- Evaluate the risks to wild stocks and their habitats from the introduction of cultured species.

- Develop the capability to distinguish cultured stocks from wild populations.
- Develop techniques to use aquaculture to enhance recovery of protected or depleted living marine resources.
- Develop effective coordination with the Department of Agriculture, and other Federal and state agencies involved in marine aquaculture.

GOAL IMPLEMENTATION

As previously described, the focus of the MEDS plan is on information management requirements for effective living marine resource management and having the NMFS centers of data serve as a "virtual" NOAA data center for the biological and environmental data they maintain. The information needs and the decision environments are different for each goal and element. This is particularly true for those that occur in the regulatory arena. There are also different data flows, types of decisions, control factors at various levels, and mixes of approaches to data assimilation and synthesis on key policy or management decisions. While the MEDS strategic plan is fully cognizant of the political environment for NMFS mission and goal implementation, most of the detailed planning on these issues is scheduled for later in the MEDS process when the focus shifts to major program areas. We perceive many opportunities for NMFS to revise its approaches for delivering products and services. Certainly the entire data management process needs to collect (in as timely and cost-efficient a manner as possible) the necessary biological, sociological, economic, trade, and political data to help managers identify options and evaluate impacts on the stocks and the industry as well as on local, regional, national, and international communities. (See Section V.)

Issues such as how best to measure results, what standards to use as we move from data to information, and whether we can rely on existing management controls for accountability and performance rewards also play a role in the more detailed planning.

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SECTION V. CURRENT NMFS DATA

INTRODUCTION

In this section, we will examine in broad terms the data NMFS currently utilizes in support of its mission of stewardship of the nation's living marine resources. An end-to-end approach to data management is employed. This covers the initial planning for and acquisition of the data; its validation and calibration; scientific research, study and analysis performed with it; planning/decision-making processes based on this analysis; and, finally, its archiving for retrospective access by scientists and decision-makers. Current efforts to improve data access, and continuity and quality, as well as efforts to rescue data at risk of being lost are also discussed.

NMFS DATA FLOW

Figure V-1 provides a high level view of the generic NMFS scientific and management processes and data flows associated with managing and providing stewardship for the nation's living marine resources.

NMFS INFORMATION REQUIREMENTS

NMFS data can be sub divided into the following six categories:

1. Bio-environmental
2. Catch and effort
3. Socio-Economic
4. Legal/enforcement
5. Technical
6. Administrative

This Information Management Strategic Plan addresses only the information requirements for the first four categories of data.

NMFS has been mandated under a number of legislative acts with acquiring and providing a wide range of data and information on the Nation's living marine resources. The most far reaching is the Magnuson Fishery Conservation and Management Act. Other major legislation which impacts the fishery management plan process called for in this act includes the Marine Mammal Protection Act, and the Endangered Species Act. Each of these acts has their own significant data requirements which are discussed briefly below.

MAGNUSON ACT

The Magnuson Fishery Conservation and Management Act established eight Regional Fishery Management Councils. Each Council is responsible for submitting to the Secretary of Commerce a fishery management plan for each fishery within its geographical area of authority that requires conservation and management and such amendments to each plan as are neces-

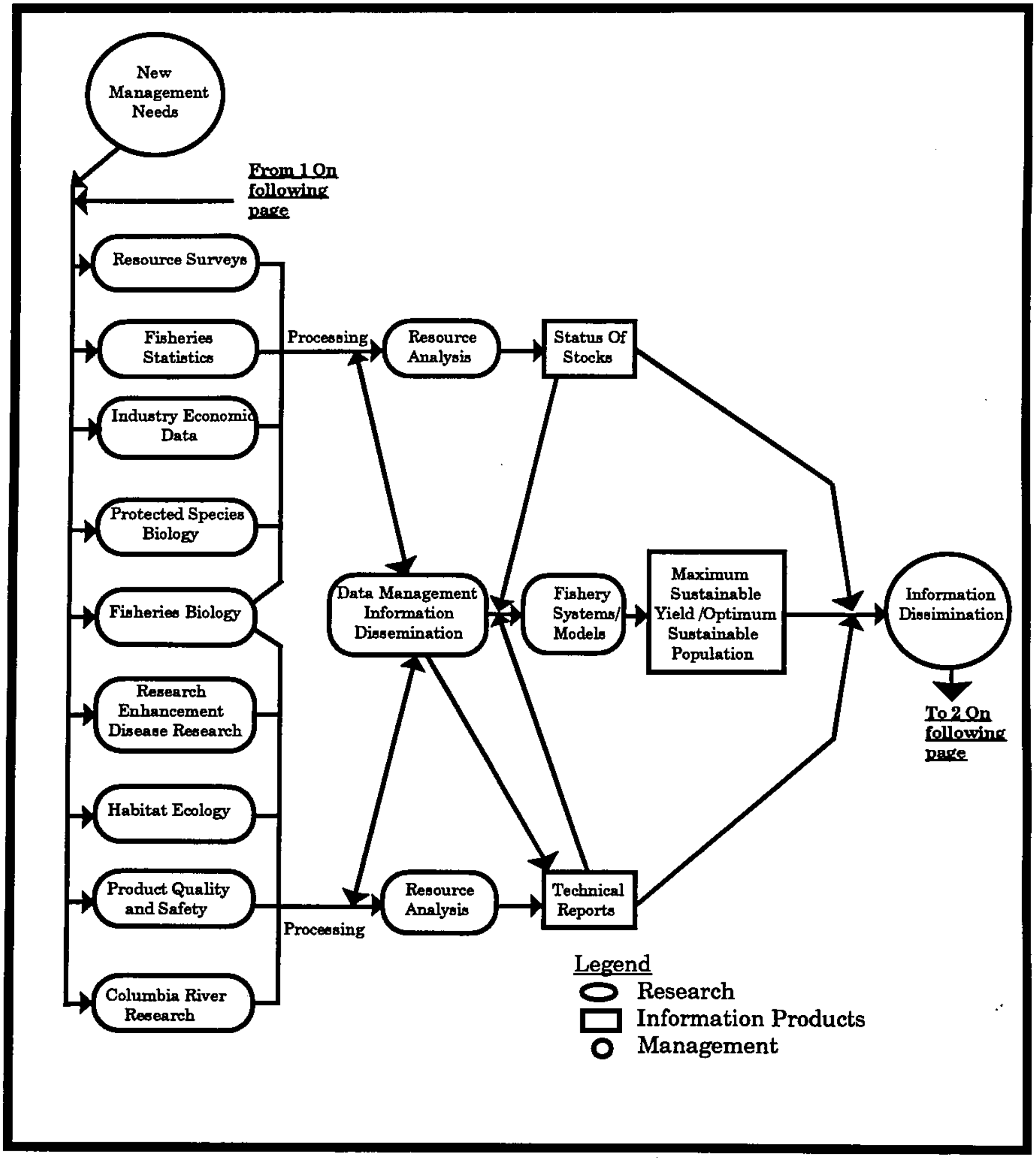

FIGURE V-1
NMFS PROCESSES AND DATA FLOWS

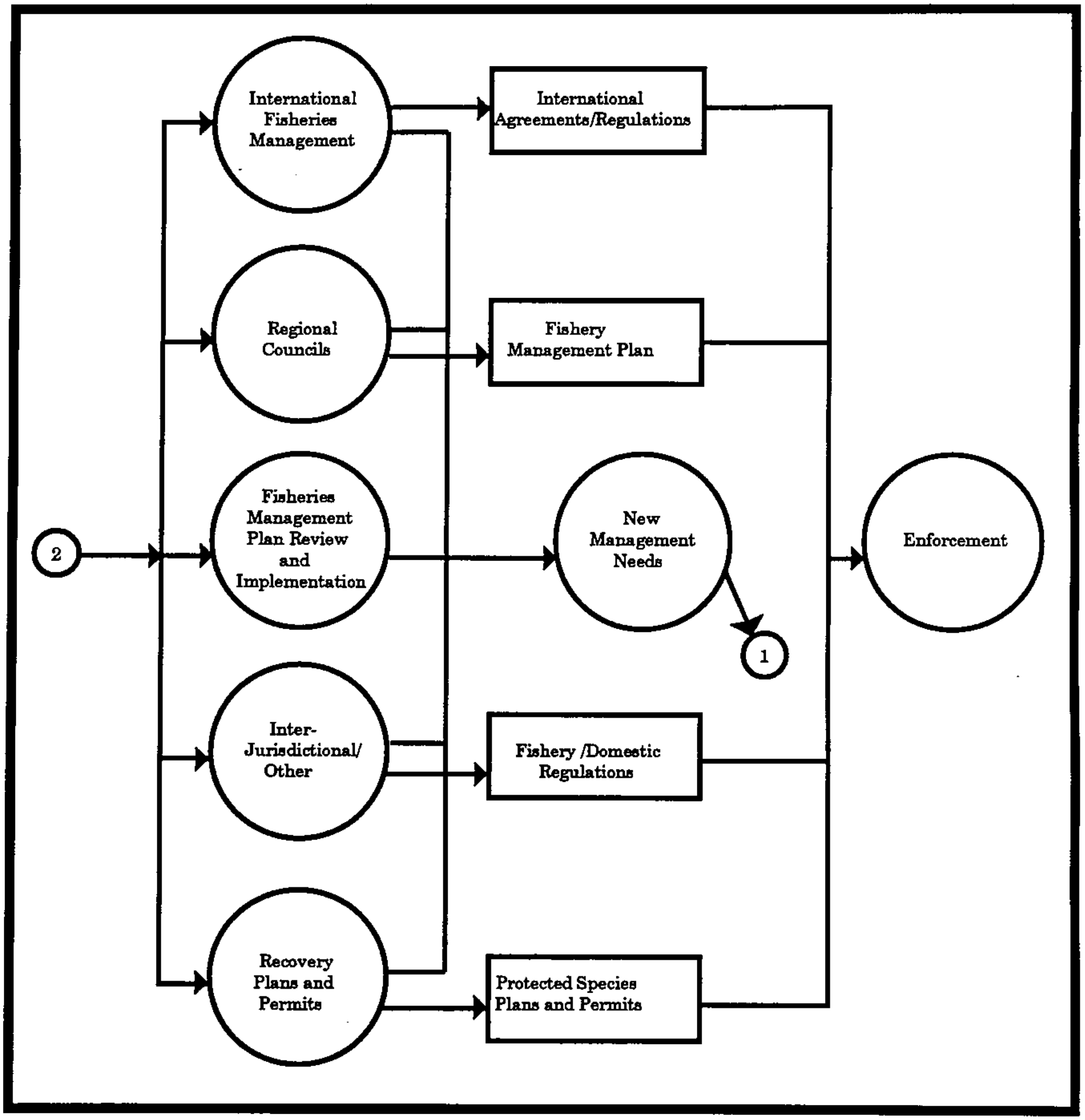

FIGURE V-1
NMFS PROCESSES AND DATA FLOWS
(CONTINUED)

sary. The content and issues to be addressed in these fishery management plans are extensively detailed in the act. It is the responsibility of the NMFS to support the Councils in developing these plans by providing the required supporting data, analyses, and recommendations. Specific areas which must be addressed in the fishery management plans include:

1. Conservation and management measures, applicable to foreign fishing and fishing by vessels of the United States which are necessary and appropriate for the conservation and management of the fishery to prevent overfishing, and to protect, restore, and promote the long-term health and stability of the fishery.

2. Description of the fishery, including, but not limited to, the number of vessels involved, the type and quantity of fishing gear used, the species of fish involved and their location, the cost likely to be incurred in management, actual and potential revenues from the fishery, any recreational interest in the fishery, and the nature and extent of foreign fishing and Indian treaty fishing rights.

3. Identification and assessment of the present and probable future condition of, and the maximum sustainable yield and optimum yield from, the fishery, including a summary of the information utilized in making such assessments.

4. The capacity and extent to which fishing vessels of the United States on an annual basis, will harvest the optimum yield specified, that portion which can be made available for foreign fishing, and the capacity and extent to which United States fish processors will process that portion that will be harvested by fishing vessels of the United States.

5. Information regarding the type and quantity of fishing gear used, catch by species in numbers of fish or weight, areas in which fishing was engaged in, time of fishing, number of hauls, and the estimated and actual processing capacity of United States fish processors.

6. Information regarding the significance of habitat to the fishery and assessment as to the effects which changes to that habitat may have upon the fishery.

7. Assessment of the nature and extent of scientific data which is needed for effective implementation of the plan.

8. Impact statement which shall assess, specify, and describe the likely effects of the conservation and management measures on participants in the fisheries affected by the plan and those in adjacent areas.

9. Information about the level of compliance under the current regulations. This is vital for judging the effectiveness of management especially for the ITQ system.

MARINE MAMMAL PROTECTION ACT

The Marine Mammal Protection Act establishes a moratorium on the taking and importing of marine mammals and marine mammal products with certain exceptions. If the fishery affects marine mammal population(s), the potential impacts must be analyzed in the plan. Councils may also be requested to consider actions to mitigate adverse impacts. Various types of biological and habitat data are also necessary here to monitor and predict the status of stocks for both domestic and international management.

ENDANGERED SPECIES ACT

The Endangered Species Act provides for the conservation of endangered and threatened species of fish, wildlife, and plants. The program is administered jointly by the Departments of Interior and Commerce. Consultation under the ESA between the Council, NMFS, and FWS, as appropriate, is required if the fishery affects, directly or indirectly, endangered or threatened species or any designated critical habitat. Several marine species are either threatened or endangered. Data must be collected to evaluate their status and to help design and implement recovery plans.

Other major laws that impact the data and information that NMFS is responsible for providing include:

- Fish and Wildlife Coordination Act
- Clean Water Act
- Agricultural Marketing Act
- Lacey Act

International treaties also place a number of requirements on the data management system. An example is the NMFS Antarctic Program that supports the CCAMLR Treaty and is based on an ecosystems approach.

DATA IN SUPPORT OF THESE INFORMATION REQUIREMENTS

NMFS currently collects data necessary to monitor the following parameters in response to the requirements of the major legislative acts cited above. Note that some of the data elements are collected through different surveys to allow cross-checking of the reporting systems, and increased understanding of the complex ecosystem processes and human behavior.

1.0 Physical Environment

Water column temperature
Sea surface temperature
Salinity

2.0 Biology
- 2.1 Survey Species Composition
  - Species identification
    (may involve DNA and other genetic techniques)
  - Location
  - Number
  - Species length
  - Species age at length
  - Species sex
  - Species maturation
- 2.2 Monitoring Species Health
  - Contaminants
  - Diseases
  - Habitat type
- 2.3 Tagging Data
  - Release/recovery date (Mo/Da/Yr)
  - Tag number
  - Location (degrees/minutes)
  - Tagger/recoverer name
  - Address
  - Length/weight
  - Gear
  - Tag type
  - Growth
  - Days free
  - Distance traveled
  - Tracking information
  - XBT information
  - Sea surface temperature
  - Beaufort condition
- 2.4 Morphometric Samples
  - Sample number
  - Sex
  - Otolith readings/estimated age
  - DNA information
  - Gonad information
  - Tooth reading data

3.0 Sociology
- Community structure
- Life styles
- Cultural/religious roles of LMRs

4.0 Recreational Fisheries Landings
- Species identification
- Number
- Fishing location
- Landing weights
- Fishing effort

5.0 Ecosystem Surveys
- Depth of pycnocline
- Primary productivity
- Chlorophyll
- Dissolved oxygen
- Zooplankton biomass
- Nutrients
- Incident solar radiation
- Stratification
- Mean wind direction and speed
- Barometric pressure
- Position of oceanographic features

6.0 Fishery Dependent Data
- 6.1 Economic Data
  - Country/market
  - Species
  - Price paid
  - Size group
  - Trade flows
  - Enforcement (level of compliance)
- 6.2 Commercial Fisheries Landings
  - Species identification
  - Landing weights
  - Fishing location
  - Fishing effort
  - Species lengths
  - Species age at length
- 6.3 Log Book Records
  - Catch by species
  - At sea transfers
  - Storage of fish
  - Gear
  - Discards
  - Date/Location
  - Wind speed/direction
  - Sea surface temperature
  - Vessel specifications
- 6.4 At Sea Observer Data (primarily commercial)
  - Date and time
  - Course and speed
  - Location

Catch by species
Location of fish in gear
Marine mammals in gear
Sightings of other species
Sightings of other vessels
Damage to catch
Drop out rates on retrieval of gear
Wind speed/direction
Sea surface temperature
Swell height/direction
XBT data
Chlorophyll

6.4.1 Fishing vessel data

- Name
- Fishing gear
- Capacity
- Area fished
- Active/inactive
- Date flag change
- Date gear change

CURRENT ADP SYSTEMS

NMFS data is currently distributed over approximately 30 major sites nation-wide on a mixture of ADP equipment. The equipment for the more complex requirements is scheduled for replacement in mid-FY 1993 by the IT-95 systems.

The current heterogeneous equipment includes:

Super computers	Access to the NSF Cray YMP-8
Mainframes	Burroughs B7900 and A-10 Time share on an IBM 3081
Mini-computers	Various DEC VAX systems (11/780, 11/785, 6210, 6310)
Scientific workstations	HP 9000, IBM 6000-540, Silicon Graphics Crimson Elan, DEC 3100, SPARC 2, IPX
Personal Computers	AT 386 & 486 (IBM and clones) Macintosh (various)

Local Area Networks	BANYAN, 3 COM, Novell, Apple Talk
Wide Area Networks	Packet Switched Service (X.25) over FTS 2000 Internet connectivity

REGIONAL DATA MANAGEMENT

Data for these parameters are maintained by the NMFS region collecting it. The guiding principle is that most NMFS data are retained close to those scientists and managers who use it the most. While there are variations in the types and methods of data collection, processing and archiving from region to region, these differences are slight. The stock assessment process of the Northeast Region, depicted in Figure V-2, is generally representative of the approach taken by each region. For clarity, the marine mammal, habitat, and enforcement data are not diagrammed but are no less incorporated.

DATA BASE DESCRIPTIONS

The following are brief descriptions of the representative data bases described in Figure V-2.

BOTTOM TRAWL SURVEY DATA BASE (SVDBS)

This data base includes offshore and inshore research vessel bottom trawl survey data by cruises since 1963. A stratified random sampling methodology is employed. Data includes species catch composition, weight, number, length distribution by tow, age samples for some species, tow environment and platform characteristics.

FOOD HABITS DATA BASE (FHDBS)

The Food Habits Data Base contains fish stomach contents and other food habits related data obtained in stratified random samples of fish in the Northeast Region. Data includes quantities, weights or and other characteristics of predator and prey animals; environmental parameters; and platform characteristics.

COMMERCIAL FISHERIES LANDINGS DATA BASE (CFDBS)

The Commercial Fisheries Landings Data Base contains catch/effort and biological samples information for domestic and foreign landings from Eastport, Maine to Norfolk, Virginia. Major data sets include: domestic fishing catch/effort statistics by individual trip and tow, biological samples, fishing vessel characteristics and activities, ocean shellfish data, U.S.-foreign joint venture data, and logbooks for permitted species.

The major portion of the data contains catch/effort statistics by individual vessel trips, gears and locations. Also included are joint ventures between domestic and foreign vessels.

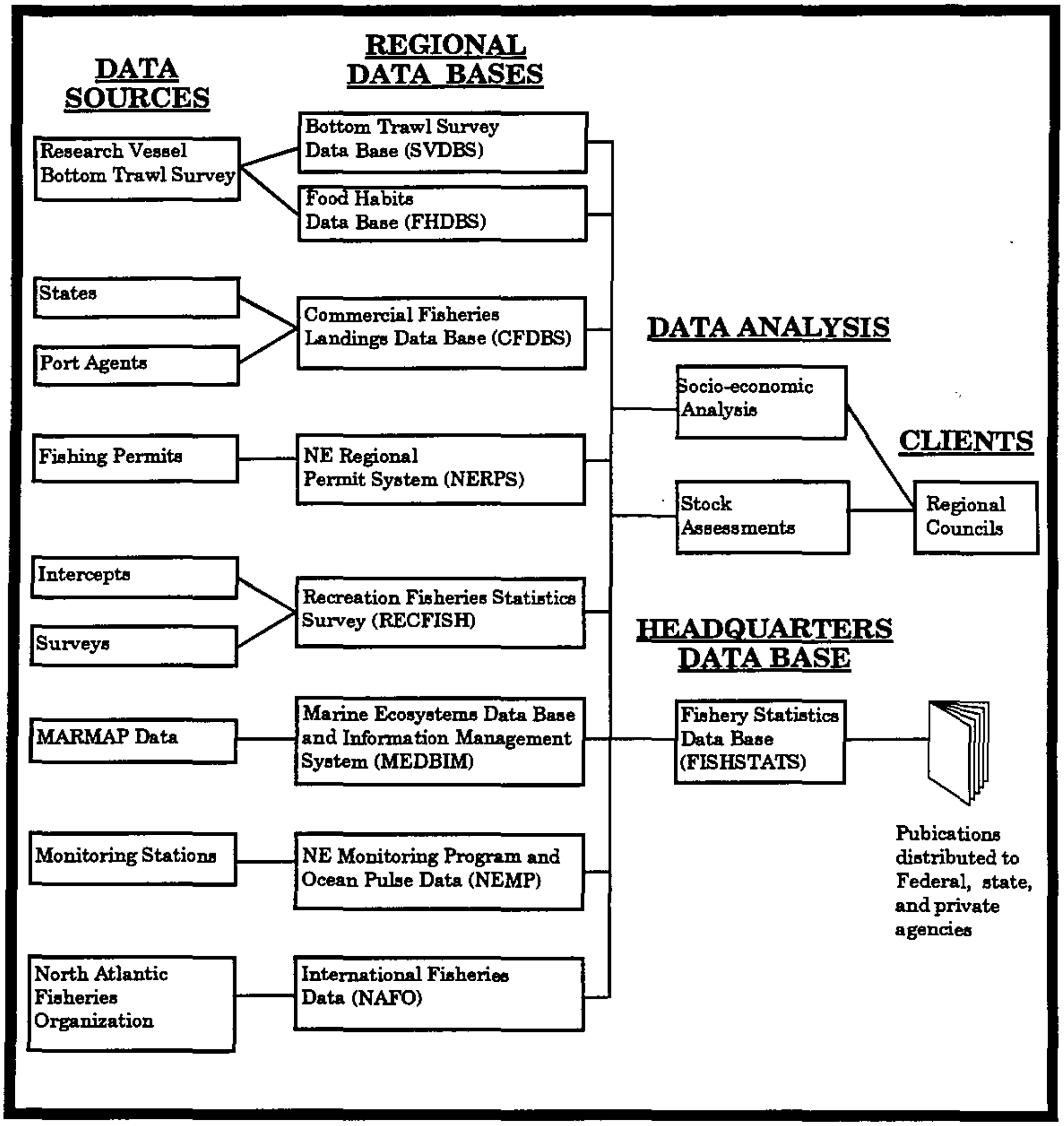

FIGURE V-2
NORTHEAST REGION
STOCK ASSESSMENT DATA FLOW

NORTHEAST REGIONAL PERMIT SYSTEM (NERPS)
This data base includes data on fishing permits, vessel characteristics and owner information for all vessels permitted for regulated fisheries in the Northeast region.

RECREATIONAL FISHERIES STATISTICS SURVEY (RECFISH)
The Recreational Fisheries Statistics Survey data base contains a survey of the recreational fishing activities along the coastal areas of the continental U.S. Data collected includes catch by species, effort in days fished, participation in terms of number of people, mode of fishing (party boat, pier, etc.), and area of fishing. The raw survey data are expanded from the U.S. Census to form the final data set.

MARINE ECOSYSTEMS DATA BASE AND INFORMATION MANAGEMENT SYSTEM (MEDBIM)
This data base contains ichthyoplankton, zooplankton, and primary productivity data for the Northeast continental shelf.

NORTHEAST MONITORING PROGRAM AND OCEAN PULSE DATA (NEMP)
The Northeast Monitoring Program and the Ocean Pulse data supported ocean pollution monitoring at approximately 140 stations along the continental shelf from Cape Hatteras to the Gulf of Maine. Data collected included bridge logs, primary productivity, biochemical, physiologic, benthic calorimetry, microbiology, phytoplankton, benthic ecology, water column respiration, seabed oxygen consumption, nutrient chemistry and hydrographic data.

INTERNATIONAL FISHERIES DATA (NAFO)
The International Fisheries Data contains data on foreign fisheries for the Northwest Atlantic and within the EEZ.

FISHERY STATISTICS DATA BASE (FISHSTATS)
The Fishery Statistics Data Base consists of many different files of national and international commercial fisheries statistics. Data includes quantity and value of monthly landings, world fishery landings, U.S. imports and exports, processed products, monthly retail prices, vessel costs and earnings, trace contaminants, ex vessel price indexes, as well as other data.

DATA DICTIONARY/DIRECTORY

Figure V-3 shows a model of the data dictionary/directory being developed. Guidance from ESDIM has been followed to ensure compliance with evolving NOAA-wide data standards. Additionally the Tri-Agency Implementation Plan (NASA, DOC, DOI) *Global Change Data and Information System (GCDIS)* and the UNESCO Intergovernmental Oceanographic Commission's *Guide For Establishing A National Oceanographic Data Centre* are being used as guides to ensure National and world-wide data standards are being meet for selected environmental data.

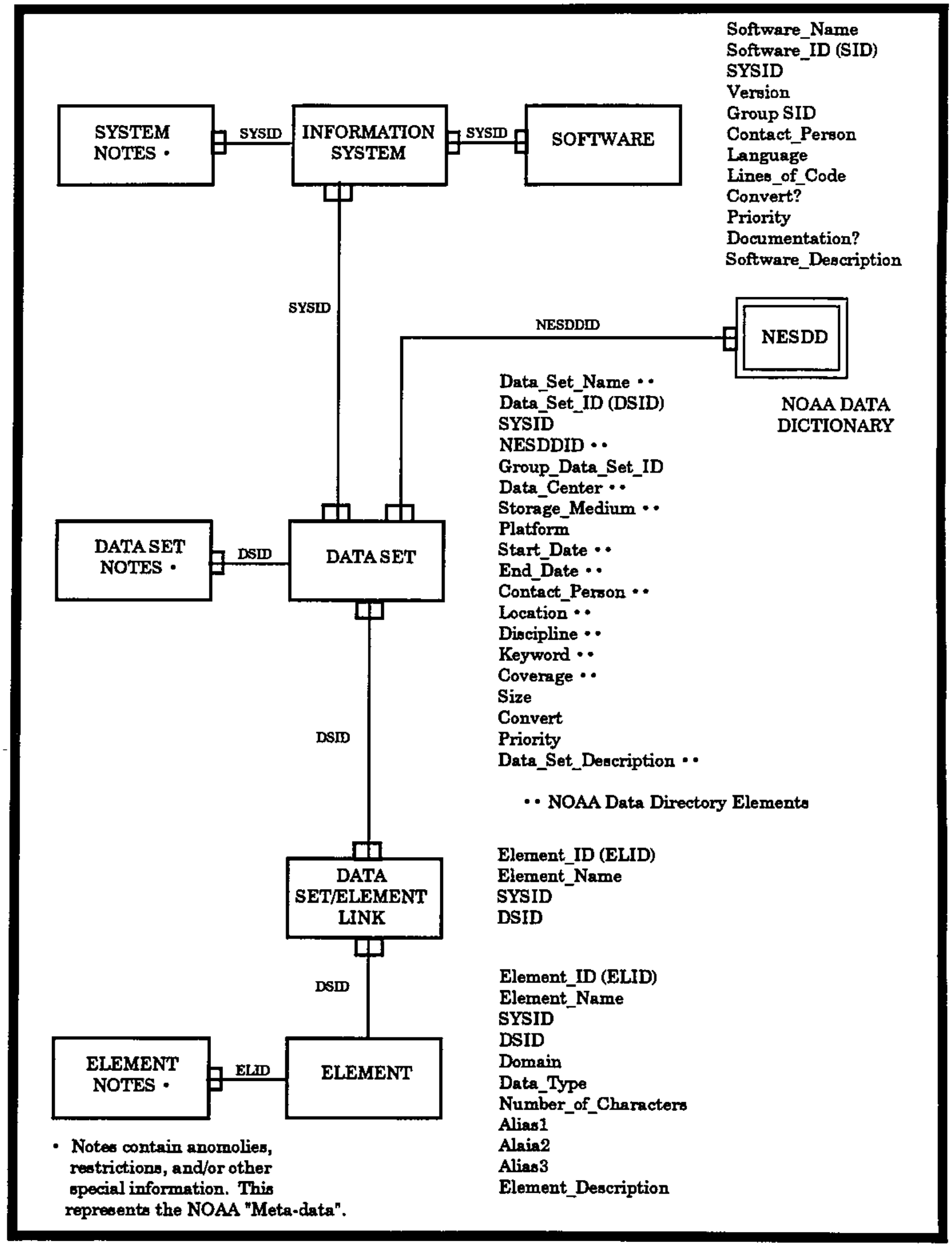

FIGURE V-3
NMFS DATA DICTIONARY/DIRECTORY
DATA MODEL

SECTION VI. MONITORING AND MANAGING THE HEALTH OF ECOSYSTEMS

INTRODUCTION

Government agencies have an increasing number of responsibilities for (1) managing fisheries; (2) mitigating polllution; (3) reducing environmental stress; (4) restoring lost habitat; and (5) protecting endangered and threatened species. Interest is growing to approach solutions to management problems from an ecosystems perspective.

The NMFS Strategic Plan articulates a new basic strategy. This strategy states that in the face of uncertainty, NMFS will reduce the risk to living marine resources by making decisions that err toward conservation not, over exploitation. The plan goes on to state that this uncertainty will be reduced by greatly expanding the scientific information upon which decisions are based and that NMFS will continue to advocate management practices that enhance the economic well-being of industries dependent on living marine resources for commercial, recreational, and non-consumptive uses..

Goal #3 Advance Fishery Forecasts and Ecosystem Models is a key element in achieving this strategy. Two of the objectives for this goal are (1) describing functional relationships and processes that control fishery systems and (2) developing higher-order forecasting models for living marine resource populations, ecosystems, and fishery systems.

Much of what needs to be accomplished relative to these two objectives involves new science in which additional research is required. This research could have a profound impact on future information requirements. A clearer understanding of what is involved in achieving these objectives, and the information needs to support them, is therefore critical. This section will review those aspects of ecosystems-based management of living marine resources and how such a shift in management may impact the requirements for an information management system within NMFS.

ECOSYSTEM SCALE AND THEORY ISSUES

Recent developments in ecosystem scale and theory issues provide a solid conceptual foundation for the expansion of the use of ecosystems-based approaches. The ecological concept that critical processes controlling the structure and function of biological communities can best be addressed on a regional basis (Ricklefs 1987) has been applied to ocean space in the utilization of large marine ecosystems as regional units for marine research, monitoring, and management (Sherman et al. 1990).

Large marine ecosystems (LMEs) are extensive areas of ocean space of approximately 200,000 km^2 or greater, characterized by distinct bathymetry, hydrography, productivity, and trophically dependent populations. Various analyses may need to shift to smaller sub-regions within LMEs. For example, within the Northeast Continental Shelf LME, the Gulf of Maine or Scotian zoogeographic region could be the basis for analysis. The long-term sustainability of fishery resources, coastal habitats, and protected marine species, requires the application of sound principles for the conservation and management of resources at risk from overexploitation, environmental stress, and global climate change.

The concept of LMEs defines the unit of resource interest on the order of thousands of kilometers in scale with regard to fish and fisheries yields, and represents an energy flow approach to factors determining variability in ecosystem productivity. In this approach, large-scale trophic, environmental, and climatic changes are examined in relation to effects of fishery removals on the long-term sustainability of marine ecosystems. The temporal and spatial scales influencing biological production in marine ecosystems have been the topic of a number of theoretical and empirical studies. The selection of scale in any study is related to the processes under investigation. An excellent treatment of this topic can be found in Steele (1988). He indicates that in relation to general ecology of the sea, the best known work in fish population dynamics are studies by Schaefer (1954), and Beverton and Holt (1965), following the earlier pioneering approach of Lindemann (1942). However, as noted by Steele (1988), this array of models is unsuitable for consideration of temporal or spatial variability in the ocean.

The LME approach overcomes this difficulty by defining a spatial domain based on ecological principles and, thereby, providing a basis for focused scientific research, monitoring, and management efforts. The fish component of LMEs has adapted reproductive, growth, and feeding strategies to the distinct environmental conditions within the LME. Changes to the fish components of these systems through fishery removals can trigger a cascade effect involving higher trophic levels including birds and marine mammals (Overholtz and Nicholas, 1979; Powers and Brown, 1987), and lower trophic levels including zooplankton (Payne et al 1990), and the economies dependent on the resources of the ecosystem.

Empirical and theoretical aspects of yield models for large marine ecosystems have been reviewed by several ecologists. According to Beddington (1986), Daan (1986), Levin (1990), and Mangel (1991), published dynamic models of marine ecosystems offer little guidance on the detailed behavior of communities. However, these authors concur on the need for covering the common ground between observation and theory by implementing monitoring efforts on the large spatial scale, and long-time scale (decadal) of 'key' components of the LMEs.

The sequence for improving the understanding of the possible mechanisms underlying observed patterns in LMEs is described by Levin (1990) as examination of: (1) statistical analyses of observed distributional patterns of physical and biological variables; (2) construction of competing models for variability and patchiness based on statistical analyses and natural scales of variability of critical processes; (3) investigation of competing models through experimental and theoretical studies of component systems; and (4) integration of validated component models to provide predictive models for population dynamics and redistribution. The approach suggested by Levin (ibid) is consistent with the recent observation by Mangel (1991) that empirical support for the currently used models of large marine ecosystems is relatively weak, and that a new generation of models is needed that serves to enhance the linkage between theory and empirical results.

MANAGEMENT CONSIDERATIONS

Effective management strategies for large marine ecosystems (LMEs) will be contingent on the identification of the major driving forces causing large-scale changes in biomass yields. Management of species responding to strong environmental signals will be enhanced by improving the understanding of the physical factors forcing biological changes, whereas, in other LMEs, where the prime driving force is predation, options can be explored for implementing adaptive management strategies.

Remedial actions are required to ensure that the "pollution" of the coastal zone of LMEs is reduced and does not become a principal driving force in any LME. For at least one LME, the Antarctic, a management regime has evolved, based on an ecosystem perspective in the adoption and implementation of the Convention for the Conservation of Antarctic Marine Living Resources. Some efforts are already underway to implement ecosystem management within the LMEs of the United States' exclusive economic zone, including the northern California Current ecosystem.

A systems approach to the management of LMEs is depicted in Table VI-1. The system allows for the LMEs to serve as the link between local events (e.g. fishing, pollution, environment) occurring on the daily-to-seasonal temporal scale and their effects on living marine resources and the more ubiquitous global effects of climate changes on the multidecadal timescale. The regional and temporal focus of season to decade is consistent with the evolved spawning and feeding migrations of the fishes -- the keystone species of most LMEs. These migrations are seasonal and occur over hundreds to thousands of kilometers within the unique physical and biological characteristics of the regional LME to which they have adapted.

As the fisheries represent most of the usable biomass yield of the LMEs and fish populations consist of several age classes, it follows that measures of variability in

SPATIAL-TEMPORAL SCALES		
SPATIAL	**TEMPORAL**	**UNIT**
Global (World Ocean)	Millennia-Decadal	Pelagic Biogeographic
Regional (Exclusive Economic Zones)	Decadal-Seasonal	Large Marine Ecosystems
Local	Seasonal-Daily	Subsystems
RESEARCH ELEMENTS		
Spawning Strategies		
Feeding Strategies		
Productivity, Trophodynamics		
Stock Fluctuations/Recruitment/Mortality		
Natural Variability (Hydrography, Currents, Water Masses, Weather/Climate)		
Human Perturbations (Fishing, Waste Disposal, Habitat Integrity, Petrogenic Hydrocarbon Impacts, Aerosol Contaminants, Eutrophication Effects)		
MANAGEMENT ELEMENTS OPTIONS AND ADVICE INTERNATIONAL, NATIONAL, LOCAL		
Bioenvironmental and Socioeconomic Models		
Management for Sustainable Fisheries Yields		
FEEDBACK LOOP		
Evaluation of Ecosystem Status		
Evaluation of Fisheries Status		
Evaluation of Management Practices		

TABLE VI-1
KEY SPATIAL AND TEMPORAL SCALES AND PRINCIPAL ELEMENTS OF A SYSTEMS APPROACH TO THE RESEARCH AND MANAGEMENT OF LARGE MARINE ECOSYSTEMS.

growth, recruitment, and mortality should be conducted over multiyear timescales. This is necessary in order to interpret the effects of environmental, biological, and fishing effects on changing abundance levels of the year class to the populations of the species constituting the fish community, their predators and prey, and physical environment.

Consideration of the naturally occurring environmental events and the human-induced perturbations affecting demography of the populations within the ecosystem is necessary. Based on scientific inferences of the principal causes of variability in abundance and with due consideration to socioeconomic needs, management options can be considered for implementation from an ecosystems perspective. The final element in the system is the feedback loop that allows for evaluation of the effects of management actions at the fisheries level (single species, multispecies) and the ecosystem level, with regard to the concept of resource maintenance and sustained yield.

To sustain the new ecosystems-based management strategy, it will be necessary to conduct supportive research on the processes controlling sustained productivity of LMEs. Within several of the LMEs, including the Northeast Shelf, Gulf of Mexico, California Current, and Eastern Bering Sea, important hypotheses concerned with the growing impacts of pollution, overexploitation, and environmental changes on sustained biomass yields are under investigation (Table VI-2). By comparing the results of research among the different systems, it should be possible to accelerate an understanding of how the systems respond and recover from stress. The comparisons should allow for narrowing the context of unresolved problems and capitalizing on research efforts underway in the various ecosystems.

ECOSYSTEM ASSESSMENT AND MONITORING

Greater emphasis has been focused over the past decade within the National Marine Fisheries Service of NOAA, on approaching fisheries research from a regional ecosystem perspective in LMEs within and adjacent to the exclusive economic zone of the United States--The Northeast Continental Shelf, the Southeast Continental Shelf, the Gulf of Mexico, the California Current, the Gulf of Alaska, the Eastern Bering Sea, and the Insular Pacific including the Hawaiian Islands. These ecosystems, in 1991, yielded 10.1 billion pounds total fisheries catch valued at approximately $16.5 billion to the economy of the United States. Consumers spent an estimated $26.8 billion on fisheries products.

A description of the sampling programs providing the biomass assessments within the U.S. Exclusive Economic Zone (EEZ) has been described in Folio Map 7 produced

ECOSYSTEM	PREDOMINANT VARIABLES	HYPOTHESIS
Oyashio Current Kuroshio Current California Current Humboldt Current Benguela Current Iberian Coastal	Density-independent natural environmental perturbations	Clupeoid Population Increases Predominant variables influencing changes in biomass of clupeoids are major increases in water-column productivity resulting from shifts in the direction and flow velocities of the currents and changes in upwelling within the ecosystem.
Yellow Sea U. S. Northeast Continental Shelf Gulf of Thailand Gulf of Mexico Eastern Bering Sea	Density-dependent predation	Declines in Fish Stocks: Precipitous decline in biomass of fish stocks is the result of excessive fishing mortality, reducing the probability of reproductive success. Losses in biomass are attributed to excess of human predation expressed as overfishing.
Great Barrier Reef	Density-dependent predation	Change in Ecosystem Structure: The extreme predation pressure of crown-of-thorns starfish has disrupted normal food chain linkage between benthic primary production and the fish component of the reef ecosystem.
East Greenland Sea Barents Sea Norwegian Sea	Density-independent natural environmental perturbations	Shifts in Abundance of Fish Stock Biomass: Major shifts in the levels of fish stock biomass within the ecosystems are attributed to large-scale environmental changes in water movements and temperature structure.
Baltic Sea	Density-independent pollution	Changes in Ecosystem Productivity Levels The apparent increases in productivity levels are attributed to the effects of nitrate enrichment resulting from elevated levels of agricultural contaminant inputs from the bordering land masses.

TABLE VI-2
SELECTED HYPOTHESES CONCERNING VARIABILITY IN BIOMASS YIELDS OF LARGE MARINE ECOSYSTEMS.

ECOSYSTEM	PREDOMINANT VARIABLES	HYPOTHESIS
Antarctic Marine	Density-dependent perturbations	Status of Krill Stocks: Annual natural production cycle of krill is in balance with food requirements of dependent predator populations. Surplus production is available to support economically significant yields, but sustainable level of fishing effort is unknown.
	Density-independent natural environmental perturbations	Shifts in Abundance in Krill Biomass: Major shifts in abundance levels of krill biomass within the ecosystem are attributed to large-scale changes in water movements and productivity.

TABLE VI-2 (CONTINUED)
SELECTED HYPOTHESES CONCERNING VARIABILITY IN BIOMASS YIELDS OF LARGE MARINE ECOSYSTEMS.

by the Office of Oceanography and Marine Assessment of NOAA's National Ocean Service. The map depicts the seven ecosystems under investigation (see Appendix B).

Sampling programs supporting biomass estimates in LMEs within and adjacent to the EEZ of the United States are designed to: (1) provide detailed statistical analyses of fish and invertebrate populations constituting the principal yield species of biomass, (2) estimate future trends in biomass yields, and (3) monitor changes in the principal populations. The information obtained by these programs provides managers with a more complete understanding of the dynamics of marine ecosystems and how these dynamics affect harvestable stocks. Additionally, by tracking components of the ecosystems, these programs can detect changes, natural or human-induced, and warn of events with possible economic repercussions.

Although sampling schemes and efforts vary among programs (depending on habitats, species present, and specific regional concerns), they generally involve systematic collection and analysis of catch-statistics; the use of NOAA vessels for fisheries-independent bottom and midwater trawl surveys for adults and juveniles; ichthyoplankton surveys for larvae and eggs; measurements of zooplankton standing stock, primary productivity, nutrient concentrations, and important physical parameters (e.g., water temperature, salinity, density, current velocity and direction, air temperature, cloud cover, light conditions); and, in some habitats, measurements of contaminants and their effects. At the shoreward margin of the LMEs, monitoring efforts include the use of mussels and other biological indicator species to measure pollution effects as part of NOAA's Status and Trends Program.

The pilot EMAP Program of EPA focused on the estuarine and nearshore monitoring of contaminants in the water column and substrate, and in selected groups of organisms. This program will be extended to more open waters of LMEs in cooperation with NOAA during 1992 and 1993. A monitoring strategy for measuring the changing states of LMEs was recommended by a panel of international experts that met at Cornell University in July 1991 (Sherman and Laughlin 1991). The two monitoring methods are regular trawling and plankton surveys using a stratified random sampling design. The large-scale changes in the fisheries of the North Sea and the Northeast Continental Shelf of the United States have been successfully analyzed using these techniques for several decades. (Azarovitz and Grosslein, 1987). The surveys have been conducted by relatively large research vessels. However, standardized sampling procedures, when deployed from small calibrated trawlers, can provide important information on fish stocks. The fish catch provides biological samples for stomach analyses, data for clarifying and quantifying multispecies trophic relationships; samples can be used for age and growth, fecundity, and size comparisons (ICES, 1991). Samples of trawl-caught fish can also be used to monitor the effect of gross pathological conditions that may be associated with coastal pollution.

The need for both biological and environmental monitoring in the North Sea ecosystem has been emphasized following the Symposium on Long-Term Changes in the Fish Stocks of the North Sea ecosystem (Hempel, 1978). In this regard, physical measurements can be made from small trawlers or ships-of-opportunity, using readily available and relatively inexpensive systems for measuring temperature and salinity of the water column. Standard logs for weather observations, important in detecting global change, are an important component of the data-collecting effort. The monitoring of changes in fish stocks is ongoing in LMEs across the North Atlantic basin, including the Northeast U.S. Shelf, the Canadian Scotian Shelf, Newfoundland Shelf; and on the Greenland Shelf, Icelandic Shelf, Norwegian Shelf, Barents Sea Shelf, and the North Sea.

To complement data from the higher trophic levels, the plankton of LMEs can be measured at a relatively low cost by deploying Continuous Plankton Recorder (CPR) systems from commercial vessels of opportunity (Glover, 1967). The advanced plankton recorders can be fitted with sensors for temperature, salinity, chlorophyll, nitrate/nitrite, light, bioluminescence, zooplankton, and ichthyoplankton (Aiken, 1981), providing the means to monitor changes in phytoplankton, zooplankton, relative productivity, species composition and dominance, and long-term changes in the physical and nutrient characteristics of the LME, as well as longer term changes relating to the biofeedback of the plankton to the stress of climate change (Colebrook, 1986; Dickson et al., 1988; Jossi and Smith, 1990; Sherman et al., 1990c). Plankton monitoring using the CPR system is at present expanding in the North Atlantic (IOC 1992).

A critical feature of the LME monitoring strategy is the development of a consistent long-term data base for understanding interannual changes and multi-year trends in biomass yields for each of the LMEs. For example, during the late 1960s and early 1970s, when there was intense foreign fishing within the Northeast Continental Shelf ecosystem, marked alterations in fish abundances were recorded. Significant shifts among species abundances were observed. The finfish biomass of important species (e.g., cod, haddock, flounders, herring, and mackerel) declined by approximately 50%. This was followed by increases in the biomass of sand lance and elasmobranchs (dogfish and skates) and led to the conclusion that the overall carrying capacity of the ecosystem for finfish did not change.

The excessive fishing effort on highly valued species allowed for low economic valued species to increase in abundance. Analysis of catch-per-unit-effort and fishery-independent bottom trawling survey data were critical sources of information used to implicate overfishing as the cause of the shifts in relative abundance among the species of the fish community within the shelf ecosystem. It is important to note, however, that the lower-end of the food chain in the offshore waters of the ecosystem remained unchanged and largely as described by Bigelow and Riley suggesting that ecosystem productivity remained high during a period of species dominance shifts among the fish community caused by human interventions through fishing (Sherman et al). The natural 'resilience' of the ecosystem in relation to recovery from stress can be documented in the recovery of mackerel to former (pre-1960) levels of abundance and the apparent recovery of herring to 1960's level of abundance on Georges Bank (Murawski and Smith, 1991). Whether this 'resilience' level can serve as a possible index of ecosystem health is the subject of studies presently underway by the NMFS staff at the Northeast Fisheries Science Center.

ECOSYSTEM 'HEALTH' INDICES

We have selected a single representative LME, the Northeast Continental Shelf, for planning purposes to help evaluate the data management requirements to support the necessary research and computation of health indices from an ecosoystem's perspective.

Initial efforts to examine the relative health within a single ecosystem are underway for four subareas of the Northeast Shelf ecosystem -- Gulf of Maine, Georges Bank, Southern New England, mid-Atlantic Bight. There are other possible ways to subdivide the LME for analysis. Initial studies of the structure, function, and productivity of the system, have previously been reported (Sherman et al, 1983, 1988, 1992). It appears that the principal driving force in relation to sustainable ecosystem yield is fishery mortality. Some managers and scientists believe that long-term sustainability of high economic yield species will be dependent on the application of adaptive management strategies

Several alternative management strategies for the fish stocks of the Northeast Shelf ecosystem are currently under consideration by the Northeast Fisheries Management Council and the Mid-Atlantic Fisheries Management Council. In addition to fisheries management issues and significant biomass flips among dominant species, the Northeast Shelf ecosystem is also under stress from the increasing frequency of unusual plankton blooms, and eutrophication within the nearshore coastal zone resulting from high levels of nitrate discharges into drainage basins. Whether the increases in the frequency and extent of nearshore plankton blooms are responsible for the rise in incidence of biotoxin related shellfish closures and marine mammal mortalities, remains an important open question that is the subject of considerable concern to state and federal management agencies (Sherman, Jaworski, and Smayda 1992; Smayda 1991).

Increasing attention has been focused over the past few years on synthesizing available information on factors influencing the natural productivity of the fishery biomass and general 'health' of LMEs, in an effort to identify principal, secondary, and tertiary driving forces causing major changes in ecosystem states and biomass yields. In present practice, assessing the health of LMEs relies on a series of indicators and indices (Costanza 1992; Rapport 1992, Norton and Ulanowicz 1992; Karr 1992). The overriding objective is to monitor changes in 'health' from an ecosystems perspective as a measure of the overall performance of a complex system (Costanza 1992). The 'health' paradigm is based on comparisons of ecosystem resilience and stability (Pimm 1989; Holling 1986; Costanza, 1992) and is an evolving concept. Following the definition of Costanza (1992), to be healthy and sustainable, an ecosystem must maintain its metabolic activity level, its internal structure and organization, and must be resistent to external stress over time and space frames relative to the ecosystem. These concepts were discussed at a workshop convened by NMFS at the Northeast Fisheries Science Center's Narragansett Laboratory in April 1992. Among the indices discussed by the participants were five that can be considered as useful measures of ecosystem health -- (1) diversity; (2) stability; (3) yields; (4) production; and (5) resilience. A summary of the workshop deliberations is available from NMFS. The data from which to derive the five indices will be obtained from the LME 'core' monitoring surveys recommended by the Cornell Workshop sponsored by NOAA/NMFS in July 1991.

The steps proposed in moving from data collections to indices of potential use in measuring the health of large scale marine ecosystems are shown in the Appendix B. The complexity of the diagram reflects both the complexity of these large marine ecosystems and the integration required before assessing the health of a particular system. Specifically, the left hand column lists real data bases in the Northeast. The second column lists certain key parameters from those databases which are combined statistically into possible indices which are listed in the third column. These calculations are in process now, both on a LME and sub-regional basis to help evaluate this potential tool. The Northeast Continental Shelf ecosystem is one of the most intensively studied ecosystems of the U.S. economic zone and, consequently, can serve as the prototype ecosystem for the probing and changing status of a LME.

<u>High quality, long-term databases are essential to provide the information from which effects of ecosystem perturbation can be determined.</u> For LME regions without a history of monitoring, the development of a consistent, long-term database is a critical feature, particularly for understanding interannual changes and multiyear trends. For regions with a rich monitoring history, such as the Northeast Continental Shelf ecosystem, the first step is evaluating the existing datasets.

Selected datasets for the Northeast Shelf ecosystem are depicted in Figure VI-2. These datasets contain the parameters required for calculating a suite of quantitative ecosystem health indices. The datasets selected incorporate the major biological, chemical, and physical features of a large marine ecosystem: phytoplankton, zooplankton, ichthyoplankton, finfish, benthos, pelagic seabirds, marine mammals, climatology, ocean physics, nutrient concentrations, habitat, weather and biotoxins. A description of each dataset, including the variables measured, the frequency of measurement, the period covered and a detailed documentation of the current data management strategy is available from NMFS. The datasets listed in the diagram are quality controlled and are typically available over at least a continuous 8 to 10 year period. The datasets thus fit the proposed requirements (e.g., decadal time frame, and various statistical criteria) for developing a set of indices to evaluate the health of the prototype Northeast Shelf system. The key to integrating the multitude of data sets is the development of common reference structures or data standards (storage and transmission formats) and an information visualizaation scheme that encompasses the documentation requirements of individual data sets and their many potential uses.

Before health can be measured, we needed to identify the relevant parameters from the chosen datasets to include in the quantitative health indices. The wealth of data represented in the Northeast Shelf datasets necessitated selection of a few key parameters. The parameters being evaluated, as seen in the figure, include: zooplankton composition, zooplankton biomass, water column structure, photosynthetically active radiation (PAR), transparency, chlorophyll A, NO_2, NO_3, primary production, heavy metal pollution, marine mammal biomass, marine mammal composition, runoff, wind stress, seabird community structure, seabird counts, finfish composition, finfish biomass, domoic acid, saxitoxin, and PSP. The parameters selected represent the increasingly accepted belief that ecological studies must be carried out in an ecosystem context and must simultaneously incorporate the behavior of individuals, the resultant responses of populations and communities, as well as their interactions with the physical and chemical environment. The chosen parameters are readily measurable in all LMEs and consequently will permit comparison of relative health status among systems. The interrelations between the datasets and the selected parameters are indicated by the arrows leading from column 1 to column 2 in the figure. The difficulties anticipated in, and suggestions for combining the appropriate parameters into a single data module for use in calculating the proposed indices, will be described in later reports after FY92 work is completed.

The final column in the figure represents the integration of the selected parameters (column 2) into a series of proposed indices (column 3) for use in examining the health of a given LME (in this example, the Northeast Shelf ecosystem). Over the past forty years, many such indices have emerged in the ecological literature. Following the

April Narragansett Workshop on LME 'health', NMFS NEFSC researchers selected for testing certain indices proposed in the literature as critical in defining the changing states and health of a large marine system and easily amenable to measurement: diversity, stability, yield (economic) productivity and resilience (see Fig. VI-2). The choices reflect the consensus of participants at the Narragansett Workshop that indices based on a single species, process or component, are inappropriate and that ecological-economic integration is essential. Calculation of the proposed indices will follow standard published procedures for statistical calculations. Since health is a relative term, NMFS researachers propose comparing recent values of the indices as determined from the Northeast Shelf data with their values as calculated in 1960, prior to the period of significant perturbation to the ecosystem. Alternative weights for the various indices will also be evaluated.

FUTURE ECOSYSTEM MODELING AND DATA ANALYSIS EFFORTS

Future efforts directed at improved definition of ecosystem health that will consider both natural environmental perturbation as well as the effects of human intervention on the ecosystem will focus on:

- The development of ecosystem health indices and indicators for LMEs.
- The development of component models of LMEs incorporating measure ments of health indicators rather than single, large models that generally have limited prediction capability.
- The development and use of models using health indicators that are directly applicable to management decisions. They should be simple in construction, allow for interaction with resource managers, and provide sufficient flexibility for testing hypotheses for a range of scenarios.

The NMFS-NOAA regional programs concerned with forecasting trends in yields are being conducted in relation to the dynamics of large marine ecosystems. The studies are now yielding fragmentary information on changes in ecosystem productivity, habitat integrity, and pollution stress. Future efforts will be needed to provide an improved information base for assessing understanding and managing the Nation's living marine resources and the relationships among the boundary areas of LMEs and the wetlands and estuaries, as critical habitats of fishes and invertebrate (shrimps, shellfish) resources.

DATA REQUIREMENTS

Changes in a shelf ecosystem may be attributed to a wide variety of causes. For management purposes, these could be categorized as: (1) climatic, (2) pollution, (3) fisheries. The utility of criteria to evaluate the health of the ecosystem will depend on the ability to separate these categories since management responses will be very different for each cause. At present, there are separate activities and operational criteria for each category: (1) Criteria for anthropogenic components of climate change are being sought; (2) pollution monitoring is the subject of many reports {National Research Council (NRC), United Nations' Environmental Program (UNEP), etc.}; and (3) commercial fish stock assessment is a major activity.

The need to integrate these criteria poses the most difficult management problems and provides interesting scientific questions that the data management system must support. Funds are needed to augment existing ecosystem data series to include information on climate change, pollution, fish community changes from nearshore environments and the margins of the Northeast Shelf ecosystem. We estimate that $5KK of annually collected pertinent information now funded in large part by the federal government (in other federal agencies) and by the states is unavailable for inputs into the NEFSC activities focused on producing triennial reports on the health of the Northeast Shelf ecosystem. The information is pertinent, but has not, as yet, been rescued for entry into a federal regional ecosystem archive.

Present evidence indicates there is a risk of significant ecosystem damage resulting from coastal eutrophication with possible consequences involving greater frequency of massive mortality from anoxic conditions and market dislocation from biotoxic events. Furthermore, significant species shifts in fish communities have been observed, particularly in the Middle Atlantic Bight. The causes for these shifts can be better understood by a thorough integration of data being collected routinely by state agencies and academic institutions. These data are presently unavailable for systematic analyses and indexing of the "health" of the Northeast Shelf ecosystem.

A dedicated data acquisition and analytical system is needed that will provide the appropriate electronic work station capacity (RISC based technology) for collation, integration, and analyses of information from pertinent ongoing and retrospective time-series data sets (e.g. fish stock assessments; status and trends; mussel-watch; coast-waters; EPA's EMAP; DOE's SEEP; and other time-series data sets). Application of recent innovations in GIS, relational and object-oriented data base technology, and new computer technology will allow for the monitoring of 'health' conditions over the extent of a large marine ecosystem. The use of domestic and international data and telecommunications standards will also be important for linking existing islands of data (see Section V.)

The recent innovations of new sampling technology, including the use of existing and planned satellite remote sensing of large-scale oceanographic features (e.g., AVHRR; SeaWIFS) and continuously profiling sensors (Undulating Oceanographic Recorders, Acoustic Doppler Current Profiler) are improving the methods of ocean research and monitoring. It is now feasible to study entire marine ecosystems by computeraided methods for tracking catch statistics, monitoring research outputs on the fish, mammal, bird, plankton, and benthic components of LMEs, as well as changes in habitats, pollution levels, and coastal zone development. These technological developments can serve to encourage greater integration among the various sectors of ocean research and monitoring supported by state, national, and international agencies. Greater effectiveness of ongoing national and international ocean research and monitoring programs can be achieved by refocusing and integrating fisheries pollution and coastal zone studies within the spatial extent of LMEs. The core LME long-term monitoring studies are being organized at three levels of activity. Reliable instruments presently exist for this purpose. Continuous Plankton Recorders to collect zooplankton and phytoplankton can be instrumented with sensors to measure temperature, salinity, chlorophyll, depth, primary productivity, and light. These instruments have a history of reliability in numerous deployments from ships of opportunity. They will be particularly appropriate for the descriptions of individual events (e.g., productivity trends, biomass yield trends), as well as other summary statistics, such as spectra or EOFs (empirical orthogonal functions).

Other appropriate technology, including acoustic sensors and moored instrumentation such as fluorometers or Acoustic Doppler Current Profilers (ADCPs), that will soon be readily available for any user should be considered for deployment as they become operational. The use of coupled circulation-biological models that update their predictions and interpolations by assimilation of both physical and biological data will soon be a reality for many parts of the world ocean. However, before such techniques can be incorporated into a stand-alone monitoring system, an appropriate data management system will be necessary. New instrumentation may provide major breakthroughs in long-term monitoring of coupled biological and physical quantities. Sensors for such tasks are not now available, but planning for their development and deployment in monitoring efforts should begin immediately. Such new measurements might include molecular tags for taxonomic identification as well as physiological rates. New acoustic devices are also on the horizon. Finally, collaboration with planned process studies, like GLOBEC and JGOFS, should be developed as part of the LME data acquisition and management effort.

THE FUTURE

As ecosystems-based LMR management evolves, stock assessment and forecasting capabilities must evolve also. One such possibility is described below to help evaluate its impact on the future NMFS data management system.

A Northeast Shelf Ecosystem Monitoring, Assessment, and Forecasting (EMAF) system could be used to provide the user community with real-time, near-real time, retrospective, and prospective analyses tailored to specific mitigation and management objectives. As custodian of the public trust for the living marine resources of the Northeast Shelf ecosystem, NOAA's National Marine Fisheries Service, Northeast Fisheries Science Center, is the appropriate organizational element to carry forward the planning, development, and implementation of the EMAF effort in collaboration with a similar activity underway for the nearshore subareas of the ecosystems by the EMAP program of EPA. The joint collaboration will allow for a common inter-agency data and information management system, onto which other pertinent federal, state, or private institutional data-sets will be integrated. As a prototype-system compatible with the Global Ocean Observing System (GOOS) advocated by NOAA, the LME "core" monitoring strategy is consistent with systems proposed for adoption by GOOS. Funding to implement this example of data collection will have to come from multiple domestic and international sources. The data management portion, however, is part of the MEDS plan based on ESDIM funding.

A Northeast Shelf ecosystem monitoring system that can serve as a prototype for all LMEs within and adjacent to the U.S. Exclusive Economic Zone will be developed. In this context, the ecosystem variables that are required to ensure compatibility with GOOS should include measurements of wind velocity, sea-surface temperature, and salinity, water-column profiles of temperature and salinity, surface currents, sea level, partial pressure of CO_2 in the surface, and chlorophyll concentrations of surface waters: Circulation models, being developed by the NSF GLOBEC program for the Northeast Shelf region and coupled ocean-atmosphere models, can be used to evaluate observing system design, to assimilate diverse data sets from in situ and remotely sensed observations, and ultimately to predict future states of the system.

The volume of ocean data will increase enormously over the next decade as new satellite systems are launched and as complementary in situ measuring systems are deployed. These data must be transmitted, quality controlled, exchanged, analyzed, and archived with the best state-of-the-art computational methods.

The variables required for determining the status and variations of Large Marine Ecosystems includes all of those listed above for the climate system plus optical properties, dissolved oxygen, nutrients, primary production, species abundance, and LME-specific pollutants.

Various new sensors will also play a significant role. Most of these collect large volumes of data and require special assimilation and quality control techniques as well as effective archival and retrieval mechanisms.

We can expect that satellite remote sensing will play a very significant role in LME observations. A scatterometer instrument and synthetic aperture radar can help to define the wind field; AVHRR can delineate thermal fronts in sea surface temperature; an ocean color instrument such as SeaWiFS can reveal the dynamics of chlorophyll concentrations; altimeters can help to define the circulation patterns. Usable satellite data can be limited in coastal regions when the "foot print" falls partly on the ocean and partly on the land. In some cases, it may be necessary to develop regionally specific algorithms to extract environmentally significant variables from the remotely sensed property. This will require *in situ* measurement programs to calibrate the satellite data in the regions of interest. If we consider that satellite ocean remote sensing is absolutely required to determine the global scale of some variables, then the contribution provided by these systems in LME observations can be regarded as an additional benefit, with only small incremental costs (regionally specific calibration). In fact, we should not be surprised if within ten years we find that much of the economic benefits derived from ocean satellites will occur from observations in the coastal regions of the world.

The meteorological agencies of the world need data from coastal regions to support their continental weather forecasts, their marine weather forecasts, and their forecasts of marine conditions that increase safety in fisheries, maritime transportation, recreation, and offshore petroleum development. Some of these data are to be acquired in LMEs by moored buoys and by Volunteer Observing Ships. These platforms can be used to support the needs for the coastal components of GOOS, especially if there is some early investment in automated measuring systems that will extend the suite of variables to include those listed above.

The Continuous Plankton Recorder (CPR) is one such instrument that has enabled the collection of biological information without the use of a dedicated research vessel. The CPR is typically towed at a depth of 10 m behind a vessel while it is underway. In addition to filtering plankton from the water, the modern CPR can be equipped with sensors for chlorophyll, temperature, conductivity, irradiance, and nutrients. This sampling capability can also be deployed on an Undulating Oceanographic Recorder (UOR) to sample vertical, as well as horizontal, gradients in the upper 70 m of the water column.

The Acoustic Doppler Current Profilers (ADCP) that have been developed in recent years provide a means of obtaining highly resolved ocean currents from ships while underway. In water depths of less than about 200 m, it is possible to use the bottom tracking mode of the ADCP to get absolute current velocities. The intensity of the backscattered acoustic signal from different depths in the water column can be used for remotely sensing the amount of acoustic-scattering particles. In the future, critical data inputs for the nearshore environment that are highly stressed may be used in the triennial NEFC status of the health of the ecosystem reports that are under consideration for part of the NMFS "Our Living Oceans" (OLO) report. These will incorporate the indices required for assessing ecosystem health including those data required for the Costanza/Ulanowicz proposed health indices and the capability for systematic reporting to the Global Ocean Observing System.

Other changes such as more frequent sampling for fish stock assessment, and adding new variables such as synoptic bottom water will also impact the data management system requirements.

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SECTION VII. CRITICAL SUCCESS FACTORS

INTRODUCTION

John F. Rockart, originator of the critical success factor (CSF) approach, described CSFs as "those few critical areas where things must go right for the enterprise to flourish". They differ from goals and objectives in that they are what must be achieved to meet the goals and objectives. By monitoring CSFs, NMFS can better shift away from managing program inputs to managing for results; improve the levels of accountability for agency performance; and influence the scope and nature of outcomes.

The level of uncertainty in natural resource management decisions is one of the most critical factors which limit NMFS success in achieving its goals and objectives. NMFS employs a strategy in achieving its goals and objectives which will, in the face of uncertainty, reduce the risk to living marine resources by making decisions that err toward conservation, not overfishing. Improved information has been identified as one of the critical success factors necessary for successful management results. Recognizing their concern for the economic well-being of fisheries, NMFS states that they will reduce uncertainty associated with it management decisions by greatly expanding the scientific information upon which decisions are based. The need for NMFS to reduce the uncertainty surrounding its decision-making extends beyond protecting the economic well being of fisheries. Achieving a relatively low level of uncertainty is a critical success factor in accomplishing its mission. Global climate change, and human caused habitat loss or damage are but two of the factors that are creating new uncertainties that must be addressed. This section focuses on identifying the critical questions which must be answered if NMFS is to be able to reduce the uncertainty in its decision environment and proposes a results oriented strategic level monitoring system based on the 8 Agency goals for use in an Executive Information System.

INFORMATION STRATEGY IMPLICATIONS

An understanding of the critical questions that must be answered and the information needed to answer them is essential for developing an information strategy that will support NMFS in achieving its goals and objectives. To this end, a small group of key senior managers were selected for interview to begin the process of identifying the information needs required to remove, or at least greatly reduce, this uncertainty. Once implemented, certain aspects of the Executive Information System will evolve to reflect the Agency's changing needs.

After these information needs have been identified and refined, the steps necessary to acquire and make the information available must be determined. Some information needs may be satisfied from existing NMFS data or be readily available from some other existing sources. However some information will require expending considerable research effort to obtain. This process of data/information source identification will require a significant involvement by those responsible for design and implementation of NMFS information and decision support systems, since it will be a major factor in determining their requirements.

THE NEXT STEPS

This report will be circulated to additional NMFS managers for their review and comment. This feedback will serve as the basis for refining and expanding the approach presented here as well as identifying additional critical information areas to be explored.

It is anticipated that as a minimum each of the eight goals in the NMFS strategic plan will be examined in detail to determine their critical information needs. Key decision makers will also be interviewed to determine additional decision support requirements to those covered above. These might include a mixture of long-term and more short-term issue tracking items such as those shown below:

- Status of various LMR stocks.
- Economic status of various components of the commercial, recreational, and non-consumptive parts of the industry.
- Status of key procurements or special study projects.
- Status of various NMFS infrastructure investments (ships, facilities, major research tools, computers, telecommunications capabilities).
- Status of legislation, budgets, employee morale, constituent viewpoints on various issues (polling data).
- Status of critical habitat during the life cycle stages for significant commercial and recreational species.
- Health of various large marine ecosystems or their major sub regions.
- Status of key negotiations with international scientific and trading partners or other Federal, state, or academic partners.
- Status of critical personnel actions such as recruitment, retirement or programs for mid-level management development.
- Trends in the "outside" national and international areas (geopolitical, economic, technical).
- Various other models, simulations, or forecasts.
- Status of on-going efforts to improve the professionalism or the quality of science within the agency.
- Technological advancement opportunities (to increase effectiveness, efficiency).
- Development of species specific harvesting approaches (methods, timing, new gear).
- Interception of future problems (study developing issues and head off or get early start on those of significance).
- Looking to the future (scenario development and evaluation).
- Mapping of critical habitat.

- Are they any new developments, issues, problems?
- Have we resolved any old issues, problems?
- How do we stand financially?
- Do we have new guidance, policy, mandates, assignments from above?
- What are the "hot" political items: regionally, nationally?
- News stories/events both in DC/Congress/Administration and in the field that affect LMR, their habitats or potential management actions for which NOAA and particularly NMFS is responsible.
- Restoration cases settled (a list and maybe a brief description).

Many of the items above could be incorporated into an early prototype of the system and made available in a short time-frame.

As a part of the information strategy described in Section VIII. a tracking system is planned to provide NMFS management the ability to monitor the efforts and accomplishments as well as any issues impacting the satisfaction of these critical information needs. Information needs will be prioritized and the efforts and individuals involved will be identified as well as an anticipated availability date. Information needs which are not addressable today should also be included.

It should be emphasized again that this document addresses only the information requirements and delivery systems for the research and associated regulatory decision and policy making processes which are central to the NMFS mission. Administrative systems (e.g., personnel, budget implementation, accounting, etc.) have not been addressed in this document.

RESULTS ORIENTED MANAGEMENT

The information management system for the future will need to be able to support the collection, analysis and display of critical top level organizational results that help answer the question "How do we know whether we are successful or not?" These measures of results will vary over time and depend on the level of the organization being measured. The measurements can be monitored with the use of an Executive Information System (EIS) linked to various internal and external data bases and sources of information. To start the process, NMFS proposes the following "strawman" results-oriented profile of critical success factors.

PROGRAMMATIC ISSUES

The factors in this category are arranged by strategic goal. As described in the example with Goal #6, there are many detailed research questions related to generating the information necessary to evaluate success. This detailed planning within each goal will occur later in the process.

1. Rebuild overfished marine fisheries.
   - Identification of each overfished stock.
   - Levels of by-catch for these overfished species in other fisheries and for within their own fishery.
   - Status of the stocks.
   - Level of capitalization in the fleet.
   - Ratio of number of overfished stocks to total under management.
   - Ratio of recreational to commercial to subsistence to ecological (forage fish) uses.
   - Number of scientific publications for both refereed journals and "gray" literature.
   - Level of compliance with enforcement regulations.

2. Maintain currently productive fisheries.
   - Identification of each productive fishery.
   - Status of those stocks.
   - Ratio of the number of productive fisheries to the total under management.
   - Ratio of recreational to commercial to subsistence to ecological (forage fish) uses.
   - Number of scientific publications for both refereed journals and "gray" literature.
   - Level of compliance with enforcement regulations.

3. Advance fishery forecasts and ecosystem models.
   - Measure (estimate) the uncertainty for stock assessments and forecasts.
   - A possible goal could be to reduce that uncertainty by 10% in year one and by 50% in year three.

4. Integrate conservation of protected species and fisheries management.
   - Identification of stocks.
   - Status of protected species stocks.
   - Trends in number and types of takings.
   - Levels of use of by-catch reduction fishing gear.
   - Number of species completing successful recovery plans in relation to the total number of recovery plans.
   - Level of compliance with enforcement regulations.
   - Number of scientific publications for both refereed journals and "gray" literature.

5. Improve seafood safety.
   - Monitor the number of incidents of seafood-related illness and death from both domestic and foreign sources.
   - Level of compliance with area closures, and mislabeling rules.

6. Protect living marine habitat.
    - Monitor the loss of critical habitat and the mix of critical habits in the coastal zone.

7. Improve effectiveness of international fisheries relationships.
    - Identification of stocks.
    - Status of stocks under international management.
    - Influence the improvements in the quality of international science used to support international management decisions and help reduce the uncertainty associated with the assessments and forecasts.
    - Monitor the level of U.S. share of internationally managed stocks.

8. Reduce impediments to U.S. aquaculture.
    - Monitor the quantity of aquaculture production as a ratio to total commercial harvest.
    - Monitor the change in percentages of species mix produced by domestic aquaculture.
    - Monitor the ratio of domestic total aquaculture production to estimated world production.
    - Number of scientific publications for both refereed journals and "gray" literature.

CONSTITUENT RELATIONS
This category could include such factors as those listed below.

1. Enhanced opportunities for two way communication between industry and NMFS leadership such as an electronic polling mechanism on a bulletin board system, e-mail or more extensive use of focus groups.

2. More extensive "town hall" type meetings in coastal communities to help identify research needs.

LEGISLATION
This category could include such factors as those listed below.

1. Status of key amendments, reauthorizations or new legislation

2. Attitudes and positions of congressional staff and committee members.

3. Hearing schedules.

EMPLOYEES
This category could include such factors as those listed below.

1. Survey results of employee morale.

2. Data on skill mix and levels of training.

3. Eligibility for retirement.

4. Data on changing demographics of the workforce.

5. Status of developmental programs for future managers and leaders.

6. Survey managerial effectiveness

TECHNOLOGY
This category could include such factors as those listed below.

1. Status of key procurements for new, or maintenance on, strategic sensors, research platforms (ships, satellites, buoys), computers, and telecommunications equipment.

2. New types or uses of existing harvesting, production, and marketing technologies by domestic and international industry.

3. Success of pilot or technology transfer projects to improve operations.

EXTERNAL ENVIRONMENT
This category could include such factors as those listed below.

1. Rate of seafood consumption both domestically and in key trading partners.

2. Changes in exchange rates in existing and new market areas for exports.

A CRITICAL INFORMATION NEEDS MODEL

During the preliminary interviews conducted with key NMFS managers is was discovered that the critical information needs for reducing uncertainty relative to the sixth goal "Protect living marine resource habitat" had already been addressed. These information requirements, which are presented below in the form of research topics to generate the needed data and information, can serve as a model for defining the critical information requirements for each goal in the NMFS Strategic plan.

CRITICAL INFORMATION NEEDS FOR NMFS GOAL #6 PROTECT LIVING MARINE RESOURCE HABITAT

The key goal is to stop further loss of critical habitat and to start mitigation and restoration efforts. One way to measure it is as a ratio of acres of critical habitat loss to total inventory in the coastal zone and a profile of the mix of critical habitat types.

Physical Alterations of Habitat

What is the relative functional importance of major habitat types to fisheries productivity (low salt-marsh, high salt marsh, brackish marsh, seagrass beds, mangroves, rocky shorelines, tidal flats, non-tidal riparian forest, etc.)?

> What are the critical fisheries habitats (for food, cover, spawning, nursery, and migration)?
>
> What habitat losses are we experiencing
>
> > location, by estuary;
> > acreage, by habitat type; and
> > due to what causes?

What are the effects of cumulative habitat loss on fisheries productivity and their economic value, both regionally and nationally?

> What conceptual approaches (models) can be used to assess and predict the effects of cumulative habitat loss on regional fisheries production?
>
> What is the relative economic value of major habitat types, based on recreational and commercial fisheries values?
>
> What are the intangible values of estuarine ecosystems to society?

FRESHWATER INFLOW

What are the effects of alteration of flows on fisheries populations and their economic value?

> What are the effects on estuarine community structure and fishery populations of changes in hydrologic flow regimes?
>
> What are the effects on estuarine fishery populations of changes in salinity regimes due to alteration of freshwater inflow?

What are the future trends in water diversion and consumption and how can we predict their effects on living marine resources?

> What conceptual approaches (models) can be used to assess and predict the effects of hydrologic changes on fishery populations?

TOXINS

What are the effects of toxins on populations of living marine resources and their economic value?

> What are the loading rates of contaminants through estuaries?
>
> What are the pathways of contaminants through estuaries:

What are valid indicators of stress on LMR's from exposure to toxic contaminants (lethal and sublethal)?

How are sensitive life history stages effected by contaminants?

What are the effects of toxins at the population level?

What are the synergistic and cumulative effects of toxics to fishery populations?

What is the relationship of toxic loadings to the incidence of disease in LMRs at the population level?

What are the economic consequences of fisheries contamination (on harvest and marketability), particularly for species managed under the MFCMA?

What are the human health risks associated with contamination of living marine resources?

Are there better indicators of human health risk than those presently being used?

How can existing regulatory programs be improved to sustain and improve estuarine living marine resources?

NUTRIENTS

What are the effects of natural and anthropogenic nutrient loadings on fishery productivity and economic values?

What are the causes and extent of hypoxia affecting estuaries (sources, loading rates and geochemical cycling)?

What are the effects of eutrophication on critical life history stages of important, estuarine-dependent populations?

What changes in community composition occur as a result of excessive nutrient loading?

What means are available to better monitor, predict, and control point and non-point nutrient sources?

LAND USE

How can we best predict the cumulative effects of various land-use options on fisheries productivity?

What are the effects of current land use practices throughout a watershed on important LMRs?

What regional land use changes can we expect?

What conceptual approaches (models) can we use to predict the effects of land use on LMRs?

How can land-use decision making processes best be influenced?

How can local zoning and planning officials be better educated in making land-use decisions?

How can the information generated through research and analysis be synthesized and presented to better inform local decision-makers?

HABITAT MITIGATION AND REHABILITATION

How does the value of rehabilitated habitat compare to natural habitat, in terms of living marine resource productivity?

What criteria should be used to select habitats for rehabilitation?

What methodology or criteria should be used ot evaluate success of rehabilitation in compensating for lost habitat functions?

How long does it take to regain the functional values of natural habitats by restoring or rehabilitating degraded habitats?

Is "mitigation banking" a viable means to compensate for lost fisheries habitat values?

How can natural resource production best be augmented?

FISHERY ECOLOGY

What are the habitat requirements of key benthic invertebrates, pelagaic and demersal finfish in coastal and estuarine ecosystems?

What are the spawning and nursery areas of important species, and what is their relative importance to reproductive success and recruitment?

What habitata characteristics, water quality parameters, food availability, etc. are necessary for successful growth, maturation, reproduction and survival of selected species?

What are the population trends of recreational and commercially important, estuarine-dependent stocks?

What are the relative contributions of fishing, natural, and "pollution-related" mortalities to the population dynamics of declining fishing stocks?

SECTION VIII. AN INFORMATION STRATEGY FOR NMFS

INFORMATION MANAGEMENT STRATEGIC PLAN OVERVIEW

Two basic goals are embodied in this MEDS Information Management Strategic Plan.

GOAL #1

Reduction of the uncertainty involved in the science supporting the NMFS decision-making process.

GOAL #2

Serving as a recognized data center for the biological and related environmental data bases for which it has stewardship.

These two goals are critical elements in the achievement of the NMFS mission and goals spelled out in the NMFS Strategic Plan. This section identifies the objectives and planned actions to achieve each of these goals.

STRATEGY

Analysis shows that the existing information and decision support systems currently in use within NMFS provide a useful foundation but must be augmented to support the achievement of these goals. A strategy has therefore been proposed which has as it central focus the development of a new information system. This proposed system is called the Marine Ecological Data System (MEDS). Key design strategies to be employed in its development are (1) a distributed data base structure; (2) a virtual system concept; and (3) adherence to NOAA-wide and International standards for data descriptions and access.

NMFS organizational elements are geographically widely disbursed. This results in critical data being similarly disbursed. It is felt that this distributed nature of its data is a strength rather a problem, but it is a major factor that must be addressed in the MEDS system. The strength rests in that the data and its management is co-located with those scientific users and decision-makers most interested in the data. They are frequently the individuals who have collected and/or generated the data and are, therefore, the individuals best able to provide stewardship for it. Integrated control features will be required to provide overall management of such systems. This approach is also advocated by the National Research Council in its report entitled *Solving the Global Change Puzzle - A U.S. Strategy for Managing Data and Information* (see Section I.).

As more complex questions must be addressed by NMFS in accomplishing its mission, discrete collections of data, no matter where they exist, increasingly fail to respond to the needs of its scientists and decision-makers. This is as true for files and/or data bases on a single system or on a multitude of systems geographically distributed across the country. Systems must be user-centered rather than machine-centered to allow scientists and decision-makers to combine and analyze data involving multiple scientific disciplines. The modeling of ecosystems called for in the NMFS strategic plan will require the integration and analysis of such cross-cutting data. The need for this type of data integration is more far reaching than just within NMFS. Other scientists in other NOAA organizations and around the world will be turning to NMFS for this data to address a multitude of challenges the world faces today such as Global Change. To meet these needs, a "virtual system" strategy will be employed in the development of MEDS. This will allow a user to see a uniform and coherent structure but be based on data and standard interfaces distributed to all major sites. The system will be composed of many separate systems located across the country each containing portions of the totality of the data for which NMFS has stewardship. To the user, however, it will appear as one monolithic information system and he/she will be unaware that the system may have assembled and/or analyzed and created the data from many disparate entities located in systems spread across the country.

This dependency on data from a wide variety of disciplines and sources cuts both ways. Just as scientists and decision-makers within other NOAA organizations and throughout the world will be looking for NMFS to provide them with the ecological and biological data for which it has stewardship, so to will NMFS need access to the wide variety data available from these other organizations. The ability to locate, evaluate and utilize this data must be facilitated if it is to support the global community of users requiring access to it. To this end, a critical strategy element in this plan is to employ the data standards proposed by groups such as ESDIM and other domestic and international standards groups. One example of the international groups is the UNESCO Intergovernmental Oceanographic Commission (IOC). Another is the Open Systems Interconnect (OSI) group.

GOALS AND OBJECTIVES

This Information Management Strategic Plan is focused on two major goals. These two goals have a number of objectives which are required for their achievement. The objectives for these two goals are so entwined that it difficult to separate them. Most serve both goals or are related to achievement of the overall strategy discussed above. For this reason, this document does not attempt to link them to a specific goal.

A number of planned actions to accomplish these objectives have been included. These planned actions are for the most part the initial (tactical) actions in addressing these goals and objectives which are more long range or strategic in nature. The objectives and planned actions to accomplish them will be reviewed annually and updated to reflect new issues and more detailed or additional actions as they are defined.

GOAL #1 REDUCTION OF UNCERTAINTY INVOLVED IN NMFS DECISION MAKING PROCESS

NMFS states in its strategic plan that it intends to employ a strategy which is a significant departure from they way it has operated in the past. This new strategy states that, in the face of uncertainty, NMFS intends to err on the side of the living marine resources for which it has stewardship. The strategic plan goes on to state that NMFS will aggressively pursue reducing that uncertainty by greatly expanding the scientific information on which these decisions are based. The reduction of this uncertainty is critical both to maintain the economic well being of fisheries, and to provide the best possible stewardship of these living marine resources.

Achievement of this Information Management Strategic Plan goal is central to supporting the achievement of each of the goals given in the NMFS Strategic Plan.

GOAL #2 SERVE AS A RECOGNIZED DATA CENTER FOR THE ECOLOGICAL AND BIOLOGICAL DATA BASES FOR WHICH IT HAS STEWARDSHIP

Finding answers to the critical questions facing scientists and decision-makers today has become much more difficult. The complex inter-relationships of many factors must be understood to address today's issues. Examination and correlation of increasingly larger and larger amounts of data is required. Scientists and decision-makers must have access to interdisciplinary scientific research data not just on a regional or national basis but also on a global level. Sharing of scientific data and research results must become a way of life for today's scientist if we are to address such issues as an understanding of ecosystems or global change.

NMFS recognizes its responsibilities to make available to researchers and policy makers the ecological and biological data for which it has stewardship as well as its own increasing dependency upon data from others. Each of the goals in its Strategic Plan explicitly or implicitly identifies a need for sharing data as a critical element in its achievement.

OBJECTIVES TO ACHIEVE THESE GOALS

- Develop a detailed program specific data management plan to implement the Marine Ecological Data System (MEDS). MEDS is envisioned to be a multi-tiered distributed information system with an interface for both internal and external users. It will also have imbedded within it an executive information system and a science/decision support system which will combine data sets and perform sophisticated data analysis and modeling for the user. The plan will address new information requirements necessary to reduce uncertainty.

- Ensure that MEDS addresses the different perspectives of the three key types of users: (1) end user (including researchers as well as managers); (2) system administrator; and (3) application developer. Each of these have their own specific requirements but all need use of the same integrated system as their primary tool.

- Ensure MEDS meets the following NOAA criteria for a National Data Center: data integrity and appropriate meta data are maintained; all users are provided access in a timely manner; the data's existence is documented in the NOAA Earth Systems Data Directory.

- Initiate needed special efforts in the following four principal ESDIM theme areas: (1) rescue of data at risk of being physically lost; (2) improving access to existing data; (3) enhancement of data continuity and quality; and (4) system modernization.

PLANNED ACTIONS TO ACCOMPLISH THESE OBJECTIVES

CURRENT DATA RELATED ACTIONS

- Identify and adopt data standards which are in keeping with NOAA wide and international standards for the exchange of data.

- Identify and capture current NMFS environmental data base listings for the NMFS data directory. Results will be forwarded for the NOAA directory.

- Identify critical data at risk and institute action to rescue such data.

- Conduct peer review of current data and initiate any required actions to ensure data is of science quality.

- Define retrospective requirements for current data to satisfy needs of both internal and current and potential external users.

- Analyze current and projected storage requirements and frequency of use for this data, and from this, determine on line versus "mounted on request" data requirements. Determine impact on storage requirement that the MEDS system will have (i.e.; will the MEDS capability to provide NMFS users with on line access to external information systems obviate the need to maintain this data within MEDS)?

- Explore other alternative to meeting low access or "mounted on request" data requirements (availability on optical disks, etc.).

NEW DATA (REDUCING UNCERTAINTY) RELATED ACTIONS

- Determine the critical information needs relative to each NMFS Strategic Plan goal.

- Determine what effort is required, the difficulty in accomplishing, and the time frame to accomplish for each of these information needs.

- Determine the interrelationships in these needs.

- Prioritize information needs and seek alternative or interim solutions to high priority needs which will be difficult or require considerable time to achieve.

- Determine information requirements for an executive information system.

- Reach consensus on the necessary data standards within each major program.

- Research the trade-offs of budget, increased sampling, risks to stocks, and risks to industry in the decision process in a risk analysis.

- Evaluate promising new technologies such as artificial intelligence and neural networks and new sampling strategies.

- Establish minimum standard stock assessment methodologies.

- Central review of data collected.

- Assign individuals responsible for data integrity.

- Produce guidelines to insure data quality.

MEDS DEVELOPMENT RELATED ACTIONS

Interface For External Users

- Identify and adopt interface standards (hardware and software) to support a interface for external users.

- Identify data security (confidentiality) issues on aggregate, computed, and individual data elements currently in or planned for the MEDS system.

- Prototype an external interface which will permit external users access to NMFS ecological and biological data bases.

Interface For Internal Users

- Prototype a interface for internal users which will allow access to distributed data within the MEDS system.

- Prototype an extended version of the interface permitting access to external data bases.

- Prototype an executive information system module to support key NMFS managers.

- Prototype a scientific/decision support system capable of combining data sets from multiple locations within the system and performing specific user requested analysis and or modeling on the data.

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SECTION IX. FUTURE TECHNOLOGY IMPACT

INTRODUCTION

In this section we examine some of the new technology that is "on the horizon" (available within the next ten years). The impact of this new technology is also explored to relate its relevance to the overall NMFS mission and goals. Particular emphasis has been placed on that technology which will impact this Information Management Strategic Plan in support of those goals. NMFS is moving to open systems to take advantage of these new technologies and their benefits.

If new technology brought only bigger, faster, and cheaper tools life would indeed be simple and there would be little necessity for considering it as a part of this plan. Technology has been changing so rapidly over the past few years, few organizations can easily keep pace. It is difficult to attempt to forecast how far these changes will go or what is going to be available. The methodology of processing data into information will be so drastically different in the next decade that organization impacts will be significant. The very core of what NMFS is doing and how it is being done will be impacted. The science, the tools being used, and the way NMFS scientists and decision-makers will be interacting with each other and with the worldwide scientific community will all be drastically altered in this coming decade as a result of this new technology. This new technology, for all that it promises, won't make life simpler. It will be a "two edged sword" offering not only new opportunities but also confronting us with new challenges for which we will have to find answers.

In the sections that follow we will briefly address some of these new technological innovations and their potential impact on the NMFS core sciences as well as the new computer technology which will support this Information Management Strategic Plan.

NEW TECHNOLOGY IMPACTS ON THE NMFS CORE SCIENCES

Data from new types of sensors and laboratory equipment will be appearing within this decade (some of which are available today). The Sea WIFS color sensor data and SAR (Split Aperture Radar) data are two well known examples of this new data. The availability of data from these new sensors is critical to the continued ability of NMFS to meets its mission and goals. They will open new doors of understanding and provide answers to questions that have been un-addressable in the past.

It is anticipated the next decade will see a large number of new sensor types with much higher resolution than is available today. These include satellite, buoy, platform, and towed sensor arrays. Additionally new and more sophisticated laboratory equipment for biological sampling and analysis will be forthcoming.

These new sensors and equipment, and the data they produce will create a number of challenges, for frequently, the data is massive, and the understanding of the physics involved is not complete (SAR data is a good example of this for while we understand much about its use for ice identification many feel it has the potential to tell us much more). This means that more powerful processors with greatly increased capabilities for scientific visualization will be needed as well as storage capacities that exceed those currently available by several orders of magnitude. Expanded techniques for large scale data assimilation and automated quality control and analyses will be necessary to cope with the large volumes. The use of this data will increasingly require interdisciplinary scientific efforts frequently involving sciences not previously addressed by NMFS. This will necessitate working closely with scientists in other organizations and locations. Tools that will permit easy exchange of research and data will be critical. (Future computer technology that will address these needs is discussed in the following section.)

On another note, a large increase in the use of remotely controlled surface and submersible vehicles will occur. This will require systems capable of handling the associated robotic functions and processing of new types of data collected by these devices. This will include not only sensor, but also image data, sound, behavior, and other real-time data in addition to the traditional data types.

These new scientific products will require advanced new technology systems not only in the laboratory but on ship board and in the field for data acquisition, storage, and preliminary analysis.

In addition to new sensors and laboratory equipment; new science is evolving. The ecosystem (as opposed to a single species) approach described in Section VI. is an example of these new and evolving sciences. The impacts of a new science, include all of the challenges described above and in addition add a very real potential to impact the very nature of how the organization goes about fulfilling its mission.

The availability of these new technological innovations be they hardware (sensors or laboratory equipment) or new science might in many ways be likened to having opened "Pandora's box". Once they are with us there is no turning back. NMFS cannot ignore them because they will provide the tools to help find answers to basic questions at the heart of its mission. NMFS plans to upgrade to the newer technology on a regular basis, as budgets allow.

NEW DATA PROCESSING TECHNOLOGY AND ITS IMPACT

In this section, we address the new data processing technology that will be available in the coming decade and assess its impact on NMFS as a whole and on this

Information Management Strategic Plan in particular. It is not the intent of this document to provide an in-depth survey of the technology. General trends and directions are what we are looking for here and we have dealt only with technologies that exist but are not yet fully developed or deployed. We have avoided the more exotic technologies that are currently being worked on such as room temperature superconducting devices and light based CPUs. Undoubtedly, some of these technologies will mature within this decade bringing with them even more profound advances and impacts.

COMPUTERS/WORKSTATIONS

General

At the mainframe and super computer level, systems will continue to get faster and more capable to address certain specialized computing requirements. The power existing today in mini-computer systems and work stations make these large systems unlikely candidates for most of NMFS needs. NMFS will require an immense amount of computing capacity but that capacity needs to be distributed throughout the organization rather than concentrated in a single super computer center. In any event today's mini-computer and workstation are so powerful they exceed mainframe or super computer computing capacity of but a few years ago. One possibility though is the use of the emerging massively parallel computers as a part of the High Performance Computing and Communications Program (HPCC) for some of the larger NMFS ecosystems models. Another is to link workstations with fiber optics to obtain equivalent performance.

Similarly, the power or capacity difference between mini-computers and workstations (micro-computers) is becoming blurred. We will use the term mini-computer here to describe a system dedicated to a specific function or utilized as a centrally accessed system, and work station for a system that is dedicated to a single user. The actual hardware in many cases might be identical.

It has been estimated that by the year 2000, Intel will be producing computer chips with over two billion components on them and that they will provide 1,000 MIPS (million instructions per second) for a cost of $1.00/MIPS.

Workstations with 32-64 MB of memory will be common place and systems with 512-1024 MB will not be uncommon within the decade.

Increasing numbers of portable computers integrated with telecommunications technology will be prevalent. Scientists and managers will likely have two or more computers of various configurations in their "tool box".

Architecture
Major suppliers offering various computer architectures will be competing for the mini and micro computer market. Potential users will be inundated with claims for these architectural features as suppliers attempt to differentiate their products. Two major architectural differences frequently referred to are RISC (reduced instruction set computer) systems such as the current IBM System/6000 family, or CISC (complex instruction set computer) systems such as the current Apple or Intel 80X86 based systems. Terms describing the degree of parallelism also abound and the potential buyer will be confronted with terms like SIMD (single-instruction, multiple data), MIMD (multiple-instruction, multiple-data), superscalar, and superpiplined to describe these architectural approaches. Bus architecture also comes in many forms including VME (virtual memory Europe), SCSI (small computer standard interface), EISA (extended industry standard architecture, and micro-channel (IBM bus architecture) to name but a few.

Each type of architecture offers some benefits and advantages, however, with each new generation of these systems the scene changes. Performance gaps widen, close, or reverse themselves. New or hybrid architectures will continue to appear. For the most part, these architectural structures are invisible to the user. Benchmarking will probably tell us all we need to know about the processor architecture itself except for special applications. We believe that the transition from 32-bit CPUs to 64-bit architecture or higher (CPU and data) will be completed during the next decade.

The implementation of the information strategy described in this document depends on the availability of new processors with greatly increased performance. The amounts of data handled and analyzed as well as the increasing complexity of that analysis will exceed the capacity of our current technology systems before the end of this decade.

Processor power however should be kept it perspective since it is seldom the most critical factor in selecting a new system. Although the speed of the processor is important, other technological factors such as software capability, input/output capabilities (band width), reliability of the hardware, and technical support can have significant weight when evaluating new systems.

Special Functionality
New systems with integrated, sophisticated architecture specifically designed to enhance system functionality will be appearing and they need to be closely evaluated. These systems usually have special instruction sets within the processor or include one or more co-processors to optimize certain functionality. NMFS critical functionality includes (1) scientific visualization; (2) telecommunications and; (3) data capture, storage and retrieval. Each of these is discussed below. Some new functionality such as pen computing which will reach maturity as a technology in the current decade will undoubtedly take on major importance in ways we can only guess at today.

Operating Systems
Proprietary operating systems have been with us for some time and will undoubtedly be with us in the coming decade. Manufacturers will continue to offer them both to exploit unique hardware architecture as well as for product differentiation. There will also be increased pressure from users and a migration to systems supporting cross systems operating system environments such as UNIX, X Windows, MS DOS and MS Windows (and their successors). While data are reasonably portable between various systems; software, both commercial and internally developed, is much less so. This is true even when written in standard languages since they depend heavily on calls to the operating system to perform many of their functions due to the graphical nature of today's operating environments. Fortunately, the problem is being reduced as the trend moves toward open systems software and standard interfaces.

Greater efforts can be anticipated in the coming decade to overcome this through (1) availability of multiple operating systems on a computer platform; (2) porting of proprietary operating systems and software to other platforms; (3) multi-processor systems capable of running a variety of proprietary operating systems and applications packages; and (4) greater use of standard application interfaces based on the OSI mode. If NMFS chooses to utilize multiple hardware platforms, these considerations will have to be carefully considered since, in addition to the software costs which are a significant portion of the total system cost, common tools must be available to all NMFS users for many core functions.

GRAPHICS

Scientific Visualization
Scientific visualization is a relatively new technology which utilizes the computer to graphically display data in a form the human mind is more able to deal with. The scientist and decision-maker are faced with data overload and the situation will worsen in the coming decade. There is too much data to be to analyzed. Not only is the volume of data increasing; the complexity factor is increasing. Scientific visualization offers the potential to combine powerful new techniques in data analysis with artificial intelligence concepts to create new graphic paradigms capable of depicting the complex relationships in this new data. We will be asking more complex questions for which answers are harder to find, and the new tools we will be using produce data that is more difficult to analyze. Significant technological advances in the field of scientific visualization represent a critical tool for this Information Management Strategic Plan. New and more powerful image recognition systems will also be required to provide analysis of visual image data.

Hardware

While advances in scientific visualization will come in the form of creative new approaches from marine scientists, mathematicians, statisticians, and software engineers there must be hardware there to support it. We can expect to see major advances in graphics equipment in the next decade to meet this requirement.

Workstation graphic display densities will move from the current range of around 1000X1000 to perhaps a 4000X4000 matrix before the decade is out. A 24 or 32 bit color capability will be the norm and 64 bit plane graphic hardware will be available for specialized applications.. Specialized functionality (graphics co-processors, and special bussing with hardware image data reduction algorithms will be found in both general purpose and specialized graphics systems to handle the associated increase in computational requirements. Systems will support full motion video and offer multimedia hardware support. Virtual reality systems will begin to make large inroads and will open exciting new possibilities for scientific visualization.

TELECOMMUNICATIONS

Introduction

The ability to retrieve and transmit large amounts of data between systems or offices is a critical requirement relative the this Information Management Strategic Plan. NMFS scientists and decision-makers will require access to increasingly larger amounts of data and much of that data will not be available to them on their own workstation or even locally. In this environment, the users are "crippled" if their workstations are not connected to a local area network (LAN) and the LAN is not further networked. NMFS scientists and decision-makers need to be able to exchange data with other NMFS and NOAA organizations, federal state and local agencies, universities and other research organizations, and corresponding international groups and agencies. Ideally this should be little more difficult than exchanging data or ideas with a scientist in an adjacent laboratory.

A common NOAA data communications network is expected to emerge by the middle of the decade.

Networking

LAN software and protocols exist today and will be expanded in the coming years to take advantage of new systems and hardware technology. Major advances in capability will be seen in the area of internetworking (the tying together of multiple LANs, into a single-network image). Figure IX-1 depicts the change in computational topologies from the centralized mainframe systems of the 1960s to the internetworked architecture of the

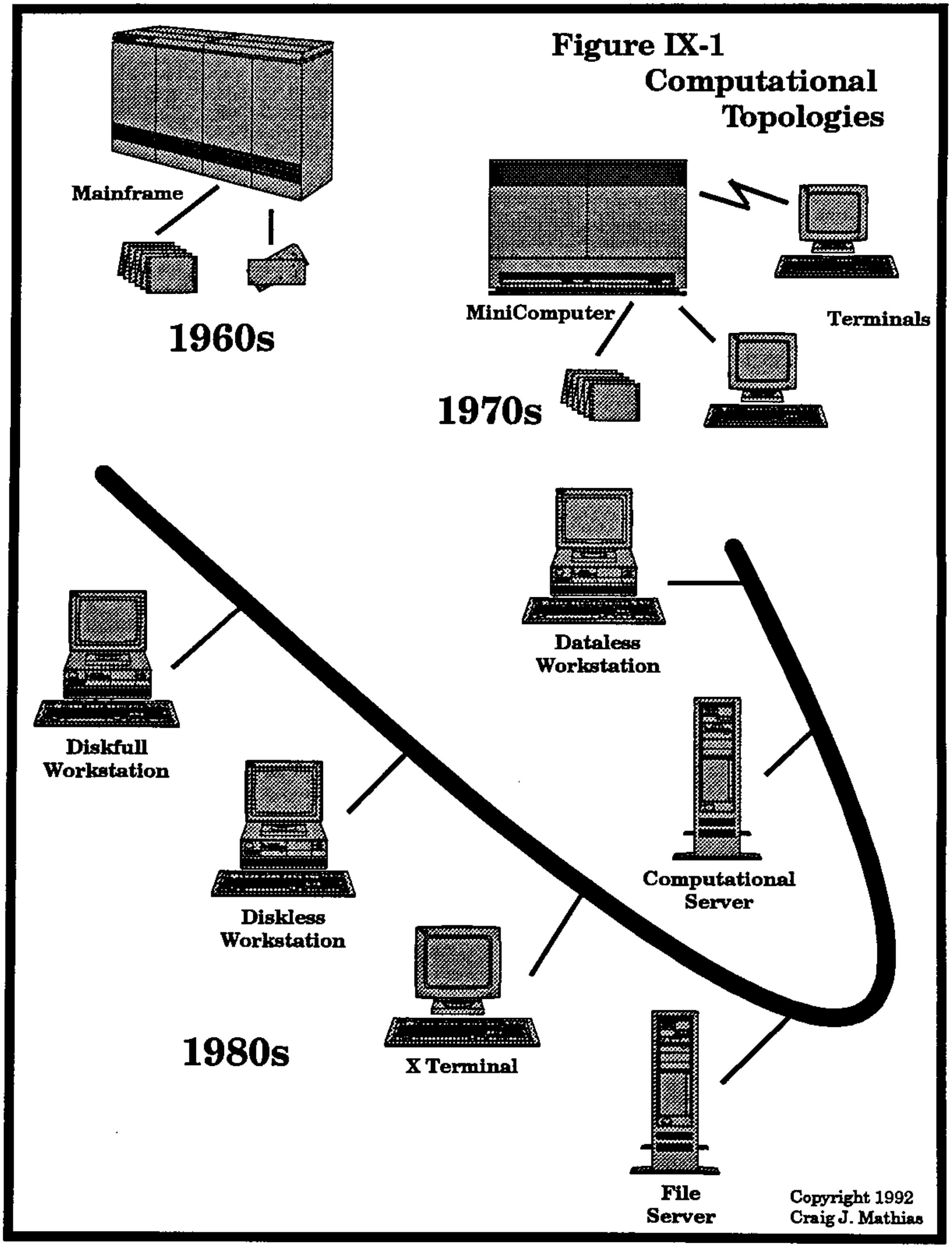
Figure IX-1
Computational
Topologies
Mainframe
1960s
MiniComputer
Terminals
1970s
Dataless
Workstation
Diskfull
Workstation
Computational
Server
Diskless
Workstation
X Terminal
1980s
File
Server
Copyright 1992
Craig J. Mathias

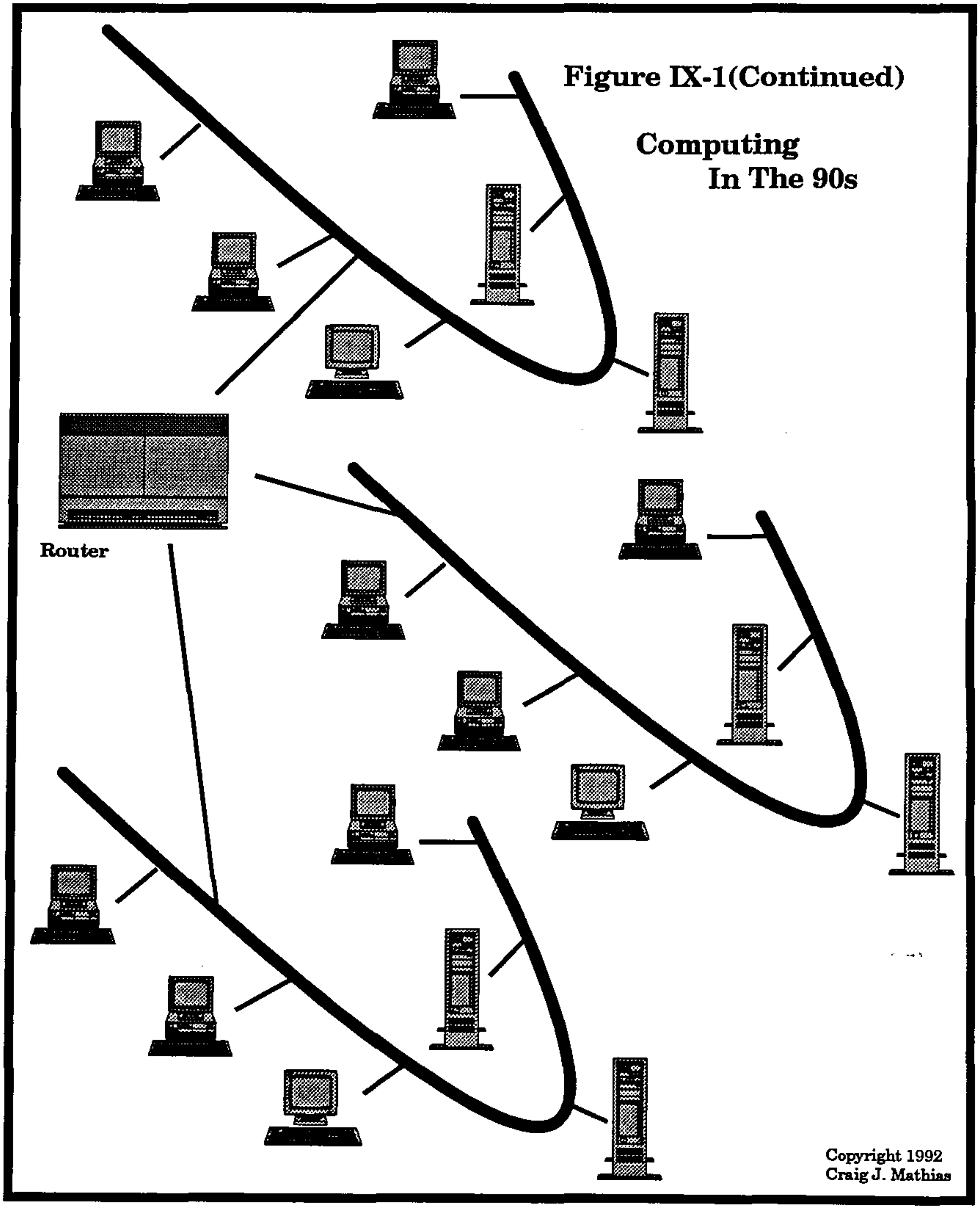
Figure IX-1(Continued)
Computing In The 90s
Router
Copyright 1992
Craig J. Mathias

1990s. (Reproduced with permission of Craig J. Mathias.) Higher speed more capable networks will appear. It is expected, for example, that the current National Science Foundation Internet system will be replaced by a 1 Gbps system NREN (National Research and Engineering Network). We anticipate more extensive use of metropolitan area networks (MANs) at key NOAA locations nation-wide and possible use of wireless LAN technology.

Client-server distributed processing will be a key feature in new telecommunications technology products and one can expect to see artificial intelligence concepts being applied to management of these new and increasingly complex networks.

Hardware
Greatly increased bandwidth communications will become available in the next decade through increasing availability of communications satellites; special purpose communications processors will provide higher degrees of parallelism and even more sophisticated data compression capabilities.

Security
We can expect increased focus on needs to protect privacy and ensure integrity of data. This will be achieved through layers of security and encryption. Since the decisions NMFS makes can have multi-million dollar impacts this sort of protection will be required for a portion of its data base. NMFS must have have the right balance between security needs and distributed processing.

DATA CAPTURE, STORAGE, AND RETRIEVAL

Introduction
The ability to capture, store, exchange, and analyze the vast amounts of information that we will be confronted with will require dramatic increases in the size of storage devices. Additionally new data base technology to exploit networked environments and distributed data bases is required. These are critical technological factors relative to meeting the goals and strategies of this Information Management Strategic Plan and are being driven by the marketplace and user requirements.

Data Base Systems
Full relational data base systems in a distributed architecture is still in its infancy. In the future inter-operable data bases in a heterogeneous computing environment will become the norm. It can be expected that this new technology will rapidly mature in this decade. More AI will be included in relational and object-oriented data bases. We can expect to see virtual interfaces and standards emerge that will permit merging of multiple data bases on a wide range of hardware platforms that are geographically distributed across the country, or across the world, into what appears to the

user to be a single robust data base. Artificial intelligence concepts and other sophisticated search algorithms will assist the user in searching, storage, and accessing this data. These systems will allow for moving and/or copying of data bases from any point in the system to any other and will automatically reconfigure the virtual interface (data dictionaries, etc.) to reflect these actions. Extensive meta data will be available to assist in this search and help the user in determining the suitability of the data for his needs. These data bases will be able to handle multiple data formats such as digital data, images, documents (bit mapped non-machine readable documents), full motion video, etc.

Hardware

Optical storage technology is just arriving. This technology will mature rapidly in the coming decade and be commonplace by the middle of the decade. When compared to magnetic storage, the capacities seem immense and we have only seen the first generation of these products. New generations will quickly follow providing faster access times and transfer rates and, perhaps most important, dramatic increases in density (storage capacity). Devices using current read only memory (ROM) and write once read many (WORM) technologies will gradually disappear in favor of erasable optical technology that will provide the same read write capability of current magnetic storage devices.

Document imaging systems will become more sophisticated and their use more general to hold data that is not in a format that would benefit from being machine readable (lab notebooks, etc.). Optical scanning technology will permit the conversion of these bit mapped documents to machine readable format at the touch of a button should it be desired.

File server hardware will become more sophisticated with special instruction sets, co-processors and specialized data busses to support data base applications.

RESPONDING TO THIS NEW TECHNOLOGY

NMFS must be able to capitalize on this new technology if it is to succeed with the information management strategy proposed in this document. To accomplish this, NMFS will have to assign individuals who are responsible for implementing this Information Management Strategic Plan, as well as key users with specific new technology requirements, the responsibility of tracking and reporting on new product and technology. Periodic formal technology reports should be prepared and widely distributed throughout NMFS.

In addition to tracking new technology it is essential that funding be available to permit prototyping of those new technologies or advances that appear to have great promise for meeting specific NMFS needs. Perhaps a new organizational unit could be staffed to investigate the applicability of these new technologies for NMFS and charged with strategic technology transfer (this would include software engineering). Another tool would be a dedicated pool of funds to be distributed each year for technology investments much like the DOC Pioneer fund except for NMFS only. Funds could come from a small tax on all Congressional add-ons and/or base funds. One other possibility being discussed is some form of user fee perhaps in the form of a Federal fishing license. The key principle is regular investments by management to upgrade and renew strategic technology throughout the agency at all stages of the end-to-end data management spectrum (sensors to information products to archiving).

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SECTION X. STRATEGIC SYSTEMS VISION

INTRODUCTION

This section explores a spectrum of alternative futures for the National Marine Fisheries Service. It focuses on those assumptions, values, and characteristics that will have an impact on the requirements of a data management system to support the agency mission through the current decade. After summary comments from a review of the spectrum, a brief futures scenario is outlined.

POLITICAL AND SOCIO-ECONOMIC ASSUMPTIONS

POLITICAL

The U.S. will continue over the next decade to be politically stable country with strong democratic traditions. This impacts the process for amending LMR management legislation, implementing regulations, and the balance between mandatory and voluntary data collection.

LEGISLATIVE

The current major legislation impacting the agency and its mission remains in place. In particular, the Magnuson Act, the Marine Mammal Protection and the Endangered Species Acts will be strengthened and streamlined to improve the ability of the agency to make decisions in support of conservation of the living marine resources i.e. risk adverse decisions. New amendments will make mandatory sea food inspection a reality and expand the use of ITQ systems for fisheries management. These laws have mandated data collection and information reporting requirements that impact system design.

BUSINESS CYCLES

During the next 10 years, there will be at least two full business cycles in the U.S. economy. The downturn between cycles will be a mild recession lasting approximately 10 months. The major negative impacts will come from the high interest rates triggered by the Federal Reserve's adjustments to the money supply. Declines in disposable income will negatively impact the rate of domestic seafood consumption and slow the rate of increase. Industry will be less hurt by these cycles since most excess capacity will have been squeezed out of the fisheries and the ITQ systems by the end of the decade.

WORLD ECONOMY

During the next 10 years, the world economy is expected to boom. The early parts of the decade will be spent adjusting to the European Economic Community, the rationalization of various tariff and non-tariff barriers that impact trade in fisheries edible and non-edible products. Various political and economic troubles will cause increased immigration to the U.S. Many less developed countries will be exporting seafood to the U.S. and other industrialized countries. This will impact seafood quality and cause tariff debates. The fisheries component of the merchandise balance of trade deficit continues to improve.

WAR AND PEACE

With the end of the cold war, the probability of a major world war disrupting normal commerce and fishing activities in the U.S. and its Exclusive Economic Zone or for major trading partners is at its lowest level since the end of World War II. This outlook is expected to continue for at least another decade of peace. This means that more of the budget "peace dividend" may be available for investment in expanding scientific efforts.

DEMOGRAPHICS

Projected demographic change in the United States in the 1990s and early twenty-first century has significant implications for fisheries management and the supporting data management system. Many new immigrants and domestic relocation will result in increased population and development pressure on the Nations's Coastal Zones. Projected decreases in rates of population growth, an aging population, and an increase in minority residents especially in Florida, California, and Texas (states with major fisheries), will affect the demand for sport fishing with implications for different management approaches. These trends play a major role as do general levels of education, skills, financial resources in the population, cultural differences, and familiarity with various types of fishing activities and products in impacting market and recreational determination. Age and race/ethnic-specific projections of the U.S. population and of participation in fishing are used to examine the impacts of future demographic trends on the number an characteristics of anglers. Research results suggest that the rate of increase in the angler population will decline, the population will become older, and the population will have larger minority components. These changes may require increase services for elderly and minority residents at a time when they are exempt from license fees or require lower access costs, respectively. As their numbers increase, older age and minority groups are likely to enjoy greater political power. Managers are likely to find themselves forced to address the needs of these groups in more direct and visible ways than had previously been required. This will require managers to investigate new sources of program funding and rethink the exemption to licensing requirements for individuals aged 65 and older. The monitoring of future demographic trends including living patterns (such as whether or not they live within 50 miles of the coast) is essential to effective management.

FISHERY MANAGEMENT AND ENVIRONMENTAL ASSUMPTIONS

FISHERY MANAGEMENT

The Regional Councils will be less active because of the increased shift to ITQ based management. Coastal states will be more active and assertive about expanding their jurisdiction into the EEZ beyond 3 miles.

ECOLOGY
Fisheries will be impacted by declining stocks, increasing numbers of endangered species, ITQ's, aqua/mariculture, increased toxins and pathologies, and deteriorating water quality in the near shore environment.

Climate and global change will result in deteriorating ozone layer and increased El Niño effects which will cause species and fisheries to shift disrupting local and regional economies. Critical coastal wetlands will continue to be lost to developmental pressures.

INFORMATION SYSTEMS ASSUMPTIONS

DATA MANAGEMENT SYSTEM ARCHITECTURE
The distributed architecture, initiated by the IT-95 project, continues to be the most cost-efficient approach and provides the best match with agency culture, and policies.

COMPUTER AND TELECOMMUNICATION INDUSTRY TRENDS
The trend of downsizing and intelligence in ADP and telecommunications equipment and shifts to end user orientation for the technology accelerate during the 1990s. The role of multimedia and artificial intelligence technologies will begin to dominate in the mid-1990s and the costs will get so low that they will be widespread in the early twenty-first century. Low cost, broad band high speed telecommunications fiber optic based systems will be ubiquitous. Extensive use of personal communications devices will have proliferated so people are no longer tied to working in offices.

INFORMATION PRODUCTS
NMFS will increasingly become dependent on and identified with its information available to the public. Data and information will no longer only be in the domain of the "computer" people.

This means that MEDS must have complete organizational commitment since it will become critical to NMFS as technology brings newer and more capable tools for managers and scientists to analyze data.

MAJOR AGENCY ORGANIZATIONAL VALUES

A data management system supports the decision process related to its mission. These decisions are guided by major organizational values, atmosphere of the organization, and representative codes of conduct.

KEY VALUES
Stewardship of the renewable living marine resources and equity in all actions. Pride in public service. Academic excellence in science. Devotion to the public interest and protection of stocks' ability to renew themselves.

QUALITY/TIMELINESS
Seek highest quality in informational products, advice and decisions. Provide timely analyses and recommendations to management. Focus on complete staff work that satisfies client and legislated mandates at all levels of the organization. NMFS staff take pride in uniformly high quality, professional advice and decisions.

EFFICIENCY
Seek low cost, high productivity behavior and maintain highly trained, motivated staff. The values impact the quality of services and information products delivered to clients.

INTERESTS TO BE SATISFIED AND BALANCED
Devotion to the public interest and protection of stocks' ability to renew themselves (long-term); Competing interests of commercial, recreational and non-consumptive users of LMR and their supporting critical habitats (short-term).

ATMOSPHERE OF THE ORGANIZATION
NMFS is a good place for people to work. The work is professionally challenging, the organization is supportive. The culture is informal with high respect for individuals and the scientific process.

CODES OF CONDUCT
Honesty, integrity (high ethics including no conflicts of interest), look for opportunities to continuously improve the agency's operations and services, demonstrate leadership at all levels, promote fairness in all dealings with each other and the general public, demonstrate effective teamwork, develop all employees, provide open opportunities for employees, encourage good organizational and individual citizenship as members of our communities, and support devotion to duty and loyalty to the organization as public servants.

ALTERNATIVE FUTURES

Table X-1 at the end of this section profiles three alternative futures. No single future is presented as a prediction. Rather, they are presented to define a spectrum of likely futures so that we can better evaluate the flexibility we need to design into the NMFS data management system to better support the agency's mission as the use of ecosystem-based management expands. We believe the "future" will be profiled in some combination of the characteristics presented on the defined spectrum.

The "Most Optimistic" future represents the hope end of the spectrum. (We hope that the future contains many of the characteristics outlined there.) The "Status Quo" future represents an approximation of the current situation. The "Most Pessimistic" future represents the fear end of the spectrum. (We fear that the future may contain a number of the characteristics outlined there.)

SUMMARY

The major conclusion from reviewing these planning assumptions, values and spectrum of alternative futures is that the MEDS data management system for the future will have its key architectural features firmly rooted in the distributed environment initiated with the IT-95 data management system in the early 1990s. The core value of stewardship of the living marine resources for the long-term will still dominate. Access to the NMFS biological and other databases will be greatly enhanced through a variety of methods. Critical data will have been rescued and converted to more usable formats. All NMFS major data bases will be augmented by meta-data and then quality enhanced to support scientific inquiry. Although the types of analyses and information needed for specific issues are well known and likely to continue, the abilities of the data management to combine data, process significantly larger data sets, and complete analyses in a much faster manner must change. High speed data communications and wide spread use of data standards will support an explosion in ecosystem's based modelling and forecasting for the agency. Trends in commercial computing hardware, relational and object-oriented data base software, and other analytical software will continue to meet our needs.

The key data and analyses though continue to be focused on the status of living marine resource stocks (fish; marine mammals including whales, porpoise, pinnipeds, sea turtles; and other endangered species), the status of the various components of industry and likely impacts on them from various regulatory actions, and the status of critical habitat during the life cycle of the commercially, recreationally, and ecologically (role in the food chain) important species. The key benefit of MEDS is to design in the ability to relate the various NMFS and NOAA islands of data to support the newer kinds of ecosystems-based analyses and to combine the data for unknown future analyses.

A FUTURE SCENARIO

A not too distant future scenario for NMFS data management might look something like this.

Population pressures in the coastal zone and the increase in the number of oil spills, toxic blooms, intense competing uses in the coastal and nearshore marine environments has caused an increase in the national and regional political attention on the ecosystems nearest large land masses. This is especially true in the environmentally sophisticated nations such as the U.S. and other major industrial countries.

Somewhere in northern Arizona, Joe, an employee of the Confederacy of Marine Biologists (CMB), logs on to his desktop computer Wednesday morning. Joe works under the flexiplace program and his part of a workgroup scattered over the western

United States. Today's number one priority is to finish revising his model of the California Current ecosystem and make a recommendation to management on the need for a mid-season closure based on the status of the anchovy and brown pelican relationships. Joe has been trained with a interdisciplinary academic background. Later today, Joe has a video conference call scheduled with his boss in Portland, Oregon, for the weekly staff meeting. Joe's computer reports that he has 25 e-mails waiting including 5 high priority responses from his number one ranked electronic conference, and 5 FAXes waiting to be read, or printed. Overnight, Joe's computer has prepared a customized digest of significant developments from the news services based on Joe's known areas of interest and search criteria. Part of Joe's e-mail referred to earlier was responses from the INTERNET electronic conference in his particular esoteric research area. He uses them and participates in the conference as an informal peer review and high level consulting group. Members reside in places like Calcutta, Moscow, Aberdeen, Nairobi, and Lima and are linked by the universal high speed network services built under NREN (successor to INTERNET and often known by the same name) which was funded during the mid-1990's.

In preparation for today's efforts, Joe had consulted an on-line expert information search application for likely sources and types of data, then turned to the browse capability of the data directories to identify useful data both within NOAA, other U.S. Federal, State, and academic databases as well as in various world data centers. Joe was also able to initiate on-line searches of the latest PhD dissertations and Master's theses related to his current research efforts. Several topical bibliographies are also available to Joe on his local CD-ROM reader. As an option for his system, Joe had previously installed several expert knowledge modules with his artificial intelligence-based stock assessment assistant to help ensure a professional level of analysis that was up to date with the latest in theories and methodologies. These types of expert systems were maintained by the parent agency and distributed through the NOAA Library system via interactive, multi-media CD-ROMs and laser disks to make them user-friendly. Joe had previously found this to be a useful, cost-effective way to stay current in his field and had contributed as an expert during earlier system updates. Such interactive systems are alsoused to train new employees, and orient new Regional Council members.

Joe's fault tolerant desktop system exceeds the power of the early 1990 super computers in terms of computing power and supporting data visualization. Joe first taps into the high quality scientific data bases in NOAA, EPA, Corps of Engineers, Mineral Mining Service of the Department of Interior, State of California and their university system, as well as relevant Russian, Japanese, Chilean, and various African databases to review their meta data and look for useful data, theoretical analogies, and innovations in methodology. Joe was also able to include real-time and near-real time data flows into his model. These data flow from an integrated system of NOAA and other international satellites, ships, buoys (moored and floating), various sensor arrays, tidal gauges, river flow meters all feeding into an automated quality control and preliminary analysis system. Another useful source was the various declassified data from Fleet Numerical in Monterey, California. Joe was also able to conduct a variety of retrospective analyses of time series and various combinations of climate, oceanographic, biological and socio-economic data available in world data bases. This data included a variety of video, satellite images, animation, sound, alpha numeric data formats based on long established international standards.

Last week, Joe had noticed a problem in the data so had sent e-mail to the help center describing the problem after being unable to solve it himself. Their interdisciplinary team of trouble shooters had logged in remotely to his machine and diagnosed a faulty chip on a memory board. A logic flaw in one of the subroutines for his ecosystem model was indicated by a service rep in the NOAA Ecosystems Modeling Center.

The various domestic fleets are able to log-in remotelly to various NOAA and NMFS on-line data bases to down load useful information including real-time data on ocean fronts that help them fish more efficiently and conserve fuel.

Current regulations and announcements are posted on regional electronic bulletin boards. The Assistant Administrator for Fisheries maintains an electronic issues polling bulletin board to enhance two-way communication with industry and to solicit their views on various issues.

CHARACTERISTIC	MOST OPTIMISTIC	STATUS QUO	MOST PESSIMISTIC
Organization and workplace	Flat, many taskforces, extensive use of flexiplace, electronic conferences, and e-mail; many self-organizing teams	Hierarchical staff offices proliferate	Same as Status Quo
Role of travel	Limited, use video conferences, picture phones	High	Budget constrained
Workforce skills	Interdisciplinary and current; trained in risk ID and mitigation; decision-making under uncertainty; consensus building; coaching; team building	Academic, single subject	Out-of-date
Use of co-operative agreements	Extensive both domestically and internationally, focus on data standards	Useful tool	Limited to revenue sharing only
Fisheries as a bargaining chip	Delinked from Defense and non-fish trade issues	Frequently linked	Extensively linked and sacrificed
Commercial harvest from wild stocks	High but also extensive aquaculture	Varies, salmon low	Low
Geopolitical focus on fish as food	High	Increasing	Low
Bureaucracy	Minimized	Excessive	Excessive
Water quality Estuaries Near shore Blue water	 High High High	 Medium Medium High	 Low Low Medium/low
Critical habitat	Identified, protected	Identified	Not identified or protected

TABLE X-I ALTERNATIVE FUTURES

CHARACTERISTIC	MOST OPTIMISTIC	STATUS QUO	MOST PESSIMISTIC
Frequency of eco-disasters (spills, toxic blooms, stock collapses)	Low	Stable	High
Level of excess fishing effort	Low	High	Collapsed commercial sector
Dominant management tools	ITQ or other effort	Traditional	None
Monitoring program in place for health of ecosystems	Yes	Early stages	None
Key values	Stewardship, public service, risk adverse (favor stocks)	Balance commercial, recreational, environmental	Favor industry
Salt water license as dedicated revenue source and data collection tool	Yes	No	No
Legislation	Ecosystems based	Early multi-species	Single species
Transition assistance program to help reduce fishing effort	Yes	No	No
Data standards such as species codes and data communications protocols	Extensive	Limited	None
Use of models, simulations that are CPU intensive	Extensive use for forecasts and training	Limited	None
Wide bandwidth, high speed fiber optic network and network management services integrated NOAA-wide	Yes	Limited	None

TABLE X-I ALTERNATIVE FUTURES (CONTINUED)

CHARACTERISTIC	MOST OPTIMISTIC	STATUS QUO	MOST PESSIMISTIC
Easy access to necessary computing facilities such as massive parallel super computers, graphics workstations and newer technology	Yes	Limited	Minimal
Hardware used	Current technology less than 1 year old	Less than 3 years old	More than 6 years old
Architecture	Distributed, client-server	Distributed	Centralized
Ecosystems modeling center	Yes	Early stages	None
Use of Executive Information System (EIS)	Extensive	Top management only	None
Use of GIS for analysis	Extensive	Pilots	None
Types of data	Multimedia, alpha numeric, video, maps, photos, sound, hydroacoustic	Mostly alpha numeric limited other, hydroacoustic, photos	Alpha numeric
Mandatory/Voluntary data	Both	Both	Voluntary
Focus of data	Real-time and retrospective visualization tools and techniques	annual, tables and reports	Infrequent
Global warming impacts	Minimal dislocation of species, small rise sea level	Occasional disruptions like ENSO, near shore and estuaries may not flush completely, storm damage high but infrequent	Frequent dislocations of stocks hurts regional economies and food chains, circulation disrupted so estuaries and nearshore don't flush, storm damage very high and frequent
Budget	Adequate for monitoring and analysis	Inadequate to reduce error bars	Critical efforts cutback or not initiated

TABLE X-I ALTERNATIVE FUTURES (CONTINUED)

CHARACTERISTIC	MOST OPTIMISTIC	STATUS QUO	MOST PESSIMISTIC
Infrastructure	Adequate for regular maintenance and investment	Minimal, buildings need repairs	Fleet shutdown, buildings neglected
Levels of regular investment in current technology	High and regular since recognized as strategic to agency success	Minimal	Absent
Wetlands	No net loss goal achieved, monitoring program, satellite image analysis	Inventory started	Neglected
Habitat mitigation program	Yes, extensive	Pilots	Not being addressed
NOAA biological data center functions	Yes, as virtual data center (distributed)	Islands of data	Doesn't exist
Use of artificial intelligence, robots, neural nets, expert systems, combinations in different stages of the data management life cycle	High especially for quality control models, and image analysis network of real time sensors	Early pilots some remote vehicles with video	Being ignored
Critical data rescued	Yes	Data identified and limited rescue efforts completed	No
Level and ease of public access to NMFS data	High and easy, extensive use of BBS, CD-ROMS, on-line directory, public information officers	Low and difficult	Low and difficult
Metadata available for major environmental databases	Yes, extensive	Some	None
Ability to cope with high volumes of data, and related quality control, analysis and archiving	High	Low	Poor

TABLE X-I ALTERNATIVE FUTURES (CONTINUED)

CHARACTERISTIC	MOST OPTIMISTIC	STATUS QUO	MOST PESSIMISTIC
Typical decisions supported by data management system	Complex new unknown ones as well as the traditional monitor, describe distribution and status of stocks, analysis, ID options evaluate impacts domestically and internationally, recommend allocations, by-catch, public health closures, smaller error bars, ecosystems and multi-species focus	Traditional, wide error bars, single species	Management decisions without science, focus on industry

TABLE X-I ALTERNATIVE FUTURES (CONTINUED)

SECTION XI. PROPOSED ACTION PLAN AND BUDGET

COST SUMMARY FOR PROJECT PROPOSALS

Based on planning and associated analysis, NMFS is proposing the following broad categories of research in support of ESDIM data management themes.

THEME AREA	DOLLARS BY YEAR (In thousands)				
	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
Rescue	1,582.4	914.0	900.0	900.0	900.0
Access	1,080.5	646.2	700.0	700.0	700.0
Continuity/Data Quality	390.0	236.0	250.0	250.0	250.0
System Modernization	1,725.2	6,000.0	1,000.0	1,000.0	1,000.0
Totals	4,778.1	7,796.2	2,850.0	2,850.0	2,850.0

TABLE XI-1
PROPOSED FIVE YEAR BUDGET
BY ESDIM DATA MANAGEMENT THEME AREA
(Out years are estimates or Planned levels subject to revision.)

Detailed project proposals for each theme area are contained in Appendix A.

DATA ACCESS

NMFS recognizes that it has a responsibility for the stewardship of these environmental and biological data bases and that stewardship alone is not enough. This data must be made available to researchers and decision-makers across the Nation and throughout the world. The data, for which NMFS has stewardship, is a part of the critical information set needed by the world's scientists and decision-makers to address critical issues such as those related to climate and global change. Fisheries, species, and other living marine resources are sensitive indicators of their environments thus close monitoring of changes can yield early signals of long-term trends.

To meet this need NMFS has begun a major effort to identify and catalog this data in a data dictionary. This is a first step in the development of an information system that will provide not only for access to this data within NMFS but by researchers and decision-makers across the world. NMFS has also commenced standardization of field elements within each major program area to promote easier analysis of data from multiple regions. This is a requirement for ecosystems-based management. Guidance from ESDIM has been followed to ensure compliance with evolving NOAA-wide data standards. Additionally the UNESCO Intergovernmental Oceanographic Commission's *Guide For Establishing A National Oceanographic Data Centre* is being used to ensure world-wide data standards are being meet.

The use of CD ROMs is being investigated as a potential media for providing retrospective data to a wide spectrum of users.

DATA RESCUE

A significant portion of the NMFS data is a risk of being lost either through deteriorating media, or because it does not exist in an archived storage, or because it is not in a digital format.

Selected data rescue efforts are currently underway, however progress has been slower than desired due to the limited availability of funding. NMFS believes that capturing data in an imaging system might significantly reduce the cost and time to rescue some of this data and is beginning to explore this possibility.

NORTHEAST FISHERIES DATA

Rescue of data including entry of coded tow-by-tow information into the Northeast Sea Sampling Database and its integration into other master databases in the Northeast.

SOUTHEAST FISHERIES DATA

Rescue of data including marine mammal pattern information, catch data for billfish and various tuna species in the U.S., and resource surveys in the Gulf of Mexico.

SOUTHWEST FISHERIES DATA

Rescue of data including recovering California gillnet and setnet fisheries historical data, and digitizing CalCOFI ichthyoplankton tow data. Also a key oceanographic time series in Hawaii.

NORTHWEST FISHERIES DATA

Early start on key salmon genetics data base.

ALASKAN FISHERIES DATA

Rescue of data including Alaska groundfish domestic observer program, NMFS coded wire tag recovery, database for longline surveys, INPFC high-seas tag information, and the modernization of ichthyoplankton database for the Northeast Pacific.

FISHERY STATISTICS DATA

Rescue of national and international fishery statistics data.

DATA CONTINUITY/QUALITY

Data quality and continuity is being examined as a complimentary part of the whole NMFS Data Management System. A peer review process will be used to examine all major data holdings collected by NMFS. Data that is not of "science quality" will be the subject of special studies to recommend what can be done to raise them to this level. NMFS is committed to assuring the quality of the data for which it has stewardship.

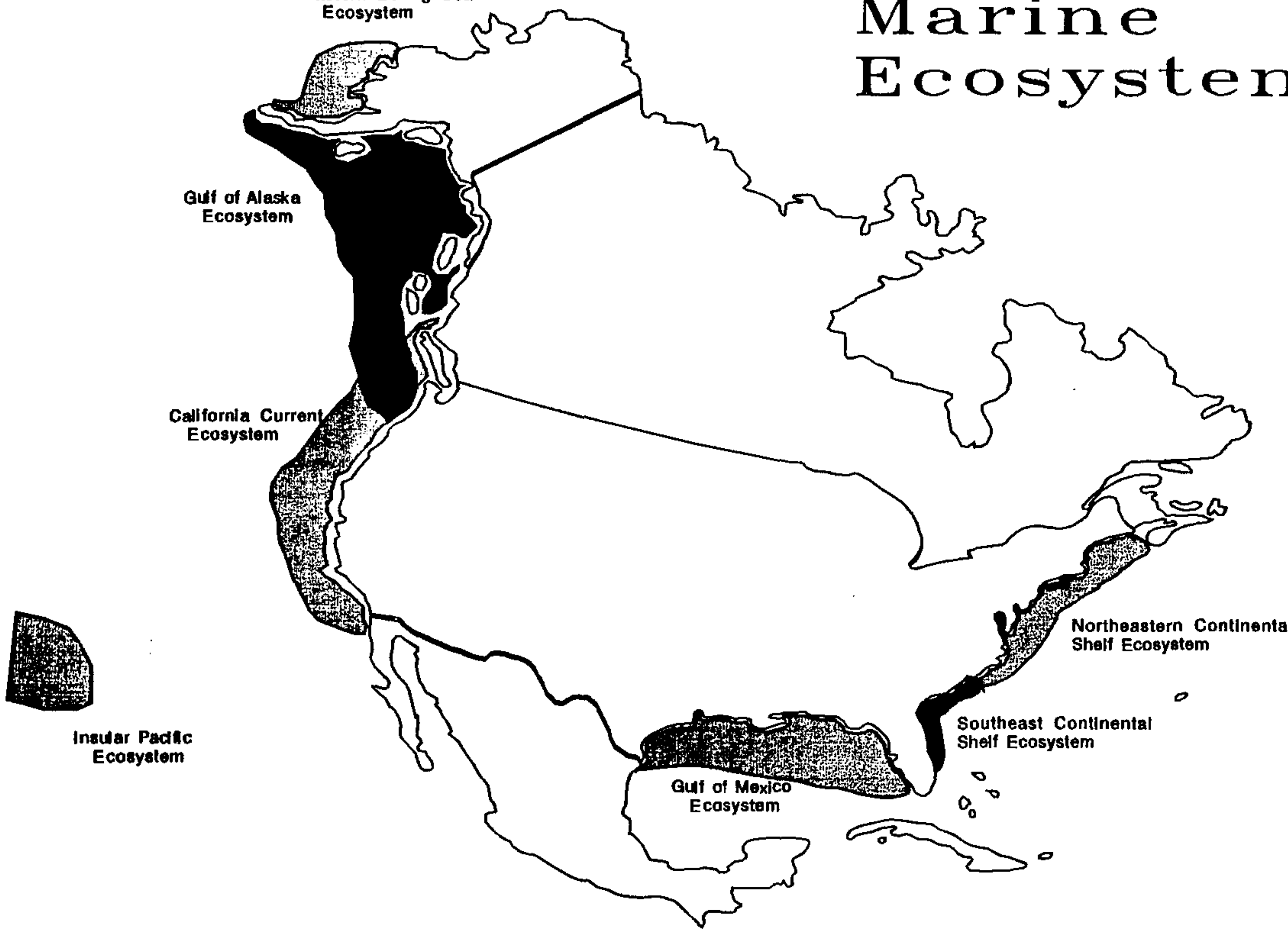
SYSTEM MODERNIZATION

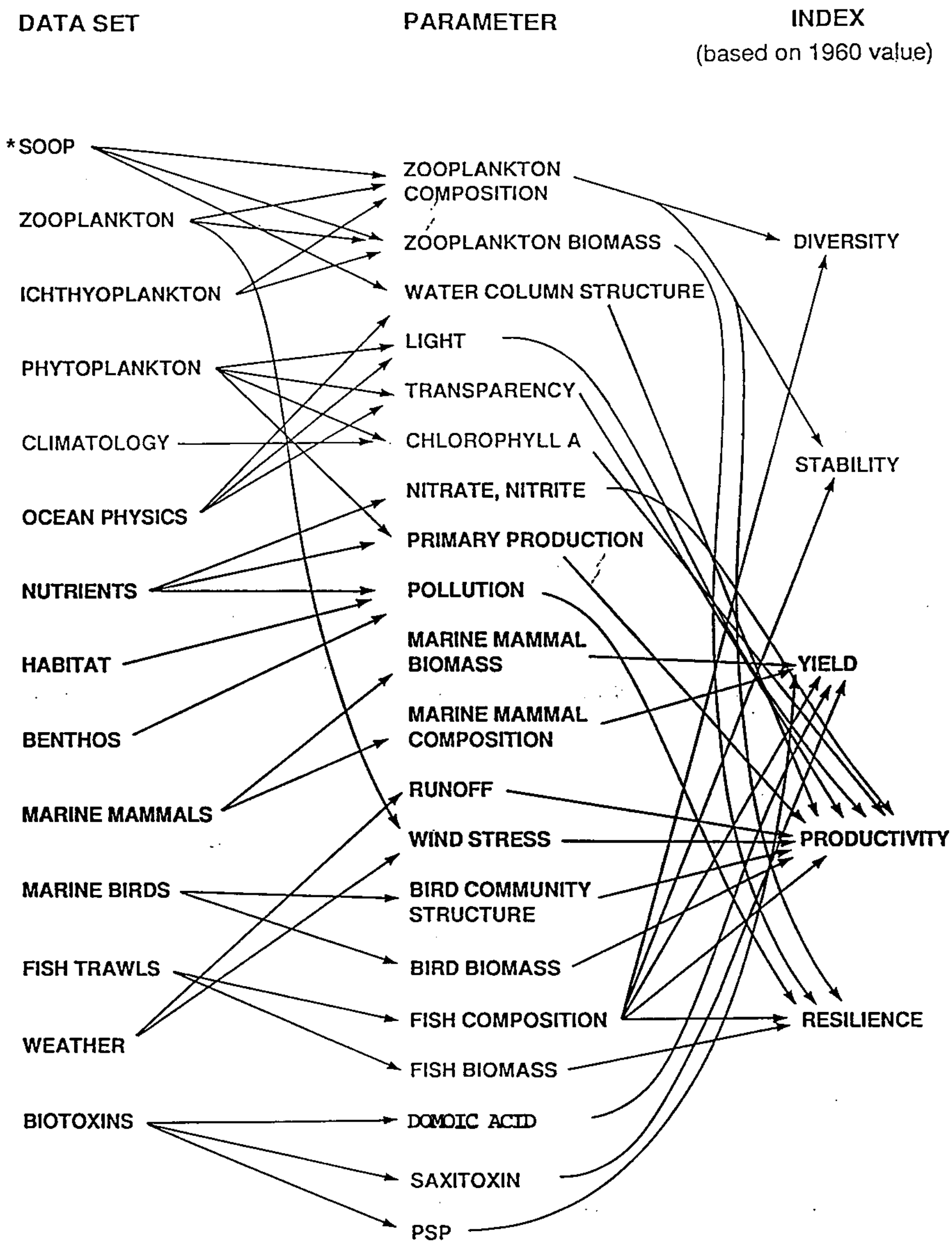
A series of pilot or demonstration projects are proposed to promote technology transfer and to accelerate the strategic use of current technology.

APPENDIX B

Appendix B contains additional background, diagrams, tables, and figures discussed in Section VI. Monitoring And Managing The Health Of Ecosystems.

Large Marine Ecosystems





* Ships of Opportunity

Table 1. Key spatial and temporal scales and principal elements of a systems approach to the research and management of large marine ecosystems.

1. Spatial-Temporal Scales

	Spatial	Temporal	Unit
1.1	**Global** (World Ocean)	Millennia-Decadal	Pelagic Biogeographic
1.2	**Regional** (Exclusive Economic Zones)	Decadal-Seasonal	Large Marine Ecosystems
1.3	**Local**	Seasonal-Daily	Subsystems

2. Research Elements

2.1 Spawning Strategies

2.2 Feeding Strategies

2.3 Productivity, Trophodynamics

2.4 Stock Fluctuations/Recruitment/Mortality

2.5 Natural Variability
(Hydrography, Currents, Water Masses, Weather/Climate)

2.6 Human Perturbations
(Fishing, Waste Disposal, Habitat Integrity, Petrogenic Hydrocarbon Impacts, Aerosol Contaminants, Eutrophication Effects)

3. Management Elements--Options and Advice--International, National, Local

3.1 Bioenvironmental and Socioeconomic Models

3.2 Management for Sustainable Fisheries Yields

4. Feedback Loop

4.1 Evaluation of Ecosystem Status

4.2 Evaluation of Fisheries Status

4.3 Evaluation of Management Practices

Table 2. Selected Hypotheses Concerning Variability in Biomass Yields of Large Marine Ecosystems.

Ecosystem	Predominant Variables	Hypothesis
Oyashio Current Kuroshio Current California Current Humboldt Current Benguela Current Iberian Coastal	Density-independent natural environmental perturbations	Clupeoid Population Increases: Predominant variables influencing changes in biomass of clupeoids are major increases in water-column productivity resulting from shifts in the direction and flow velocities of the currents and changes in upwelling within the ecosystem.
Yellow Sea U. S. Northeast Continental Shelf Gulf of Thailand Gulf of Mexico Eastern Bering Sea	Density-dependent predation	Declines in Fish Stocks: Precipitous decline in biomass of fish stocks is the result of excessive fishing mortality, reducing the probability of reproductive success. Losses in biomass are attributed to excesses of human predation expressed as overfishing.
Great Barrier Reef	Density-dependent predation	Change in Ecosystem Structure: The extreme predation pressure of crown-of-thorns starfish has disrupted normal food chain linkage between benthic primary production and the fish component of the reef ecosystem.
East Greenland Sea Barents Sea Norwegian Sea	Density-independent natural environmental perturbations	Shifts in Abundance of Fish Stock Biomass: Major shifts in the levels of fish stock biomass within the ecosystems are attributed to large-scale environmental changes in water movements and temperature structure.
Baltic Sea	Density-independent pollution	Changes in Ecosystem Productivity Levels: The apparent increases in productivity levels are attributed to the effects of nitrate enrichment resulting from elevated levels of agricultural contaminant inputs from the bordering land masses.

Table 2 continued.

Ecosystem	Predominant Variables	Hypothesis
Antarctic Marine	Density-dependent perturbations	Status of Krill Stocks: Annual natural production cycle of krill is in balance with food requirements of dependent predator populations. Surplus production is available to support economically significant yields, but sustainable level of fishing effort is unknown.
	Density-independent natural environmental perturbations	Shifts in Abundance in Krill Biomass: Major shifts in abundance levels of krill biomass within the ecosystem are attributed to large-scale changes in water movements and productivity.

Table 3 Definitions of some important variables (adapted and expanded from Pimm 1984 and Holling 1986)

Variable	Definintion	Units
Stability		
Homeostasis	Maintainance of a steady state in living organisms by the use of feedback control processes	
Stable	A system is stable if and only if the variables all return to the initial equilibrium following their being perturbed from it. A system is locally stable if this return applies to small perturbations, and globally stable if it applies to all possible perturbations.	binary
Sustainable	a system that can maintain its structure and function indefinetly. All non-successional (ie. climax) ecosystems are sustainable, but they may not be stable (see resilience below). Sustainability is a policy goal for economic systems	binary
Resilience	1. How fast the variables return towards their equillibrium following a perturbation. Not defined for unstable systems (a la Pimm 1984) 2. The ability of a system to maintain its structure and patterns of behavior in the face of disturbance (a la Holling 1986)	time
Resistance	The degree to which a variable is changed, following a perturbation	nondimensional and continuous
Variability	The variance of population densities over time, or allied measures such as the standard deviation or coefficient of variation (sd/mean)	
Complexity		
Species richness	The number of species in a system	integer
Connectance	The number of actual interspecific interactions divided by the possible interspecific interactions	dimensionless
Interaction strength	The mean magnitude of interspecific interaction: the size of the effect of one species' density on the growth rate of another species	
Evenness	The variance of the species abundance distribution	
Diversity indices	Measures that combine evenness and richness with a particular wieghting for each. One important member of this family is the information theoretic index, H.	bits
Ascendency	An information theoretic measure that combines the average mutual information (a measure of connectedness) and the total throughput of the system as a scaling factor (see Ulanowicz this volume)	
Other Variables		
Perturbation	A change to a system's inputs or environment beyond the normal range of variation.	varies
Stress	A perturbation with a negative effect on a system	
Subsidy	A perturbation with a positive effect on a system	

Table 4. Core marine ecosystem monitoring program. The Core Program is based on transects sampled by UOR or instrumented CPR, supplemented by satellite oceanography and systematic trawl and acoustic surveys.

Candidate parameters for the Core Program include:

*Chlorophyll Fluorescence	*Salinity structure	*Temperature structure
*+Primary Production	*Nutrients	
*Diatom/Flagellate Ratio	NO_2	*Stratification index
Zooplankton composition and Biomass	NO_3	*Transparency
*Copepod Diversity	Pollution index (e.g., hydrocarbons, sewage)	*PAR
Fisheries Survey		Rainfall or Runoff, Wind strength and direction

*Measurements derived from instrumented CPR/UOR sensors.

*+Based on inclusion of double-flash pump and probe system.

Table 5. Fisheries survey - Core component.

Assessment
Changes in Abundance and Distribution
Biology
Length
Age and Growth
Predator-Prey
Pathology
Acoustics for Pelagics
Nets for Demersals
Physical Measurements
Temperature
Salinity
Chemical Measurements
Water samples (nutrients, productivity, pollutants)

Table 6. Status of State Bottom Trawl Surveys in the Northeast

State/Contact	Status	Gear	Area	Frequency
Maine [1]Rich Langton	Proposed for 1st year *looking for funding in future	3/4 North Atlantic type 2 seam ("whiting") trawl	Mid coastal--3 transects inshore-offshore (± 12 mi) Pemaquid, Sheepscot, Saco Bay	5 day/month 12 mo/yr
[1]Dan Schick juvenile fish/shrimp	Start May S/K funds--1 yr analysis of by-catch	undecided S-F shrimp trawl or above	Portsmouth N+E--transects by depth (9 tows)	Seasonal (4)
[1]Jay Krause lobsters	Port agents Aug '66 sea sampling 1986	Set pots (fishing boats)	Southern, mid coast, down east	May-Dec monthly
Massachusetts [2]Arne Howe	Since 1978	3/4 North Atlantic type 2 seam ("whiting") trawl	Mass territorial waters--12 mi Random stratified 23 strata ~100 stations	Spring-Autumn
Rhode Island [2]Timothy Lynch	Since 1979	3/4 scale 340 high rise bottom trawl	Rhode Island, Block Island Sounds (fixed locations); Narragansett Bay (stratified random) juvenile beach seine survey--1986	Spring-Autumn
	Since 1987	Skiff trawls, fyke nets gill nets	Little Narragansett Bay, Pawcatuck River estuary, South County coastal ponds	
Connecticut [2]Penny Howell	Since 1984	Combination sweep net	Greenwich to New London and Race excluding NY waters	Monthly-- Apr-Nov
New York [2]Alice Weber	Since 1985	16' Marinovich semi- balloon trawl	Peconic Bay block grid w/15-20 stations randomly selected weekly	Weekly May-Oct
New Jersey [1]Donald Byrne	Since 1988	3 in 1 trawl 100' sweep, 80' head rope	Sandy Hook to Fort Henlopen 15 strata (NMFS zones 12-26) out to 90'--39 stations	Jan, bimonthly Apr-Oct
Delaware [2]Richard J. Seagraves	Since 1977	16' semi-balloon trawl	Western Delaware Bay 35 fixed stations	Monthly, Apr-Oct

Table continued

State/Contact	Status	Gear	Area	Frequency
Maryland-Chesapeake Bay Trawling Project (Chesfish) [2]Mudhusudan Bhandary	1988--5-year project	Wilcox high-rise No information previous trawl surveys	Chesapeake Bay	
Virginia [1&2]Jim Colvocoresses	(Some sampling since 1955) currently	30' otter trawl	James, York, Rappahannock River 22 fixed mid-river stations	Monthly
	Effort being made to develop a standardized trawl sampling program for entire Bay--see Maryland		Lower Chesapeake Bay stratified random sampling on 70-80 stations	Monthly

[1]Pers. commun.
[2]Special Rept. #17 ASMFC--Aug. 1989.

Compiled by Carolyn Griswold

Table 7. **Complementary, Ongoing, Northeast Shelf Ecosystem Projects**

Project	Ecosystem Subarea	Areal Scale	Ecological Process	Ecosystem Components: Nutrients	Phytoplankton	Zooplankton	Ichthyoplankton	Pelagic fish	Demersal fish	Benthos	Mammals	Birds	Currents	Water properties	Air-Sea interface	Wind stress
Satellite-derived estimates of primary productivity Bigelow Labs., NEFC, BIO. J. O'Reilly, J. Campbell, T. Platt, M. Lewis	Northeast Continental Shelf	Macro	Primary productivity		x											
Measurements of primary productivity. Bigelow Labs.	Gulf of Maine	Meso	Primary productivity	x	x											
Coupling between phytoplankton and zooplankton dynamics. State Univ. of N.Y., Stonybrook. E. Cosper, D. Lonsdale	Long Island coastal embayments (Great South Bay, Peconic Bay)	Meso	Phytoplankton productivity, zooplankgon grazing and productivity.	x	x	x								x		
Trophic coupling between juvenile demersal fishes and the benthos in Sheepscott Bay. Univ. Maine, Maine Dept. Marine Res. L. Watling, R. Langton	Gulf of Maine	Meso	Trophodynamics		x				x	x				x		
Shelf Edge Exchange Processes (SEEP); (ongoing project) WHOI, Lamont-Doherty, Brookhaven National Labs. P. Falkowski, S. Smith, C. Wirick, C. Flagg	Southern New England, Mid-Atlantic Bight	10-100 km	Physical and biological processes at shelf edge. Primary productivity, benthic dynamics, secondary productivity.	x	x	x				x			x	x	x	x
Secondary productivity, Georges Bank; Cornell Univ., C. Greene	Georges Bank	Meso	Secondary productivity			x										
Distribution of micronekton, euphausiids in relation to fish and bird populations. Secondary production models. Manomet Bird Observatory, WHOI, P. Wiebe, M. Paine	Georges Bank Mid-Atlantic Bight	Meso	Secondary productivity Trophodynamics			x		x				x				

Table 7 continued.

Project	Ecosystem Subarea	Areal Scale	Ecological Process	Ecosystem Components												
				Nutrients	Phytoplankton	Zooplankton	Ichthyoplankton	Pelagic fish	Demersal fish	Benthos	Mammals	Birds	Currents	Water properties	Air-Sea interface	Wind stress
Determine effects of frontal processes on zooplankton production; St. Andrews, Canada J. Perry	Georges Bank	Meso	Zooplankton dynamics			x								x		
Genetics of copepod population in the Gulf of Maine. K. Wishner, URI/GSO.	Gulf of Maine	Meso, Laboratory	Population interactions			x								x		
Interannual variation in physical transport, the spring bloom, and <u>Calanus</u> <u>finmarchicus</u> production in the coastal waters of the Gulf of Maine. A. Durbin, T. Durbin, J. Yoder, URI/GSO	Gulf of Maine	Meso	Spring bloom/zooplankton reproduction interactions		x	x								x		
Coastwatch, remote sensing. J. Yoder, URI/GSO.	Northeast Shelf	Meso	Primary production dynamics	x	x	x							x	x	x	x
Effects of circulation on biological processes of Eastern Georges Bank--pre-proposal Bigelow Labs, Texas A&M, Univ. New Hampshire D. Townsend, P. Holligan, J. Christiansen, D. Brooks, W. Brown BIO, T. Loder (possible collaboration)	Gulf of Maine, Northeast Channel	Meso	Trophodynamics, population dynamics of herring and zooplankton, frontal dynamics.	x	x	x		x					x	x		
Environmental linkage to 1987 haddock anomaly; EDB, POB, CUD; D. Mountain, W. Smith, J. Green, T. Polacheck, M. Ingham	Georges Bank Mid-Atlantic Bight	Meso	Effect of hydrological and climatic conditions on haddock spawning areas and haddock recruitment			x	x		x				x	x		
Measure extent of recovery of herring; St. Andrews, Canada NEFC, State of Maine, R. Stevenson, D. Townsend	Georges Bank Gulf of Maine Scotian Shelf Bay of Fundy	Meso	Herring population dynamics					x								

Table 7 continued.

Project	Ecosystem Subarea	Areal Scale	Ecological Process	Ecosystem Components: Nutrients	Phytoplankton	Zooplankton	Ichthyoplankton	Pelagic fish	Demersal fish	Benthos	Mammals	Birds	Currents	Water properties	Air-Sea interface	Wind stress
Feeding behavior of sand lance; URI, T. Durbin S. Larimer, in cooperation w/NEFC, Narragansett	Georges Bank	Meso	Trophodynamics Species definition Reproduction, Early life ecology					x	x							
Population dynamics of sand lance in the NW Atlantic. G. Nelson, M. Ross, U of MA.	Various	Meso	Population dynamics					x	x							
Influence of Merrimac River on contaminant transport to and the physical structure of MA Bay. G. Wallace, G. Gardner, C. Krahforst, WHOI	Gulf of Maine	Meso	Transport										x	x		
Global Ocean Ecosystem Dynamics and Coupling Project (GLOBEC) Various, e.g., Scripps, Univ. MD, NSF, ONR	Various	Various	Proposed for NE shelf: Effect of thermocline on cod and haddock recruitment						x					x		
Planktonic delivery of larval lobsters, *Homarus americanus*. Bigelow Lab., L. Incze	Gulf of Maine	Meso	Recruitment		x					x						
Population structure of lobster in the Gulf of Maine. Univ. of Maine, I. Kornfield	Gulf of Maine	Meso	Population interactions, larval recruitment							x						
Modelling of offshore recruitment in the lobster, *Homarus americanus*. URI, S. Cobb, C. Katz, and M. Spaulding.	Southern New England	Meso	Larval dispersal and recruitment							x			x	x		x
Assessment of recent growth and nutrition in larval lobsters using RNA:DNA ratios in laboratory and field. URI, S. Cobb, D. Bengtson	Rhode Island waters	Meso, Laboratory	Early life stage dynamics							x				x		

Table 7 continued.

Project	Ecosystem Subarea	Areal Scale	Ecological Process	Ecosystem Components: Nutrients	Phytoplankton	Zooplankton	Ichthyoplankton	Pelagic fish	Demersal fish	Benthos	Mammals	Birds	Currents	Water properties	Air-Sea interface	Wind stress
A comparison of processes leading to variations in survival and recruitment in spring and summer spawned bluefish. SUNY, Stonybrook. R. Cowen, D. Conover	Long Island coastal embayments	Meso	Recruitment					x								
Right whale population dynamics and spatial distribution in New England waters. U. Mass., J. Finn	Southern New England, Georges Bank, Gulf of Maine	Meso	Distribution								x					
Influence of temperature or survival during the "critical period" of larval development in winter flounder. URI, A. Durbin, G. Klein-MacPhee, and T. Durbin.	Narragansett Bay	Meso	Climatic effects on survival						x					x		
Potential effects of skate abundance on food resources of Georges Bank. U. Mass., G. Nelson	Georges Bank	Meso	Species interactions, predation						x							
Seabird trophodynamics Manomet Bird Observatory M. Paine	NE Shelf	Meso	Trophodynamics									x				
Coastal, Physical Oceanography (CoPO); multidisciplinary study, national in scope. NSF, ONR, Various universities, institutes, NOAA	Various	Meso	Cross-shelf transport.										x	x		
Water mass evolution and the circulation and nutrient environment of the Gulf of Maine. Univ. of N.H., W. Brown, J. Irish, T. Loder	Gulf of Maine	Meso	Circulation, productivity	x									x	x		
Numerical analysis of tides, mixing, and three-dimensional flow-structure. Dartmouth Coll., F. Werner, D. Lynch	Gulf of Main	Meso	Circulation											x	x	x

Figure 1. Large marine ecosystems of the United States. (From Sherman, 1989.)

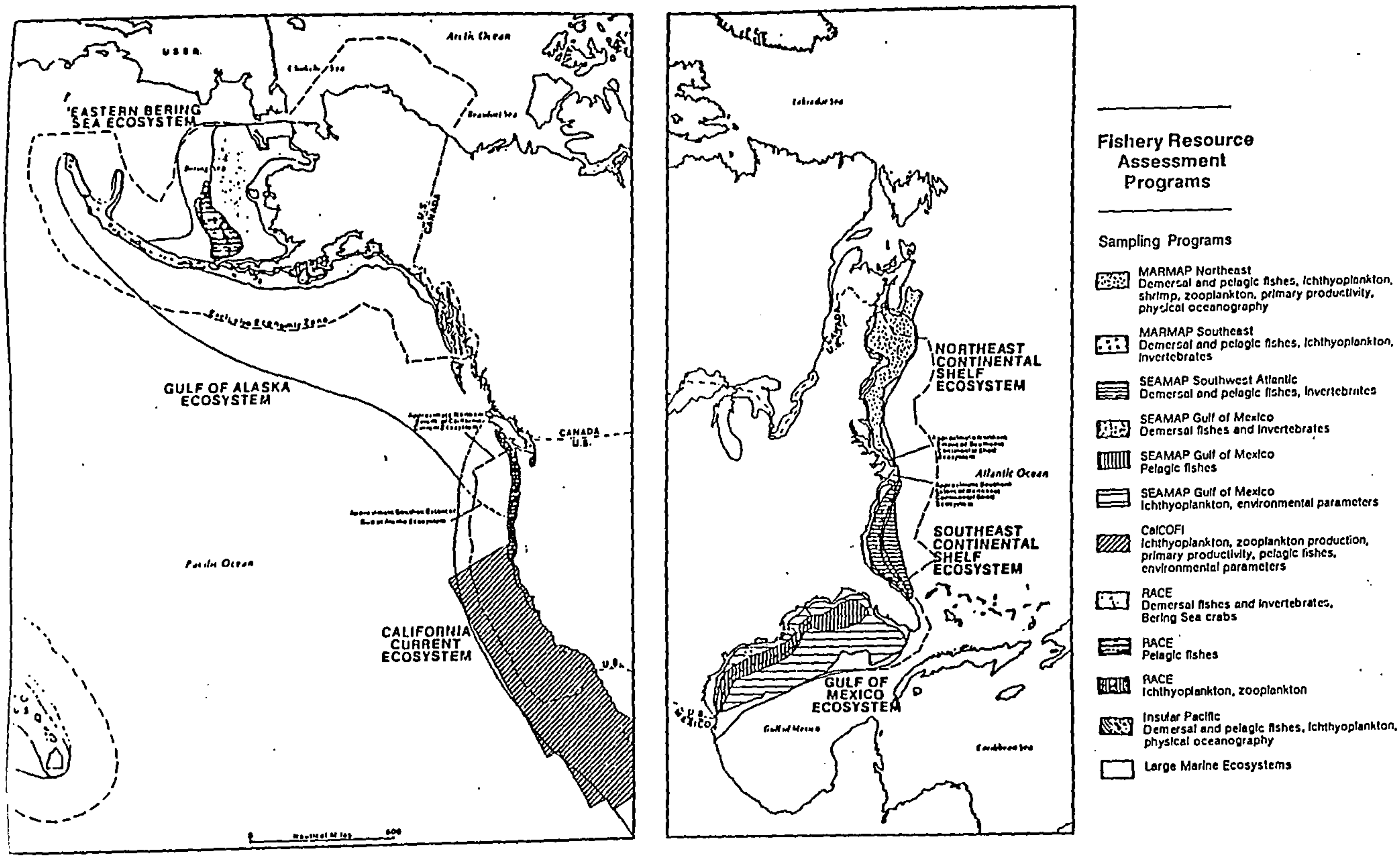
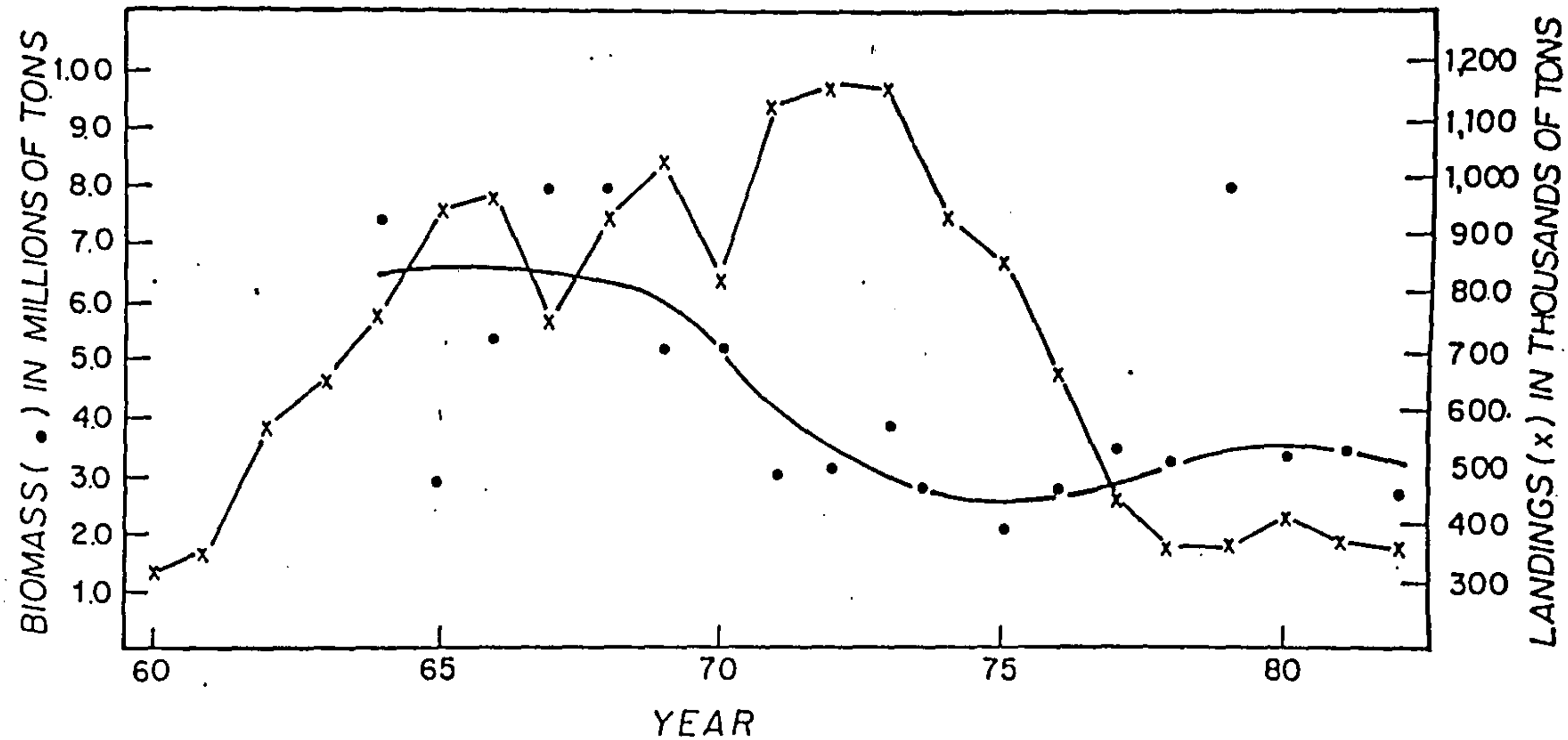

U.S.S.R.
Arctic Ocean
EASTERN BERING SEA ECOSYSTEM
U.S. CANADA
GULF OF ALASKA ECOSYSTEM
CANADA U.S.
Pacific Ocean
CALIFORNIA CURRENT ECOSYSTEM
Labrador Sea
NORTHEAST CONTINENTAL SHELF ECOSYSTEM
Atlantic Ocean
SOUTHEAST CONTINENTAL SHELF ECOSYSTEM
GULF OF MEXICO ECOSYSTEM
Gulf of Mexico
Fishery Resource Assessment Programs
Sampling Programs
MARMAP Northeast
Demersal and pelagic fishes, ichthyoplankton, shrimp, zooplankton, primary productivity, physical oceanography
MARMAP Southeast
Demersal and pelagic fishes, ichthyoplankton, invertebrates
SEAMAP Southwest Atlantic
Demersal and pelagic fishes, invertebrates
SEAMAP Gulf of Mexico
Demersal fishes and invertebrates
SEAMAP Gulf of Mexico
Pelagic fishes
SEAMAP Gulf of Mexico
Ichthyoplankton, environmental parameters
CalCOFI
Ichthyoplankton, zooplankton production, primary productivity, pelagic fishes, environmental parameters
RACE
Demersal fishes and invertebrates, Bering Sea crabs
RACE
Pelagic fishes
RACE
Ichthyoplankton, zooplankton
Insular Pacific
Demersal and pelagic fishes, ichthyoplankton, physical oceanography
Large Marine Ecosystems

Figure 2. Annual catch trends, excluding menhaden and large pelagic species, e.g., large sharks and tuna, and estimated biomass of "exploitable" fish and squid of the Northeastern Continental Shelf ecosystem, 1960 to 1982. (From Sissenwine, 1986.)



BIOMASS (•) IN MILLIONS OF TONS
1.00
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
LANDINGS (x) IN THOUSANDS OF TONS
1,200
1,100
1,000
900
80.0
700
600.
500
400
300
60
65
70
75
80
YEAR

Figure 3. Decline of Atlantic herring and Atlantic mackerel and apparent replacement by the small, fast-growing sand eel in the Northeast Continental Shelf ecosystem, 1963-87.

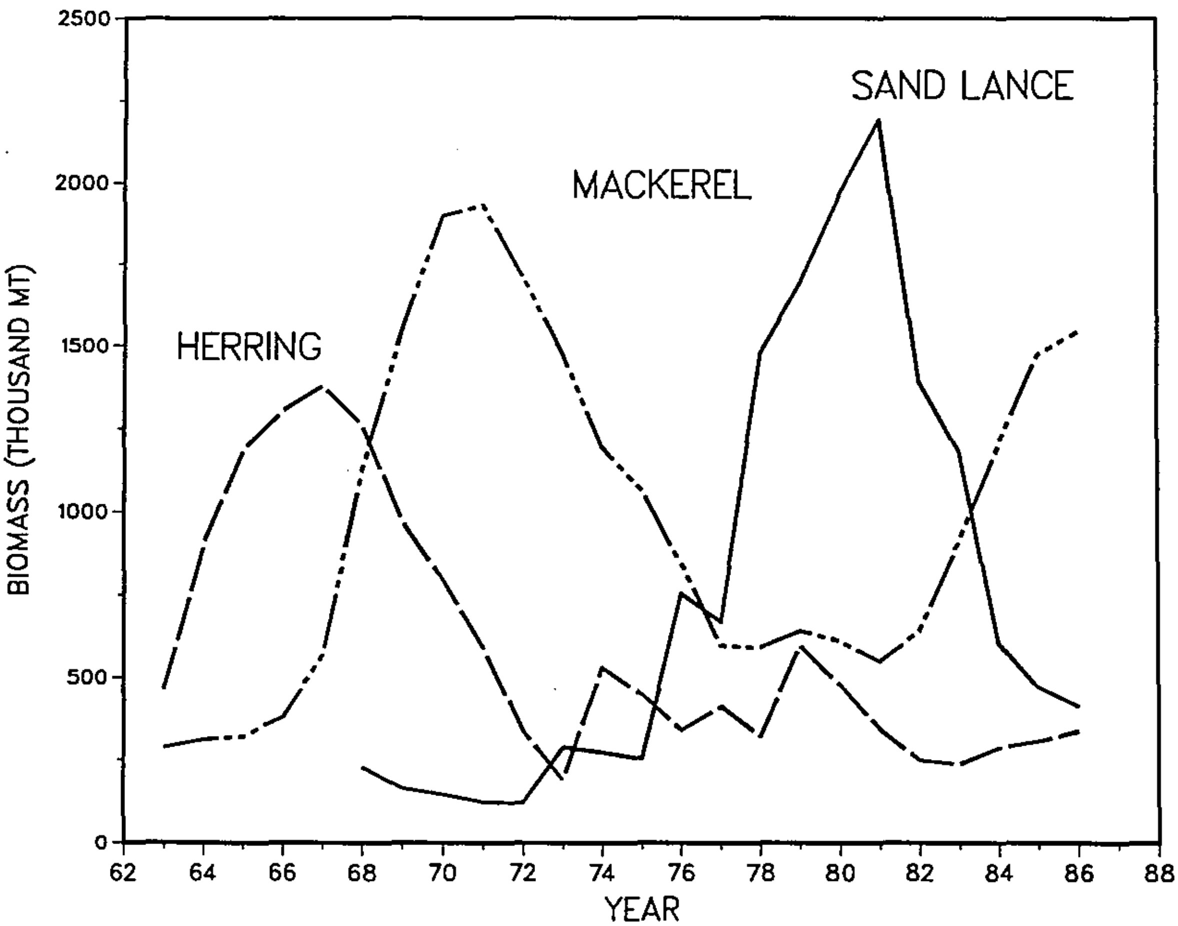

SAND LANCE
MACKEREL
HERRING
BIOMASS (THOUSAND MT)
YEAR
0
500
1000
1500
2000
2500
62
64
66
68
70
72
74
76
78
80
82
84
86
88

Figure 4. Species shifts and abundance of small elasmobranchs (dogfish and skates) on Georges Bank within the Northeast Continental Shelf ecosystem of the United States compared with the North Sea ecosystem. (From Sherman et al, 1990c.)

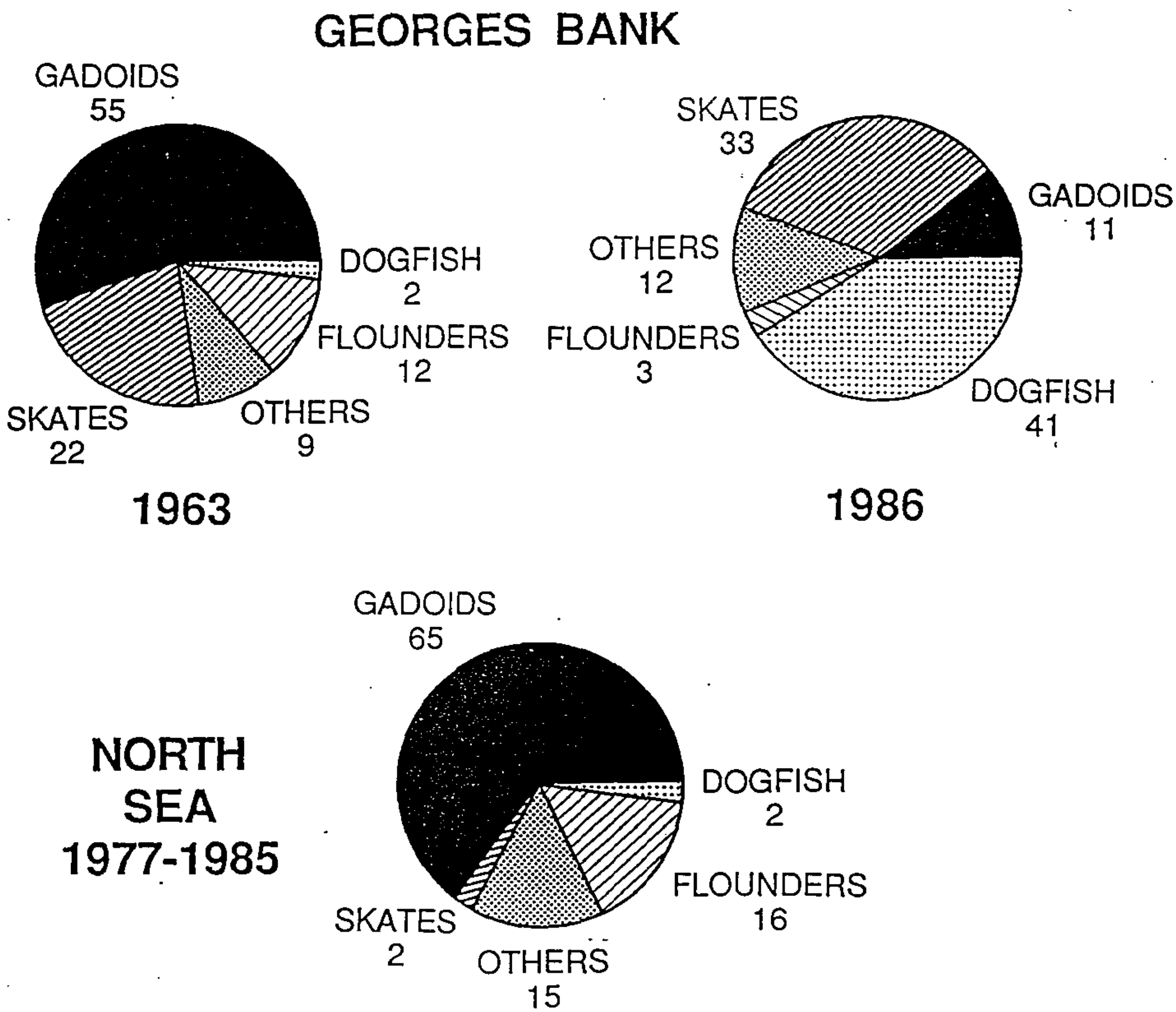

GEORGES BANK
GADOIDS 55
DOGFISH 2
FLOUNDERS 12
OTHERS 9
SKATES 22
1963
SKATES 33
GADOIDS 11
OTHERS 12
FLOUNDERS 3
DOGFISH 41
1986
NORTH SEA 1977-1985
GADOIDS 65
DOGFISH 2
FLOUNDERS 16
SKATES 2
OTHERS 15

Figure 5. Biological, chemical, and physical parameters of an LME used for deriving ecosystem health indices.