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NOAA Estuarine Programs Office

1986 Annual Report to the Under Secretary

June 1987

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NOAA Estuarine Programs Office

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U.S. DEPARTMENT OF COMMERCE
Secretary of Commerce

National Oceanic and Atmospheric Administration
Anthony J. Calio, Under Secretary

NOAA Estuarine Programs Office
Virginia K. Tippie, Director

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I. INTRODUCTION

The National Oceanic and Atmospheric Administration (NOAA) Estuarine Programs Office (EPO) was instituted by the Department of Commerce (DOC) in December 1984 to provide Agency-wide leadership and coordination for NOAA's estuarine programs. This was done in response to a need articulated during a NOAA-wide estuarine workshop in June of 1983 and again by an Estuarine Task Force convened by the NOAA Under Secretary.

In its March 1984 report, the Task Force noted that estuarine science is an inherent part of NOAA's environmental and statutory responsibilities. While many Federal agencies provide information and exercise regulatory authority in estuaries, no Federal agency has a mission as broad as NOAA's. NOAA is responsible for: research, management, and conservation of fish, shellfish, and marine mammal resources; charting coastal waters (including estuaries); the Federal coastal zone management program; the acquisition and designation of estuarine research reserves; monitoring coastal and estuarine waters; and coordinating Federal activities with respect to marine pollution.

The Task Force concluded that while the strengths of individual NOAA programs were evident, improved coordination and internal communication would significantly strengthen the Agency's ability to achieve its own estuarine-related objectives, and also influence the direction and use of estuarine science and management across the Federal government.

Recognizing the critical nature of the problems facing our estuaries and the need to coordinate an Agency-wide program to address these problems, Congress formally established the NOAA EPO in 1986. The functions of the office are:

1. to develop and implement a national estuarine strategy for NOAA that integrates the research, regulatory, and trusteeship responsibilities of the Agency;

2. to coordinate the estuarine activities of the various organizations within the Agency, including activities in estuarine research and assessment, coastal management, and habitat conservation;

3. to coordinate the estuarine activities of the Agency with the activities of other Federal and state agencies; and

4. to provide technical assistance to the Administrator of NOAA, to other Federal agencies, and to state and local government agencies in --

-- assessing the condition of estuaries;

-- identifying estuaries of critical national or regional importance; and

-- identifying technical and management alternatives for the restoration and protection of estuarine resources; and monitoring the implementation and effectiveness of estuarine management plans.

The purpose of this Annual Report is to describe significant accomplishments of NOAA's estuarine program activities and the EPO during 1986, to outline current national estuarine needs, and to make recommendations on key estuarine issues. The Report will also briefly describe the activities of other Federal agencies in the estuarine and coastal ocean environment.

II. SIGNIFICANT ACCOMPLISHMENTS OF THE ESTUARINE PROGRAMS OFFICE

Planning: NOAA's National Estuarine Strategy

The principal accomplishment of the Office during this year was the development of a NOAA Estuarine and Coastal Ocean Science Framework. This document, described in detail in Chapter III, outlines the major estuarine and coastal ocean science issues toward which NOAA should direct its resources. The report also addresses how NOAA will cooperate with other Federal and state agencies to solve national problems. The Framework was developed through an extensive consensus building process that involved all NOAA line organizations and academic leaders in the field of estuarine science. In addition to being the long-term planning document that will carry the Agency forward in estuarine science, the Framework is also the basis for year-by-year program plans that NOAA will develop.

Coordination

Since its inception, EPO has worked to coordinate the estuarine and coastal ocean science programs and activities of the Agency. During the drafting of the NOAA Estuarine and Coastal Ocean Science Framework, EPO solicited and incorporated input from all of the NOAA line organizations. EPO sponsored an Internal Planning Meeting for the NOAA Under Secretary and upper level managers where the draft Framework document was finalized. EPO also holds monthly line organization meetings to aid in the development of a unified Agency voice for important estuarine and coastal issues and events. EPO has the responsibility for recommending the appointment of NOAA representatives for each major estuarine region. On a nationwide basis, these representatives enhance coordination and communication within the Agency, and between NOAA and external organizations.

In addition, EPO has held a number of specialized meetings to enhance external coordination on estuarine issues. Two of these meetings were held in June of 1986. The first was the "Estuarine Research Workshop", which brought together key NOAA and academic scientists to develop a list of recommended issues for future agency attention. The second, the "Estuarine Management Workshop," brought together NOAA and state environmental managers to identify management issues for Agency attention. The results of these workshops formed the basic structure for the NOAA Estuarine and Coastal Ocean Science Framework.

National Estuary Program

In its role of coordinating estuarine activities with other agencies, EPO is responsible for NOAA's involvement in the estuaries designated by Congress in the National Estuary Program (NEP). These estuaries include: Long Island Sound, New York and Connecticut; Narragansett Bay, Rhode Island; Buzzards Bay, Massachusetts; Puget Sound, Washington; New York-New Jersey Harbor, New York and New Jersey; Delaware Bay, Delaware and New Jersey; Delaware Inland Bays, Delaware; Albemarle Sound, North Carolina; Sarasota Bay, Florida; San Francisco Bay, California; and Galveston Bay, Texas. To coordinate estuarine activities, EPO participates in NEP management conferences convened by the Environmental Protection Agency (EPA). EPO has appointed NOAA representatives to serve on the management and technical committees of each of the designated estuaries. EPO is also participating in meetings with the EPA, state managers, academia, and other Federal agencies to discuss the need for a comprehensive interagency regional approach to the management of the estuarine and coastal waters of the Gulf of Mexico and other coastal regions.

Another area of strong EPO involvement in the NEP has been the Chesapeake Bay. NOAA has supported activities in the Chesapeake Bay over a number of years and its involvement substantially increased in 1985 when Congress appropriated $1.5 million to the Agency to undertake fishery resource assessments, oxygen depletion studies, and to collect fishery statistics. Studies are underway and preliminary results are anticipated in the near future.

Communication

Other internal and external coordinating activities of EPO revolve around communication of estuarine issues through a variety of mechanisms. These include:

Seminar Series

To provide forums for effective communication, EPO has sponsored day-long Estuary-of-the-Month Seminars for scientists and managers dealing with estuarine issues such as ecological change in selected estuaries. To date, seminars have been held on Narragansett Bay, Delaware Bay, Long Island Sound, Boston Harbor and Massachusetts Bay, Chesapeake Bay, San Francisco Bay, Puget Sound, Louisiana Estuaries, Hudson/Raritan Bays, and Albemarle/Pamlico Sounds. The Estuary-of-the-Month Seminar series has become one of the most important ways in which NOAA gathers and synthesizes the information necessary to produce a coordinated national approach to estuarine science and management. Seminar proceedings published to date include Delaware Bay, Long Island Sound, and Boston Harbor and Massachusetts Bay.

In addition, EPO cosponsored the Coastal Society's Tenth National Conference, "Estuaries and Coastal Management -- Tools of the Trade." The conference brought together coastal professionals to exchanges ideas and information on tools used in estuarine and coastal management. Sessions at the conference examined the strategies and progress of management programs across the country; the changing role of government agencies in these programs; and the pressures of accountability and how managers measure progress. During 1986, EPO also sponsored informal weekly luncheon seminars on estuarine related scientific topics and management issues. A wide-range of topics were addressed by these seminars with presentations being given by staff people from several NOAA line organizations and by non-NOAA employees.

NOAA Involvement Series

The Office has developed and disseminated a series of "NOAA Involvement Papers" that describe Agency program activities for specific estuarine regions. The series now includes Chesapeake Bay, Albemarle/Pamlico Estuaries, Long Island Sound, Narragansett Bay, Gulf of Mexico, San Francisco Bay, and Southeast Estuaries. Papers being developed include Hudson/Raritan Estuary, Buzzards Bay, Great Lakes, and Puget Sound.

Special Publications

In addition to the above, EPO has written and published a number of special publications which address estuarine and coastal ocean issues. Estuaries: NOAA Estuarine Capabilities paper has been developed that describes the full range of NOAA's estuarine programs. EPO also publishes an annual Estuarine Projects Catalog that describes each project the Agency has done in estuaries during the previous year. A quarterly Estuarine Calendar and Bulletin is also published by EPO, listing current estuarine publications and upcoming events.

A major publication developed by EPO in 1986 was the Legislative Crosscut. This document outlines the legislation by which NOAA has the authority to assess, research, and manage our Nation's estuaries and coastal ocean regions. Another report published by EPO in 1986 was Ecological Change Through History in Chesapeake Bay.

1986 EPO Publications:

Long Island Sound: Issues, Resources, Status and Management Seminar Proceedings

Delaware Bay: Issues, Resources, Status and Management Seminar Proceedings

Boston Harbor and Massachusetts Bay: Issues Resources, Status and Management Proceedings

NOAA Involvement in the Albemarle/Pamlico Estuaries

NOAA Involvement in the Narragansett Bay

NOAA Involvement in San Francisco Bay

NOAA Involvement in the Chesapeake Bay

NOAA Involvement in Gulf of Mexico Estuaries

NOAA Estuarine Programs Office Annual Report to the Administrator

NOAA Estuarine Projects Catalog

Chesapeake Bay Stock Assessment Committee Annual Report

NOAA Estuarine Legislative Crosscut

Ecological Change through History in Chesapeake Bay

Estuaries: NOAA's Estuarine Capabilities

If you would like copies of any of these publications, please contact:

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Universal Building South
1825 Connecticut Ave., NW
Room 625
Washington, DC 20235
(202) 673-5243

NOAA ESTUARINE PROGRAMS OFFICE
Organizational Structure

Director - Virginia Tippie
Technical Manager - Samuel McCoy
Senior Policy Analyst - Joseph Bishop
Senior Scientist - James Thomas
Operations Research Manager - Carl Berman
Publications Coordinator - Alice Roberson

Regional Coordinators:
- Northeast - Carl Berman
- Chesapeake Bay - James Thomas
- Southeast - Sharon Shutler
- Gulf of Mexico - Catherine Mills
- Southwest - Joseph Bishop

Northwest - Darlene Finch
Great Lakes - Carl Berman

NOAA EPO/Line Organization Representatives
NESDIS - Elaine Collins, Kurt Hess, James Zaitzeff
NMFS - James Chambers, Mary Gessner
NOS - Harold Stanford, John Paul Tolson
OAR - Garry Mayer
NWS - Marshall Hansen

NOAA EPO Policy Committee
NOS - John Carey
NMFS - Nancy Foster
OAR - Larry Swanson
BF - Kathleen Charles
Academia - B.J. Copeland

<u>The 1986 NOAA Regional Representatives to the National Estuary Program</u>

Buzzards Bay:

Management	- Thomas Bigford (F/NER)*
	- Bruce Higgins (F/NEC)
Technical	- Marvin Grosslein (F/NEC)
	- Robert Murchelano (F/NEC)

Narragansett Bay:

Management	- Thomas Bigford (F/NEC)*
	- Carolyn Griswold (F/NEC)
Technical	- Kenneth Sherman (F/NEC)
	- Larry Buckley (F/NEC)

Long Island Sound:

Management	- Robert Lippson (F/NER)*
	- Michael Ludwig (F/NER)
Technical	- Anthony Calabrese (F/NEC)
	- Frederick Thurburg (F/NEC)

CHesapeake Bay:

Management	- James Thomas (EPO)*
	- Robert Lippson (F/NER)
Technical	- Aaron Rosenfield (F/NER)
	- Robert Lippson (F/NER)

Albemarle/Pamlico Sound:

Policy	- Ford Cross (F/SEC)*
Management	- Sharon Shutler (EPO)
	- Donald Hoss (F/SEC)

San Francisco Bay:

Management	- James Bybee (F/SWR)*
Technical	- Jeannette Whipple (F/SWC)
	- Norman Abramson (F/SWC)

Puget Sound:

Management	- Howard Harris (N/OAD)*
Technical	- Edward Long (N/OAD)
	- Richard Freely (R/PMEL)
	- Donald Brown (F/NWC)
	- Bruce McCain (F/NWC)

Puget Sound Water Quality Authority:

Research	- Usha Varanasi ((F/NWC)
Monitoring	- Howard Harris (N/OAD)

Gulf Initiative

Steering Committee	- Donald Atwood (R/AOML)
	- Richard Hoogland (F/SER)

* Indicates Lead NOAA Representative for the Region

III. NOAA ESTUARINE AND COASTAL OCEAN SCIENCE FRAMEWORK

Purpose of the Framework

In early 1986, the NOAA Under Secretary initiated a NOAA-wide planning effort to coordinate and focus NOAA's estuarine and coastal related programs. The purpose of this effort was to:

1. define the major estuarine/coastal problems and related issues of national or broad regional concern;

2. integrate existing NOAA estuarine/coastal programs and activities to address the priority issues;

3. identify those NOAA estuarine/coastal programs and activities that may require increased emphasis to address the priority issues; and

4. provide the basis for the development of annual NOAA estuarine/coastal program plans that identify activities requiring new or enhanced funding.

Planning Process

To develop the Framework, a committee of representatives from the NOAA line organizations gathered information from all the NOAA components to identify important estuarine and coastal ocean issues. To ensure that the Framework reflects the concerns of academia and the states, EPO sponsored two workshops that focused on estuarine and coastal research and management needs.

A NOAA estuarine planning committee organized the priority issues identified into categories that correspond with the major programmatic responsibilities of NOAA. The committee decided the Framework should be organized by the following problem areas: 1) freshwater inflow and circulation; 2) toxic, nutrient, and pathogen contamination; 3) habitat degradation; and 4) living resource declines. These areas are appropriate given NOAA's legislative responsibilities and the most amenable to interdisciplinary scientific investigation. Figure III-1 is a conceptual diagram showing the relationships among these problem areas, the environment, and society.

Within each problem area, questions were designed to ensure the acquisition of critical information. These questions and their implementation strategies form the basis of the Framework. The Framework provides a foundation for the development of an Estuarine Research Program Development Plan that defines specific

NOAA ESTUARINE AND COASTAL OCEAN SCIENCE FRAMEWORK

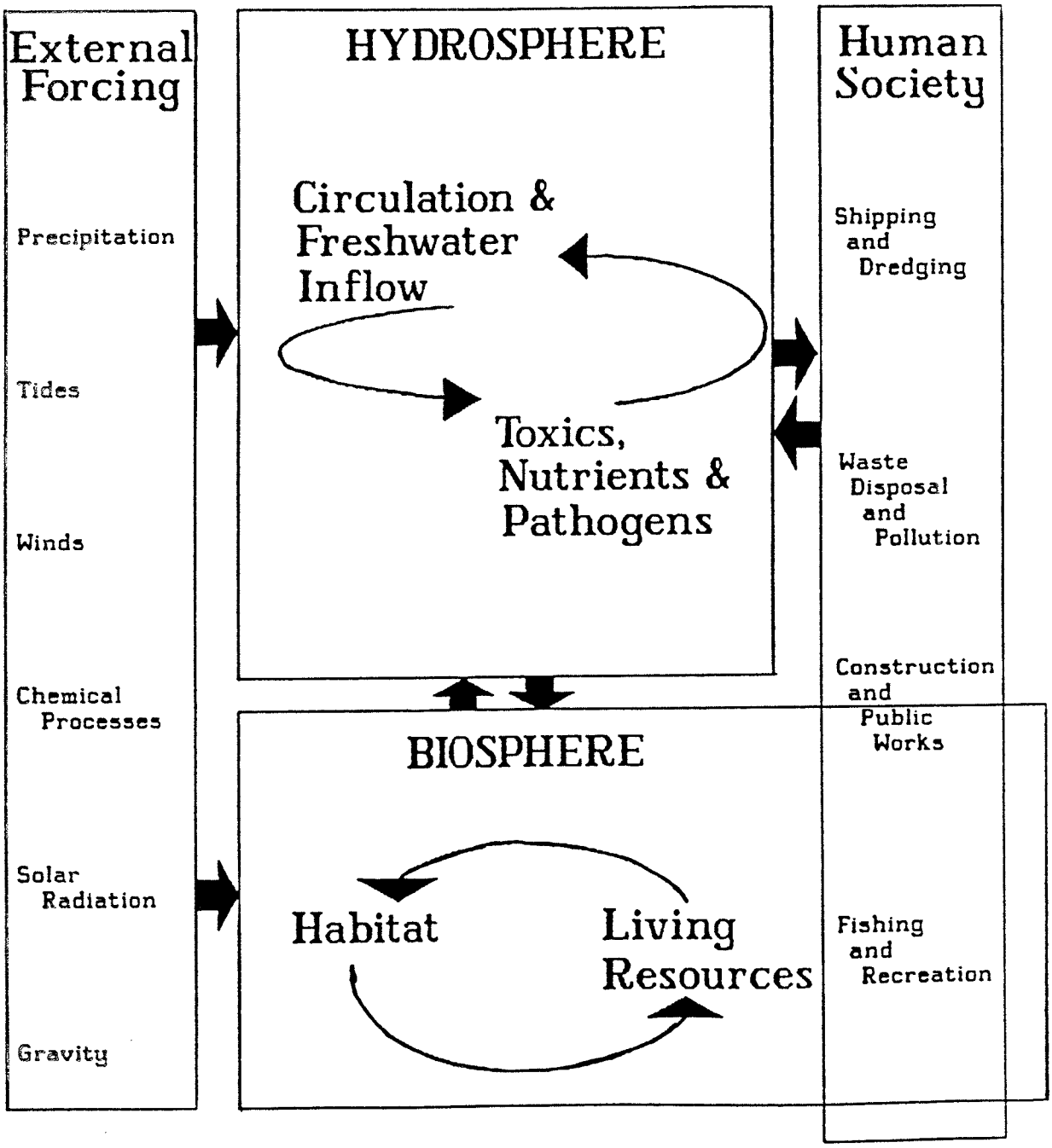

Figure III-1

tasks and establishes relative priorities. The Program Development Plan will be revised annually to: 1) provide an evaluation of progress to date; 2) allow for a reaffirmation and/or restructuring of the goals and objectives; 3) provide an assessment of future program needs; and 4) to be used as the basis for additional funding.

Framework Goal and Objectives

The estuarine and coastal ocean system is affected by human and natural factors. To effectively manage estuarine resources, we must determine the relative importance of each of these factors. As a result, the goal of the Framework is:

> "To understand and predict natural ecosystem processes to provide the capability to assess the effects of human activities on estuarine and coastal ocean resources."

This goal statement reflects the fact that improved management of estuarine and coastal areas requires a better understanding of ecosystem functioning. With improved understanding, we can better predict the impact of human activities. Within the context of the goal, objectives for each problem area were developed:

Freshwater Inflow and Circulation -- To improve our capability to predict the effects of hydrological forcing on estuarine and coastal ecosystem functioning through increased understanding of circulation and changes in freshwater inflow.

Toxics, Nutrients, and Pathogens -- To define the extent of environmental degradation caused by to contaminants in the estuarine and coastal ocean environment and to determine the effects of contaminants on living resources.

Habitat -- To understand the importance of habitat and to predict the effects of habitat loss or physical alteration on populations of living resources.

Living Resources -- To understand the causes of living resource declines and to predict the effects of human activities on populations of important species.

Framework Overview

In Figure III-2, the priority problem areas and information needs derived from these objectives are shown within the categories of observation and assessment, research, and synthesis and prediction. These categories represent the steps required to address management problems -- observation and assessment of existing information, research to answer unresolved questions, and synthesis of information to improve our predictive ability and to understand the effects of management actions.

Estuarine and Coastal Ocean Science Framework

	OBSERVATION & ASSESSMENT	RESEARCH	SYNTHESIS & PREDICTION
CIRCULATION AND FRESHWATER INFLOW	A. hydrological data B. future inflows	A. forcing functions B. inflow and fisheries C. ecosystem functioning D. episodic events	A. model ecosystem effects B. apply circulation models
TOXICS, NUTRIENTS AND PATHOGENS	A. sources and rates B. historical trends C. toxics effects D. monitoring environment	A. internal cycling B. episodic events' role C. toxics & populations D. nutrients and productivity E. pathogens and resources	A. model population effects B. health concerns C. contaminated seafood
HABITATS	A. critical habitats B. historical trends C. past mitigation	A. functional value B. natural variability C. cumulative effects D. compensation by restoration	A. model population effects B. offshore dependency
LIVING RESOURCES	A. historical trends B. abundance and health C. economic value	A. key trophic pathways B. effects on pathways C. pollution & mortality D. harvest on ecosystem	A. model population effects B. cumulative effects, all threats C. policy option tradeoffs D. inshore vs. offshore E. management regulations effects F. priority estuaries

Figure III-2

NOAA Programs and Their Relationship to Framework Priorities

The following is a brief summary of NOAA's current programs in observation/assessment, research, and prediction/synthesis.

Observation and Assessment

NOAA's assessment efforts include collecting, archiving, and synthesizing environmental data. A major assessment effort is the National Estuarine Inventory (NEI) which describes the characteristics of 92 U.S. estuaries. The NEI includes information on physical, hydrological, and land-use characteristics for each of these estuaries.

As part of NOAA's estuarine and coastal ocean observation and assessment activities, NOAA has national monitoring programs to compare the current status and trends of key contaminants in selected fish and sediments at sites around the country. This program does not address the problem of low or no dissolved oxygen and needs to be supplemented in areas where a more detailed understanding of the magnitude of the contaminant problem is required.

Because current data on critical habitat types are incomplete for broad regions of the country, the Fish and Wildlife Service (FWS) is conducting a baseline mapping effort of all inland and coastal wetlands. Since an easily updated format is a priority need, NOAA and its counterpart state coastal management programs are using the FWS maps to estimate acreage by habitat type and to digitize the information. NOAA is also assessing the number of acres of wetlands lost since the completion of various surveys in order to provide a strong basis for making recommendations to regulatory agencies. Studies are needed to document vegetation coverage and to permit the development of a standardized permit reporting and computer network. NOAA is also gathering information to assess the relative importance of habitats and to advise regulatory agencies on which habitats to conserve.

Trends in fisheries recruitment, distribution, and abundance are key to determining the effects of fishing activities, natural variability, and the effects of contaminants or habitat loss on fishery resources. NOAA is developing information on the distribution and abundance of approximately 150 species of estuarine-dependent fish and invertebrates. NOAA has also attempted to improve the fishery statistics available from the states for estuarine species. NOAA is working with Maryland and Virginia to conduct stock assessments for key species in the Chesapeake Bay that should lead to advanced statistical and analytical studies that can be used in other coastal areas.

Research

One of the least studied problems identified in the NOAA Framework are those associated with estuarine dynamics and, in particular, freshwater inflow. NOAA has developed computer models to describe the circulation in selected estuaries, such as the Delaware, San Francisco, and Chesapeake Bays. Cost effective models and other analytic tools should also be developed for use in assessing the effects of alterations in freshwater inflow and changes in circulation patterns on estuarine productivity. These modeling efforts should be integrated with research on the quantitative relationships between freshwater inflow circulation and fisheries production.

NOAA laboratories are investigating the effects of contaminants and pathogens on the reproductive success of flounder, and are attempting to correlate contaminant levels in the sediments with observations of tumors in fish. These efforts have focused on fish and shellfish in urbanized and industrialized estuaries. NOAA's research must be expanded to address how selected contaminants, as well as pathogens, affect the food chain and ultimately important fishery populations. Research should also address the synergistic effects of contaminants within the ecosystem.

Phytoplankton, submerged aquatic vegetation, and benthic algae are important units of productivity in both the open ocean and the estuaries. Understanding the nutrient cycle in the estuaries, and the natural and human-caused perturbations affecting this cycle is important for effective regulation of nutrient inputs. Moreover, a thorough understanding of the lower end of the food chain will assist in the management of fishery resources and work on this aspect of estuarine productivity should be integrated into a larger study.

Few resources within NOAA have been allocated to establish the functional value of estuarine habitat types to fisheries productivity. Applied research on the relative importance of major habitat types is important to provide regulatory agencies with the information necessary to demonstrate the cumulative effects of thousands of small-scale habitat alterations on the long-term productivity of the ecosystems.

Synthesis and Prediction

NOAA has several estuarine predictive modeling efforts underway. However, most of these do not directly address the questions concerning estuarine dynamics and productivity. For example, storm surge models for selected east and Gulf coast estuaries have been developed, but these models simulate sea level changes, instead of physical processes more related to productivity such as circulation and density stratification.

To estimate cumulative effects of pollution or habitat loss on living marine resources, NOAA has begun an effort to develop synthesis models to predict population changes attributable to these factors. The pollution models focus on species that could be exposed to lethal contaminants during their early life in nursery areas. Also, the accurate modeling of the resuspension and transport of bottom sediment and associated contaminants is essential to evaluating the effects of pollutants on living marine resources. Two current NOAA efforts include: 1) a simulation model of marsh disintegration and its effects on fisheries due to loss of interface between marsh and open water; and 2) a model to predict salinity distributions and consequent effects on fisheries caused by modified freshwater inflow caused by channelization.

To enhance scientific understanding of the structure, function, and productivity of estuarine and coastal systems, a hierarchy of synthesis models of environmental processes should be developed. For nutrients, toxics, and contaminant studies, physical circulation models should extend the salinity/temperature simulation to include water quality constituents such as nitrogen, phosphorus, and dissolved oxygen. For habitat studies, models of circulation and water quality should be combined with biomass and planktonic productivity models to simulate ecosystem relationships and pathways. For living resources, population and recruitment models which include fishing pressure and human-caused mortality are needed to estimate future stocks.

The Framework anticipates that the modeling of environmental processes will become an increasingly important aspect of NOAA's estuarine and coastal programs. The Agency will continue to devote resources to the development of models that provide the greatest benefit for estuarine and coastal resource management purposes. In addition, NOAA should initiate the development of a hierarchy of models that can be linked to produce a successful estuarine and coastal ocean ecosystem predictive capability. Such an effort is needed if the Agency is to enhance its capability to support complex management decisions that require trade-offs between ecosystem uses.

Implementation of the Framework through the Estuarine Research Program Development Plan will be coordinated by NOAA's Office of the Chief Scientist. An ad-hoc NOAA policy level committee is recommended to be established to define the respective Federal roles and responsibilities in the Nation's estuarine and coastal ocean waters. The Committee will be comprised of senior scientists and/or resource management experts from each of the NOAA line organizations. Senior scientists from academic institutions and/or state coastal management and resource agencies may also be invited to participate in Committee discussions. The Committee will provide a mechanism for problem definition and the assessment of priorities.

IV. NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION ACTIVITIES IN ESTUARIES

Historically, NOAA has been the lead Federal Agency in the development and dissemination of scientific information and products for the Nation's estuarine and coastal ocean waters. In fact, the Agency's authorities to describe, assess, and support research in these waters and to provide information for wise use and management dates back to the early 1800s. NOAA's current mandates require the Agency to provide a wide-range of observational, assessment, research, and predictive services for estuarine and coastal ocean regions. With 27 coastal and marine research facilities, 16 National Estuarine Research Reserves, and direct ties to 29 universities and colleges through the National Sea Grant College Program, NOAA has developed an impressive array of programs to address not only national-scale estuarine issues, but also specific problems affecting individual estuarine and coastal ocean systems.

This section of the report provides a brief overview of the major types of estuarine activities performed by NOAA Line Organizations. The Estuarine Projects Catalog (also distributed by the NOAA Estuarine Programs Office) and the Appendix to this Annual Report contain a more detailed listing and description of NOAA estuarine projects.

National Environmental Satellite, Data, and Information Service (NESDIS)

NESDIS has three programs directed toward coastal and estuarine waters. The Coastal Dynamics Study is developing scientific techniques to study the relationship of circulation to living marine resources. The Marine Environmental Assessment Program provides assessments of the impacts of environmental events on estuarine waters. The National Environmental Data Referral Services (NEDRES) Data Management Program for the Chesapeake Bay is a computerized, on-line data base inventory that facilitates environmental data identification and acquisition for the Chesapeake Bay Program. Although NESDIS has no remote sensing programs focused directly on estuaries, it is conducting studies related to the remote sensing of estuaries by both satellites and aircraft. The majority of NESDIS' estuarine work is done under its data and information program; the National Oceanographic Data Center (NODC) and the Assessment and Information Services Center (AISC) both contribute to NOAA's estuarine capabilities. NODC is responsible for developing an archive of estuarine data, responding to queries, and producing several specialized data catalogues for estuarine regions. The Marine Environmental Assessment Division (MEAD) of AISC generates reports that assess the effect of climate on marine transportation, recreation, and fisheries for several estuarine areas. An

estuarine circulation modeling capability also exists within MEAD; this modeling effort is being used to examine recruitment of fish and shellfish larvae in the Chesapeake Bay.

National Marine Fisheries Service (NMFS)

NMFS has a strong interest in estuaries; nationally, about two-thirds of the Nation's fish landings are estuarine-dependent. NMFS has two major programs directed specifically toward coastal and estuarine waters. The National Fishery Ecology Program provides information to support fishery conservation in coastal and estuarine waters. The Habitat Conservation Program carries out management and research activities directed at the conservation of habitats for important fisheries stocks. In 1986, the estuarine activities within NMFS were divided along functional lines between fisheries resource management and fisheries science. The management responsibilities are carried out by NMFS Headquarters and the Regional Offices, while scientific and technical aspects of NMFS fisheries programs are carried out by Headquarters and Fisheries Centers.

Much of NMFS's interest in estuarine habitat stems from its responsibilities under the Magnuson Fishery Conservation and Management Act. Since most species for which NOAA has management authority spend some portion of their life cycle in estuaries, NMFS is concerned about the ability of our estuarine habitats to sustain these resources. Habitat conservation activities are carried out through the Regional Offices and Fisheries Centers through Regional Action Plans. These activities include providing recommendations to reduce the degradation or loss of valuable estuarine habitats caused by development.

National Ocean Service (NOS)

NOS supports a variety of estuarine activities related to the broad mission of NOAA. Much of these efforts are associated with the historical mission related to navigation in estuarine and coastal waters. NOS has a major program in tide and tidal current prediction and in nautical charting. Maintaining accurate charts of U.S. coastal waters is a primary responsibility of NOS. NOS supplements their tabulated tidal predictions for selected ports with instruments that provide real-time tidal information to ships. The tidal observation network also provides information for marine boundary determinations and generates records of long-term sea level change. In recent years, numerical modeling combined with observational programs are replacing the shipboard surveys as the primary means of generating data for tidal and current predictions.

NOS also has specific programs directed at estuarine assessment. Within the Oceans Assessment Division (OAD) of NOS, assessments of multiple resource uses are carried out by the Strategic Assessments Branch. Products include a National

Estuarine Inventory and Atlas and the National Coastal Pollution Discharge Inventory. These studies include information on 92 estuaries nationwide. The Coastal Estuarine Assessment Branch examines marine environmental quality through the National Status and Trends Program, which monitors contaminant levels in sediments, bottomfish, and bivalves (mussels) in many estuaries nationwide. This Branch has also sponsored major regional research programs in Puget Sound and the Hudson-Raritan estuarine system. Also located within the OAD is the Hazardous Materials Response Branch which provides scientific support for hazardous material spills using numerical modeling and environmental sensitivity analyses.

NOS has a number of programs directed at coastal and estuarine management. Within the Office of Ocean and Coastal Resources Management (OCRM), the States Assistance Program promotes rational use of the U.S. coastal zone, the Interstate Grants Program provides monies to coordinate interstate coastal zone planning, and the National Estuarine Research Reserve System manages estuarine reserves.

In the OCRM, the National Estuarine Research Reserve Program operates 16 research reserves nationwide as natural field laboratories for research and education. A total of 13 site-specific research projects are being carried out in these sanctuaries. NOAA also administers the Coastal Zone Management Act (CZMA) of 1972. States participating in coastal management under the CZMA have developed programs designed to ensure effective management and development of the coastal zone. Of particular interest to estuarine management is Section 309 of the CZMA, which allows NOAA to make grants to states to coordinate interstate coastal management activities, as occurs frequently in large estuaries under the jurisdiction of two or more states.

National Weather Service (NWS)

NWS has three programs directed toward coastal and estuarine waters. The Hurricane Guidance Program, the Tsunami Warning Program, and the Marine Weather Warning Forecast Program all provide timely forecasts and warnings for coastal and estuarine waters. Other activities related to coastal and estuarine waters that are familiar to the public are the marine forecasts and advisories routinely issued by NWS Forecast Offices. In addition, operational storm surge modeling is carried out by the National Meteorological Center to announce warnings during the passage of hurricanes. These models have also been used to determine hurricane vulnerability studies in estuarine areas. Many of the NWS' flood prediction and mitigation activities also relate to estuarine regions.

Oceanic and Atmospheric Research (OAR)

Within OAR there are four major programs directed toward coastal and estuarine waters. The National Sea Grant College Program funds studies of estuarine productivity, pollution of estuaries, and circulation modeling. The Fisheries-Oceanography Coordinated Investigations (FOCI) program (a joint effort with NMFS) is studying recruitment variability of commercial coastal fisheries. The Marine Assessment Program investigates coastal environmental pollution. The Great Lakes Environmental Research Laboratory (GLERL) researches pollution and the ecological environmental processes of coastal and estuarine waters. The estuarine activities within NOAA's Environmental Research Laboratories (ERL) are focused on physical and chemical oceanography and are carried out in Puget Sound and the Great Lakes by the Pacific Marine Environmental Research Laboratory and GLERL, respectively. The Puget Sound research programs concentrate on determining particle-associated pollutant transport and fate. Other research areas in the Great Lakes include hydrologic properties, circulation, lake eutrophication, cycling of toxic chemicals, and ecological succession.

Within the National Sea Grant College Program, estuarine investigations are funded by competitive grants awarded to academic investigators working in association with Sea Grant programs in their state or region. Programs encourage the development of integrated studies of specific estuarine problems by investigators at individual Sea Grant institutions and across the Sea Grant network. The priority research areas are set annually in proposal guidance, and proposals are considered in accordance with this guidance.

Environmental studies compose the largest segment of Sea Grant estuarine research. Major areas of study relate to nutrient and carbon dynamics (especially nutrient enrichment/eutrophication and trophic dynamics), toxicants (transport, cycling, and effects on living marine resources), habitat (especially wetland dynamics), and environmental management. Approximately 20 percent of Sea Grant estuarine studies relate to fisheries and aquaculture. Major interests include environmental control of reproduction and recruitment in estuarine stocks, improved management of estuarine fisheries, and relationships of habitat to fisheries production. Sea Grant also sponsors economic and policy studies related to estuarine issues, as well as educational and information transfer services such as the Sea Grant Marine Advisory Services.

V. FEDERAL ESTUARINE AND COASTAL OCEAN ACTIVITIES

The Federal Government, working closely with the states, has a responsibility to address the problem of the deterioration of our Nation's estuarine and coastal resources. Federal legislation related to water quality, coastal zone management, and fisheries conservation and management has provided incentives for states to adopt policies that would encourage the wise use and management of their estuarine and coastal resources. These incentives have generally been directed toward strengthening state and regional resource management capabilities and making the results of Federal scientific and information programs available for management decisions. With the recent establishment of a National Estuary Program, Congress has reinforced the Federal role that was established in the Coastal Zone Management Act of 1972 -- that of providing the management and technical infrastructure necessary for the states to address local estuarine and coastal problems of national concern. As a result of these and other legislative actions, a number of important estuarine and coastal programs have evolved in several Federal agencies, in addition to NOAA.

This section provides a brief summary of the major estuarine and coastal ocean activities supported by Federal agencies other than NOAA, including the Environmental Protection Agency (EPA), the U.S. Geological Survey (USGS), the Fish and Wildlife Service (FWS), the Corps of Engineers (COE), and the Soil Conservation Service (SCS). While many other agencies have related programs, this section focuses on those perceived to have a central role in Federal estuarine and coastal ocean research and management.

Environmental Protection Agency (EPA)

The EPA assumes lead responsibility in the Federal Government for identifying, evaluating, and controlling environmental pollutants. Priority elements of the EPA mission are to reduce public exposure to harmful pollutants, protect sensitive ecosystems, regulate hazardous waste facilities, clean-up Superfund sites, and improve management of environmental regulatory programs. The Clean Water Act (CWA) requires the EPA to promote studies of the Nation's estuaries and to report every six years.

EPA's National Estuary Program was originally established in 1985 through a Congressional appropriation under the CWA. Estuaries included in the first year were Narragansett Bay, Buzzards Bay, Long Island Sound, and Puget Sound. San Francisco Bay and Albemarle/Pamlico Sound were added in 1986. The 1987 amendments to the CWA, the Water Quality Act of 1987, established the responsibility for the National Estuary Program in Sections 317 and 320. The Act instructs the Administrator of EPA to give prior-

ity consideration to 11 named estuaries (the six estuaries already participating and New York-New Jersey Harbor, Delaware Bay, Delaware Inland Bays, Sarasota Bay, and Galveston Bay). In addition, the Water Quality Act continued funding for the Chesapeake Bay and Great Lakes Programs.

Program Description

EPA has substantial responsibilities in estuarine research, management, and planning.

o Research

Through its laboratories at Narragansett, Rhode Island and Newport, Oregon, EPA conducts research on marine, coastal, and estuarine water quality and marine processes.

EPA's Environmental Research Laboratory, located at Narragansett, responds mainly to legislative requirements of the CWA, the Marine Protection Research and Sanctuaries Act, and to a lesser extent, the Toxic Substances Control Act, Resource Conservation and Recovery Act, and Superfund legislation. The Laboratory is responsible for the following research: 1) estuarine and marine disposal, discharge of single contaminants or complex effluents, dredged materials, and other wastes; 2) water use designation and quality criteria for estuarine and marine water and sediment; and 3) environmental assessment of ocean discharges. These research program areas involve the development, evaluation, and application of techniques and test systems for measuring and predicting the transport, fate, and biological and ecosystem effects of wastes in estuarine and marine systems.

o Management

Through the Water Quality Act, EPA is conducting management-oriented estuarine restoration and protection programs in 7 major estuaries around the country.

The EPA's National Estuary Program is designed to take advantage of existing authorities within the Water Quality Act, other Federal statutes, and state and local legislative authorities for point and non-point sources to adequately protect the Nation's estuaries. The EPA program emphasizes the need to focus and integrate the efforts of existing pollution abatement and control monies. The goals of the program are to: 1) increase public understanding of the complexities of a particular estuary; 2) increase understanding of the need for and benefit of area-wide

or basin planning, management and pollution control; 3) develop plans for the control of pollutant loadings; 4) encourage acceptance of the public and private costs of increased pollutant abatement; 5) transfer technical assistance and scientific expertise to state and local governments to implement action plans; and 6) protect and restore water quality and living resources to the estuary.

o Planning

Near Coastal Waters Strategic Plan: EPA has begun implementing its Near Coastal Waters Strategic Plan, a long-term planning strategy designed to improve EPA's ability to manage near coastal waters environmental quality. The term "near coastal waters" is defined as inland waters to the head of the tide, the territorial seas, and the contiguous zone including areas of greater distance where necessary to protect coastal barrier islands and the mouths of certain estuaries. The Great Lakes are also included. The implementation plan will address five major national environmental problems: toxic contamination; eutrophication; pathogens; habitat loss/alteration; and changes in living resources. The plan will incorporate the following types of tools: regulatory; research and data collection; innovative management techniques; institutional changes; intra- and interagency coordination; technology transfer; and public outreach.

U.S. Geological Survey (USGS)

The USGS is responsible for the classification of public lands, and examination of the geological structure, mineral resources, and products of the national domain. Over the years, its mission has expanded to include hydrological investigations of water in streams and underground. Some of this work is conducted in estuaries or at the fall line for waters flowing into estuaries. For example, the USGS is examining the influence of different land uses on the water quality of the streams that flow into the Susquehanna River.

Program Description

The Water Resources Division of the USGS provides hydrological data on surface and ground water and conducts research to assure competent hydrologic investigations. Programs of particular interest include long-term operations of down-stream gauges on major rivers and streams, site-specific investigations of estuarine circulation, geochemistry, and ecology. Much of this work is conducted in the Potomac River, where hydrodynamic and geochemical processes, as well as long-term changes in wetlands

ecology are being studied, and the San Francisco Bay, where the USGS is researching processes that influence water and sediment chemistry.

U.S. Fish and Wildlife Service (FWS)

The FWS has general responsibility for maintaining the fish and wildlife resources in the United States and providing public access to these resources. Its functions include responsibility for fish and wildlife resources and habitats of national interest through research, management, and technical assistance to other Federal and non-governmental agencies.

Program Description

The operations of the FWS include those conducted in the coastal zone, the contiguous lands, and the waters that flow into the zone. Major FWS programs involving coastal issues include permit review and resource planning; land acquisition and habitat management (through refuges and easements); management of migratory birds, anadromous fish and endangered species; and broad research activity addressing causes and effects of habitat change and coastal contaminants. These programs provide for the collection, synthesis, and interpretation of diverse information on species, populations, and habitats that is assembled, analyzed, and applied for management purposes.

An example of FWS estuarine studies is research in the Northeast Region that includes documentation of coastal wetland changes, migratory waterfowl distributions, and the effects of hunting pressures. In addition, the FWS conducts special studies on striped bass and American shad; damage to estuarine systems, such as the Chesapeake Bay, from point and non-point discharges; and the effects of development activities on important fish and shellfish breeding grounds and waterfowl habitat.

In the Southeast Region, the FWS conducts research on endangered species, such as the Florida manatee and various coastal birds and sea turtles. For example, FWS has initiated field studies to evaluate the habitat requirements of the manatee. Additionally, FWS personnel are examining the effects of peat mining in coastal areas on coastal fish and wildlife.

Major research in the Texas gulf coastal area is being conducted on the impact of soil deposition on bays and channels, largely through deposition of dredged materials dumped in shallow estuarine waters and from contaminated agricultural runoff. Studies of wetland losses are being aided by Geographic Information Systems (GIS). The GIS technology that documented wetland losses of 80 percent in Louisiana have resulted in public recognition of

the potential long-term effects of coastal change on fish and wildlife populations. GIS has become a major decision-making tool for predicting potential impacts of development activities of habitats. Prototype methodologies are also being developed to assess cumulative impacts.

Primary research in the Southwest Region focuses on the restoration of fish and wildlife to the San Francisco Bay area, the study of impacts caused by diversion and diked systems, and management and restoration of the endangered southern sea otter. Kesterson National Wildlife Refuge research on selenium and other problems is being guided by an Interagency Technical Coordination Committee comprised of state, other Federal agencies, and FWS personnel.

Contaminant monitoring in the Great Lakes Region includes examination of fish tumors, research into the causes of the declining lake trout populations, and the fate and effects of contaminated sediments. In addition, research efforts focus on the impacts of power plant discharges to the Lake Erie system and biota.

In Alaska, the FWS is examining the impact of North Slope oil and gas development on migratory fish. It is also developing techniques for the genetic identification of Alaskan and Canadian stocks of salmonids for fisheries management purposes.

Finally, most of the development of the analytical tools for estuarine planning and management is centered at the National Wetlands Research Center (NWRC), formerly the National Coastal Ecosystems Team, of Slidell, Louisiana. Principal NWRC activities are: 1) development of habitat-descriptive methods -- their validation and transfer to users; 2) the development of community and species "profiles" to assist with site-specific and regional planning; and 3) special issues studies for FWS operations.

U.S. Army Corps of Engineers (COE)

The COE has broad responsibilities in inland waters and nearshore areas stemming primarily from the Rivers and Harbors Act, the Clean Water Act, the Water Resources Development Act, and the Marine Protection, Research, and Sanctuaries Act. These laws provide the COE with the authority to maintain navigable waterways, and to issue permits for the transportation of dredged material for ocean dumping and for the discharge of dredged or fill material into the waters of the United States.

Program Description

The COE missions require coastal engineering expertise in the design, construction, operation, and maintenance of three general types of projects or facilities in and near the surf zones of the U.S. oceanic and Great Lakes shores: 1) harbors for small craft

for commercial and recreational fishing; 2) harbors for large, ocean-going vessels for coastal and international commerce; and 3) shore and beach restoration, protection, and stabilization. Research activities in the following areas were underway in 1986: developing methods for predicting sediment transport and shoaling; improving methods to collect littoral data; and improving wave estimation to assess physical factors in beach erosion and nourishment.

A Flood Control and Navigation Program was designed and initiated by the Corps of Engineers to improve cost-effectiveness of flood control programs and navigation-related activities including channel or canal construction and maintenance. Research in this area included developing: 1) improved methods for dredging; 2) more effective sediment traps; and 3) estuarine-specific physical models (numerical and physical) to assist project design and maintenance.

Projects associated with an Environmental Quality Program were undertaken that focused on determining the impact of COE water resources projects on the environment. In particular, research examined methods to mitigate shore-line erosion, to identify the ecological effects of rubble structures, and to determine the effects of channels and jetties on fish and shellfish migration.

A Wetlands Project was undertaken to address priority wetland research needs in two major areas: 1) development of techniques to identify and delineate wetlands; and 2) assessment and quantification of wetland values for use in evaluation of permit activities. These studies include developing regional procedures in identifying and delineating wetlands during the fall and winter seasons, and evaluating plant tolerance to inundation and saturated soil conditions.

A Dredged Material Research Development, and Monitoring Program was undertaken in 1986. Under Section 404 of the CWA and Section 103 of the Ocean Dumping Act, the COE is responsible for permitting the placement of dredged and fill material in the Nation's waterways and the transportation of dredged material for disposal in the oceans. At present, the COE receives more than 10,000 permit applications annually under Sections 404 and 103. These permits must comply with criteria and the COE's long-term effects of dredging operations provides the information for the criteria. Studies were designed to: 1) determine bioaccumulation and biomagnification in the aquatic environment; 2) develop procedures to reduce adverse impacts; 3) develop upland plant and animal bioassays procedures; 4) develop or improve techniques for predicting contaminant concentrations in the effluent from these sites; and 5) improve methods for leachate prediction and control. The COE is also examining procedures to identify and assess the elements necessary for a long-term strategy for dredged material disposal and to provide user guidance to permit effective disposal.

To mitigate the impacts of dredging contaminated sediments, the COE undertook a Dredged Contaminated Sediments Project to collect data on the re-suspension of sediments and contaminants. The COE is also developing guidelines for dredging highly contaminated sediments. The COE is conducting a demonstration project at Indiana Harbor-Great Lakes, where innovative foreign equipment will be used in a pilot demonstration for PCB sediments.

A Satellite and Surveying Application Program develops and applies new technology for surveying and satellite remote sensing and positioning interpretation techniques, data handling, and assessing satellite-acquired data for water resource planning and management models. Research activities in the current program include using satellite data for detecting and mapping area wetlands, applying satellite data to solve coastal engineering problems, and evaluating remote sensing techniques to monitor changes in aquatic vegetation in coastal and estuarine environments.

Soil Conservation Service (SCS)

The Soil Conservation Service of the Department of Agriculture has a mission that covers three major areas: soil and water conservation, natural resource surveys, and community resource protection and development. Through its nationwide network of conservation specialists, the SCS provides technical assistance to farmers, ranchers, and foresters on methods to control erosion and sedimentation through best management practices and to control non-point sources of water pollution. The SCS maintains extensive data archives on wind and water erosion, land-use and cover, conservation practices, and treatment needs. To assist landowners in protecting natural resources, the SCS also administers cost sharing programs that offer special assistance for installing certain conservation practices, protecting wetlands, and improving water quality.

VI. NATIONAL ESTUARINE NEEDS: A REGIONAL PERSPECTIVE

Water quality, habitat, and living resource conservation are concerns applicable to all the Nation's estuaries. However, these problems are manifested differently in degree and scope among the various regions of the country. This summary provides a regional perspective to the national strategies developed in the NOAA Estuarine and Coastal Ocean Science Framework.

Northeast Region

The shoreline of the Northeast United States has numerous estuaries that range in size and physical characteristics. In the regions extending from Maine to Cape Cod, estuaries were formed by glaciers leaving rocky shorelines and deep channels. From Cape Cod to Maryland, the estuarine characteristics are the result of drowned river valleys flooded by melting glaciers and rising sea level. Examples of these estuaries include the Narragansett and Delaware Bays, and the Long Island Sound. Many of the Northeast estuaries had an important role in the development of this region as early centers of industry and population. Estuarine waters served as routes for transportation and commerce, and provided the surrounding populations with recreational opportunities and abundant seafood.

With respect to living resources, the Northeast estuaries serve as critical habitats to commercially and recreationally important fisheries. The extreme northern portion of this region supports salmon, sea-run brook trout, shad, and river herring as well as clams, scallops, and lobster. From Cape Cod southward, important fisheries include striped bass, bluefish, flounder, menhaden, oysters, and clam.

Unfortunately, many of the estuaries in this region also serve as receptacles for human and industrial wastes. The legacy of the American industrial revolution is reflected in high metal concentrations in the sediments of many Northeast estuaries, and historical archives are replete with accounts of sewage contamination and typhus outbreaks caused by eating tainted shellfish. Many problems remain today because of outdated and overloaded sewage treatment facilities and inadequate treatment of industrial wastes. High levels of PCBs have been found in New Bedford Harbor, Massachusetts, and in the resident lobsters and finfish. Increased incidences of fish disease in Boston Harbor and Buzzards Bay have led to shellfish bed closures. In Narragansett Bay, major concerns include the deterioration of the quahog fishery, beach closures from contaminated waters and the long-term decline in finfish, oysters, scallops, and soft clams because of eutrophication. The major threat to estuarine quality in the Northeast generally is contamination, rather than the physical destruction of estuarine habitats.

Key issues associated with the Northeast region include:

- -- eutrophication;
- -- large phytoplankton blooms;
- -- toxic contamination;
- -- toxic transport and resuspension;
- -- microbial contamination (shellfish, for example, in the New York Bight);
- -- municipal and industrial discharges;
- -- urban runoff;
- -- raw sewage discharges; and
- -- combined sewer overflows.

The major accomplishment in the Northeast Region has been the development of a Long Island Study Plan. The draft plan, being done in cooperation with EPA, identified both priority projects to be accomplished and funding levels. Cooperative projects with EPA are also proceeding in Buzzards Bay and Narragansett Bay.

Southeast Region

The Southeastern estuarine region, beginning with the Chesapeake Bay and extending south to Florida, is characterized by three distinct types of shoreline formations. The first formation, typified by the Chesapeake Bay, is a coastal plain estuary formed from a river bed. The estuaries of North Carolina and central Florida consist of lagoons landward of extensive barrier islands, while low-lying, marshy shorelines characterize the coasts of South Carolina and Georgia. With the exception of Florida, the Southeastern coast is characterized by tidal marshes, riverine swamps, and wetlands.

The region is well known for its abundance of fishery resources. In the Chesapeake, oysters and blue crabs are the key shellfish resources, while menhaden, bluefish, flounders, and anadromous species represent some of the most important finfish. Extending from North Carolina to Florida, popular shellfish include blue crabs, oysters, shrimp, and scallops. Finfish include menhaden, bluefish, anadromous species, croaker, mullet, seatrout, spot, and flounder.

The attractive coastal islands off Georgia, the beautiful beaches of the Outer Banks and intricate estuarine waterways, combined with the pleasant climate of the Southeast has made this region a haven for primary residences and vacation homes. This very attraction has led to explosive development pressures from residential construction and industrial relocation. All population projections indicate the Southeast will continue to face the problem of balancing growing population and development pressures with the need to protect and preserve the coastal region.

An example of increasing stress on the shorelines can be witnessed in the population along the shores of Maryland's portion of the Chesapeake Bay growing by 50% between 1950 and 1980, and Florida's coast being settled at a rate of 3,000-4,000 people a week.

Non-point source runoff is a critical problem throughout the Southeast. Runoff from agricultural practices along the rivers of the Chesapeake and from the "mega-farms" of North Carolina dump loads of sediments, pesticides and nutrients into these estuaries. Runoff has often led to severe problems of eutrophication, low levels of dissolved oxygen, and changes in the fishery structures and in fishery habitat. Wetlands and marshes, critical as nursery areas for larval and juvenile fish, are being lost to agricultural land conversions and construction at alarming rates.

With respect to the Chesapeake Bay, the major issues can be summarized as follows:

- -- dramatic increases in anoxic bottom water from nutrient enrichment;
- -- drastic declines in submerged aquatic vegetation;
- -- increases in turbidity;
- -- shift from freshwater spawning fishes to saltwater fishes;
- -- increasing prevalences of fish diseases; and
- -- contaminant hot spots in Baltimore Harbor and Elizabeth River.

For estuaries extending south of the Chesapeake Bay through Florida, the issues include:

- -- large scale effects of "mega-farms" in North Carolina;
- -- massive development impacting wetlands;
- -- changes in and movement of nursery areas seaward;
- -- heavy nutrient loadings;
- -- periodic hypoxia/anoxic conditions;
- -- loss of seagrass beds, especially in Tampa Bay;
- -- loss of shellfish caused by residential and urban development;
- -- physical loss of habitat from dredge and fill, especially in Tampa Bay; and
- -- contaminant hotspots in the Savannah River.

The major accomplishment in the Southeast Region has been NOAA's continued support of the EPA Chesapeake Bay Project. In addition, work has been initiated on development of a study plan for Albemarle/Pamlico Sounds.

Gulf of Mexico

The Gulf of Mexico is characterized by low coastal plains, extensive saltwater marshes, and high levels of sediment deposition.

It also has the largest volume of wetlands in the country, constituting nearly 50 percent of the total coastal wetlands in the contiguous United States. Major features include the Mississippi and Atchafalaya River Deltas, where large amounts of land-based sediments are deposited outside the river mouth in adjacent shallow coastal waters forming deltas. In other areas, sediment transported and deposited by ocean currents has built offshore bars enclosing shallow, sometimes extensive bodies of water known as bar-built estuaries. Entrances to these estuaries tend to be narrow, so that exchanges with the sea are highly restricted. Estuaries of the northern Gulf also have the largest drainage areas in the Nation, receiving runoff from two-thirds of the contiguous United States, primarily through the Mississippi River watershed.

The Gulf is reknowned for its recreational and commercial fisheries, a resource upon which the local coastal economies have become increasingly dependent with the decline in the oil industry. The fish and shellfish of highest importance include menhaden, shrimp, oyster, blue crab, spotted seatrout, red drum, pompano, grouper, snapper, and flounder. The Gulf produces the largest volumes of menhaden and shrimp in the country. Total fisheries of this region represent 39 percent of the national total by weight, and 28 percent by value. An overwhelming majority of these fish are dependent on estuaries as critical habitats and food sources.

The coastal wetlands and adjacent inland wetlands of the Gulf are being lost at dramatic rates. It has been estimated that nearly 50 square miles of these valuable wetlands are being lost each year. Subsidence, channelization, pipelines, draining and levee construction along the Mississippi River all combine to further the demise of the wetlands and vital fisheries habitat in the region. The Gulf also suffers from extensive hypoxia, believed to be related to excessive nutrients flowing from the Mississippi River and into its delta. In 1985 alone, 8,000 square kilometers of the Louisiana shelf were hypoxic. This severely affected the local fisheries resources.

Important estuarine issues in this region can be summed up as follows:

- -- loss of up to 25,000 acres/year of marsh habitat because of oil and gas development, canals, dredging, saline intrusion, levee construction, development, and subsidence;
- -- freshwater diversion leading to changes in salinity levels in estuaries and population levels of fisheries, especially in Texas;

-- large quantities of industrial and municipal waste water discharges, petrochemicals, and pesticides, adversely affecting water quality to the detriment of public health;
-- the Barataria estuaries complex in Louisiana, a highly productive region for seafood, water commerce, mineral extraction, and recreation, is becoming anoxic and polluted from expanded urban and agricultural development; and
-- eutrophication and oxygen depletion (especially as a result of a two-fold increase in nitrogen concentrations from agricultural runoff into the Mississippi River) may be connected to noxious blooms of "red tide" organisms and other noxious phytoplankton that has toxic affects on predators of seafood.

In the Gulf of Mexico, NOAA and EPA have participated in the development of a comprehensive inter-agency regional approach to the management of estuarine and coastal waters. Work on this planning process will continue into the next year.

Southwest Region

The Southwest region extends from the Mexican border to Mendocino, California. The coast is characterized by uniformly uplifted, resistant rock. The largest estuary in the region, the San Francisco Bay, formed when sections of the continent containing former river valleys sank below sea level because of active mountain building.

Estuarine-related fisheries of long standing regional importance include salmon, steelhead trout, striped bass, and sturgeon. Marine mammals frequent the numerous open bays, and harbor seals and sea lions use San Francisco Bay as hauling grounds.

The beautiful estuaries and bays of the Southwest offer scenic vistas of rugged cliffs and headlands with windswept trees above a pounding surf. The beauty of San Francisco Bay and of the semi-tropical palm-fringed bays of Southern California, such as Mission Bay and San Diego Bay, are highly valued.

This region is not without environmental problems. The San Francisco Bay area, for example, has lost nearly all of its wetlands from diking and levee construction to provide land for massive agricultural development. Irrigated agriculture presents one of this estuary's greatest challenges -- a redirection of 40-60 percent of the freshwater flow resulting in a decline in water quality, dramatic alteration of fisheries resources and the ecosystem.

In San Francisco Bay, the most critical issues are:

- -- industrial and municipal discharges and agricultural drainage from the Sacramento and San Joaquin;
- -- loss of wetlands caused by diking and filling;
- -- radical changes in fish populations due to large diversions in freshwater inflow;
- -- very high levels of toxic contaminants in shellfish;
- -- reduction of striped bass by 80 percent;
- -- accumulation of toxic contaminants in sediments;
- -- bioaccumulation and/or biomagnification of toxic contaminants in the marine food web;
- -- altered benthic species distribution, including kelp, from sewage and other offshore discharges; and
- -- contamination by pathogens of coastal recreational areas caused by sewage, vessel discharges, and runoff.

In the Southwest Region, NOAA has been cooperating with EPA to plan a comprehensive study of the San Francisco Bay. When approved, the project will become part of the EPA National Estuary program.

Northwest and Alaska

This region encompasses Oregon, Washington, and Alaska, and is characterized by rugged, rocky outcroppings gradually shifting to low coastal flats and marshes in Washington. The Columbia River estuary and Puget Sound are the dominant estuarine systems of the Northwest region.

In Alaska, 34,000 miles of tidal shoreline represents approximately one-third of the total U.S. coastal shoreline. This large area is characterized by glacier-fed fjords (large open low relief estuaries) and hundreds of small bays and inlets. The delta regions along the Alaskan coast contain broad tidal and freshwater marshes. The Yukon River Delta is comparable in size and complexity to the Mississippi River Delta.

The fisheries are extremely important to the estuarine regions of the Northwest Region and Alaska. In the Northwest, key species include Pacific salmon, steelhead trout, shad, flounder, crabs, and clams. In addition to these species, important Alaskan fisheries include sablefish and scallops. Both regions support abundant populations of marine mammals including harbor porpoises, sea lions, and harbor seals. Both support habitat for the endangered humpback whale. Alaska also supports other mammals such as northern fur seals, sea otters, walruses, and beluga whales.

The problems in the Northwest differ largely in magnitude from those of Alaska. The Northwest area, as typified by Puget Sound, has become increasingly industrialized and suffers from high concentrations of contaminants. These contaminants are

introduced from a large number of point sources including municipal treatment plants, and from industrial dischargers such as oil refineries, pulp and paper mills, aluminum and steel processing plants, and chemical companies. Non-point source pollution from urban areas as well as logging and farming practices supply substantial volumes of metals and fecal coliform. Shellfish bed closures caused by bacterial contamination from runoff are rising even in rural embayments in the Sound. The entire eastern shore, where most of the population in the Puget Sound live, is uncertifiable for shellfish harvesting as a result of sewage treatment plants, combined sewer overflows, and urban runoff. Major problems facing Northwest estuaries include:

-- toxic concentrations in sediments;
-- toxic bioaccumulation in food webs;
-- bacterial contamination of shellfish; and
-- liver tumors and fin erosion in bottom fish, such as English sole.

In Alaska, population pressures have yet to exert comparable degradation of estuarine waters and habitat. It is the resource extraction industries such as fishing, oil and gas, logging, and mining, that will continue to be the focus of estuarine management concerns.

Great Lakes Region

The Great Lakes estuarine zone includes Lake Michigan and the United States shore of Lakes Superior, Huron, Erie, Ontario, and St. Clair. The Lakes occupy pre-glacial erosional basins and valleys of the St. Lawrence River system carved and deepened by Pleistocene glaciers and by the erosion of sedimentary rocks along structural axes. No true estuaries occur in the Great Lakes, although their coastal shallows and marshes have qualities common to estuaries. More importantly, the coastal population along the lakes rivals or exceeds in size any other region of the United States. The retention of contaminants is far longer and more severe than ocean coastal areas because of the absence of flushing tides and indirect access to the vast sink provided by the oceans. The watershed of the lakes is largely a plain with hundreds of small streams. Many of the streams have glacial lakes and swamps in their courses. Large areas of the northern part of the watershed around Lakes Superior, Michigan, and Huron are forest, scrub, swamp, or bog. The southern parts are cultivated.

The Great Lakes are of great value to waterfowl and other fish and wildlife. The freshwater fishes include trout, bass, smelt, salmon, whitefish, northern pike, walleye, alewife, herring, yellow perch, and many others. Some of the native fishes, including longjaw cisco, deepwater cisco, blackfin cisco, and blue pike are endangered, and the lake sturgeon is close to extinction. The Lakes and their basin are migration stops for

many species of migratory birds of the Central, Mississippi, and Atlantic flyways. Many varieties of ducks and Canada geese use the Lakes. The marsh and upland, bay, and river habitats also are important for upland game birds, and small and big game animals.

Areas of the southern regions of the Great Lakes are heavily populated and industrialized with the accompanying discharge and runoff problems. For example, combined sewer overflows and storm drains in many cities deliver untreated sewage or industrial wastes shunted away from Publicly-Owned Treatment Works together with toxic urban runoff, directly into near coastal waters whenever it rains. Combined Sewer Overflows (CSOs) along the Rouge River in Detroit, Michigan produce a flow of industrial waste equal in volume to the Rouge, that enters the Detroit River and the western end of Lake Erie during major storm events. Phosphorus loads from these CSOs constitute the third largest municipal load of nutrients to Lake Erie.

For the Great Lakes, atmospheric deposition is considered a significant source of degradation. Studies show that a significant portion of all loadings of metals to the Great Lakes are through atmospheric deposition, with trace organisms believed to follow the same path.

Other activities that create problems are agricultural runoff, land-fills, wetlands drain and fill, sediment dredging/disposition, and 61 hazardous waste sites that have the potential to contribute contaminants to Lake Ontario.

A summary of environmental quality problems include:

- -- loss of habitat;
- -- microbial contamination of swimming waters;
- -- significant species changes observed in plankton, benthos, and finfish;
- -- fishing closures, public health advisories due to PCBs, pesticides and dioxins;
- -- annual anoxic episodes in Lake Erie and Green Bay;
- -- phytoplankton blooms in swimmable waters due to nutrient loadings; and
- -- closure of commercial fisheries and sport fishing consumption advisories due to toxic contaminants.

VII. SUMMARY

Both the Administration and Congress have mandated a strong estuarine program within NOAA. In 1986, Estuarine Programs Office made significant progress in focusing the Agency's planning efforts in estuarine and coastal ocean issues. The NOAA Estuarine and Coastal Ocean Science Framework sets the Agency's direction in estuarine science and management into the next decade. Significant accomplishments have also been made by EPO in the areas of coordination and communication related to NOAA's estuarine activities. The continued progress of the Office in leading NOAA's efforts in estuarine science and management should be enhanced during the next year as EPO is moved from its present location within a line organization to the Agency-wide Chief Scientist's Office. In addition, with the potential for increased funding levels for estuarine science, future growth in NOAA's estuarine programs looks promising.

In the upcoming years, the Framework document will form the basis for NOAA's annual estuarine planning activities and its interaction with other agencies on estuarine science and management issues. This document, therefore, represents a major step forward for the Agency that will enhance both internal and external agency activities. The EPO will continue its planning, coordination, and communication roles for NOAA's estuarine and coastal ocean science and management activities.

APPENDIX

The following is a description of NOAA's estuarine activities during 1986, as submitted by the NOAA line organizations and edited by the Estuarine Programs Office. A more complete listing of projects can be found in the Estuarine Projects Catalog, also published by the Estuarine Programs Office.

NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE (NESDIS)

Assessment and Information Services Center (AISC)

National Environmental Data Referral Service (NEDRES) Program Office

1. Joint AISC/National Oceanographic Data Center Data and Information Support for the Chesapeake Bay Program

   A grant to the Sea Grant Office of the University of Maryland and the University of Virginia has been extended through 1986 and early 1987 to support NESDIS data identification and acquisition for tasks for the Chesapeake Bay Program (CBP). These tasks focus on identification and description of NOAA and other Federal and non-Federal data sources for inclusion in the NEDRES data base. As this task is completed, the Chesapeake Bay Program Data Subcommittee and other personnel concerned with Chesapeake Bay data will review and assign priorities to the described data sets; those with the highest priority and most immediate need will be considered for conversion to the CBP data base or other accessible data base systems, such as the National Oceanographic Data Center.

Marine Environmental Assessment Division (MEAD)

1. Coastal Dynamics Study

   In 1986, the interdisciplinary study of Chesapeake Bay and the local continental shelf continued. The study is attempting to integrate different types of data from several sources, including: satellite observations of sea surface temperature and turbidity; wind observations; water current measurements; temperature and salinity data; and river discharge data. The integrated data provided initial and boundary conditions for a three-dimensional numerical

circulation model. The currents from the model are being used in a study of the influence of wind and tidal currents on blue crab larval drift after hatching near the Bay mouth. The initial effort to combine the data sources and use them in a modeling study are described in the report Interdisciplinary Synoptic Assessment of Chesapeake Bay and the Adjacent Shelf.

Several papers were written to document progress and applications of the methodology. Further refinements in the circulation model are described in Numerical Model of Circulation in Chesapeake Bay and the Continental Shelf. Results of an experiment which simulated the blue crab hatching and rate of larval retention using larval catch data were presented in Circulation Modeling as an Aid to Management of the Blue Crab Fishery in Chesapeake Bay. Another manuscript, Sediment Transport in Chesapeake Bay During Floods: Analysis Using Satellite and Surface Observations, describes remote sensing applications to estuarine turbidity distributions.

An extension of satellite imaging techniques to the detection of chlorophyll is described in Satellite Detection of Bloom and Pigment Distribution in Estuaries.

2. Chesapeake Bay Assessment

During 1986, quarterly assessments provided a multidisciplinary view of the Bay, focusing on the impacts of environmental events (weather, oceanography) on the economic sectors of fisheries, recreation, and transportation.

3. Gulf of Mexico Assessment

MEAD completed its 1985 Annual Summary for the Gulf of Mexico. The assessment includes information on weather, oceanography, hydrology, water quality, fisheries, recreation, transportation, marine pollution, and the dismantling of out-of-service oil platforms. The assessment focuses on environmental factors and economic impacts such as four hurricanes and a tropical storm which struck the Gulf Coast during the year with one, Hurricane Juan, causing over $1.5 billion in damages.

4. San Francisco Bay Assessment

The first assessment for the San Francisco Bay area was completed during 1986. The assessment is an annual summary for 1985 which includes information on weather, oceanography, fisheries, recreation, transportation, and pollution. The report emphasizes environmental and economic features unique to the San Francisco Bay area such as unusually dry

weather in 1985 with below-normal streamflow which caused above-normal salinities, and increased landings of fishes at Bay-area ports with an apparent recovery from the exceptionally warm years of 1982 and 1983.

5. Prototype Southeastern U.S. Marine Environmental Assessment

The Marine Environmental Assessment Divison (MEAD) of NOAA's Assessment and Information Services Center (AISC) began a project to assess the effects of environmental events on sectors of the marine-oriented economy of the Southeastern United States The study areas includes the coastal Southeastern United States and adjacent coastal ocean of North Carolina, South Carolina, Georgia, and the east coast of Florida. The study period covers the calendar year 1986.

The assessment focuses on the effects of environmental events (meteorology, oceanography) on the marine resources of the region. Impacts of short and long-term processes and events are identified and quantified, where possible, for several marine-oriented resource sectors: fisheries, recreation, and transportation. The assessment provides a unique multi-disciplinary view of the Southeast derived from data from numerous agencies and line offices of NOAA. The report includes a special section on environmental research projects conducted around the Southeast in 1986. The final document will be available in fall 1987.

National Oceanographic Data Center (NODC)

1. Coastal Information System for Chesapeake Bay

The NODC, through a cooperative agreement with the State University of New York's Marine Sciences Research Center, is generating a Coastal Information System for the Chesapeake Bay. The system will use personal computer hardware and the latest software to interrelate a broad range of environmental, pollutant, historical, cultural, economic, and general information. The Chesapeake Bay was selected over other possible coastal areas because of the current high level of interest by the public and state and Federal agencies in the environmental problems of the Bay. The computerized system will provide an inexpensive, user-friendly source of information for Bay planners and decision-makers and will enable users to explore relationships between problems and possible causes.

2. Identification of Marine Pollution Data Collection Activities

The Ocean Pollution Data and Information Network (OPDIN) evaluated all the Federally-funded projects described in

the annual National Marine Pollution Information System (NMPIS) and the associated annual Federal Projects Catalog for the fiscal years 1978 to 1983. OPDIN identified nearly 400 projects that could be sources of data. With the primary focus on marine pollution, nearly all projects involve coastal or estuarine investigations. OPDIN published a report describing each project by title, manager or investigator, agency affiliation, regions of study interest, and data types collected. Future efforts are planned to locate and verify the data collections, and to determine their status, quality, and availability.

3. Involvement in Long Island Sound

The characterizations for oxygen data sets/sources in Western Long Island Sound were completed and published as Data Characteristics for Western Long Island Sound. The document was the result of cooperative involvement between NODC and National Ocean Service in the evaluation of the annual oxygen depletion event in the Sound. Information for the 72 characterizations was obtained from Federal, state, and municipal data bases via personal contact by the NODC regional representative.

4. Involvement in Albemarle and Pamlico Sounds

The characterizations for data sets/sources in the Albemarle/Pamlico Sounds area of North Carolina were completed and published as Data Characterizations for Albemarle/-Pamlico Sounds. The document contains information on 57 sources of data from Federal, state, and university bases. The information was obtained from the regional representative via personal contacts and by extraction from grey literature files. The characterizations will be used as part of the five-year plan which is being drafted by the state of North Carolina. In addition to the data characterizations, several persons are participating in working groups on data evaluation and hardware and software as part of the Albemarle/Pamlico Estuary program.

NATIONAL MARINE FISHERIES SERVICE (NMFS)

Northeast Region

1. Increased Estuarine Research

In cooperation with the Environmental Protection Agency (EPA), the states, and academia, NOAA began expanding its research efforts in several Northeast estuaries. Research

emphasis is on the reproductive success, survival, and recruitment of key species subject to contaminant effects. Major emphasis is on studies of the winter flounder (Pseudopleuronectes americanus) and the hard clam (Mercenaria mercenaria). Limited research is being conducted on the oyster (Crassostrea virginica) and the American lobster (Homarus americanus). Studies are also being conducted in Long Island Sound, Narragansett Bay, and Buzzards Bay. Stock assessment and population modelling techniques will be used to link pollutant effects on individual organisms to population-level impacts.

2. Analysis of Sediment Contaminants in Northeast Estuaries

As part of NOAA's National Status and Trends (NS&T) program, NOAA analyzed sediment samples from several Northeast estuaries for 17 metals, 14 of which are possible contaminants. The estuaries first analyzed were those expected to be most polluted -- Hudson-Raritan Bay, Long Island Sound, Narragansett Bay, Boston Harbor, and Salem Harbor. As expected, the Hudson-Raritan system had the highest concentrations for most heavy metals, followed by Boston Harbor. However, the highest concentrations of chromium and cadmium were found in Salem Harbor.

3. Contaminant Levels in Ocean Quahogs

Scientists from NOAA and Battelle New England Laboratory found that contaminant levels in ocean quahogs (Arctica islandica) in the northwestern Atlantic between Virginia and Nova Scotia are generally low. The study investigated body burden levels of polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAH), total petroleum hydrocarbons (PHC), and trace metals (silver, cadmium, chromium, copper, nickle, lead, and zinc.) The highest levels of these contaminants were generally found in samples from known areas of inputs (e.g., inner New York Bight, Rhode Island Sound, and Buzzards Bay/New Bedford Harbor, MA).

4. Liver Disease in Winter Flounders

In a cooperative study with the Massachusetts Division of Marine Fisheries, 42 percent of the winter flounder examined from New Bedford's Clark Cove had areas of inflamed and dead liver tissue that could reasonably be interpreted to affect the health of these fish. Fish from other areas along the Massachusetts coast had lower occurrences of liver lesions. The species most affected, winter flounder, spends much of its time on the bottom within a relatively small territory. The area in question, New Bedford harbor,

has bottom sediments with exceptionally high concentrations of PCB, which are known liver toxins.

5. Dredging Restrictions and Oyster Production

NOAA participated in a workshop that produced a model for evaluating the effects of channel dredging restrictions on Chesapeake Bay oyster production. The U.S. Army Corps of Engineers (COE) found that a new suction dredge design retains most of the silt, thereby minimizing the siltation of oyster seed beds with the subsequent reduction in juvenile oyster abundance.

6. Monitoring of Sewage Dumping at the 106-Mile Dumpsite

In cooperation with the University of Rhode Island, NOAA is monitoring infrared images from NOAA satellites of sea-surface temperatures for the area around the 106-Mile Dumpsite. Large temperature differences within a short distance usually indicate a boundary between water masses, and thus can delineate the locations of water masses in and around the dumpsite. The fate of sewage sludge dumped at the 106-Mile Dumpsite will be determined by estimating the percentage of sewage sludge ending up in each water mass.

7. 12-Mile Dumpsite Recovery Study

NOAA launched a concerted study to document changes in living resources and their habitat following the anticipated cessation of sludge dumping at the 12-Mile Dumpsite in the inner New York Bight by 1988. Cessation of sewage sludge dumping should be followed by physical, chemical, and biological changes that will directly and indirectly affect the abundance, distribution, and utilization of fishery resources. The studies will evaluate: the roles of water mass movement, nutrient loading and hypoxia; sediment contamination and transport on seabed oxygen consumption; changes in benthic macrofauna and their trophic significance; and changes in tissue levels of microbial and chemical contaminants in fish and shellfish. Complimentary field and laboratory studies will address causes and effects of episodic hypoxia, organic chemical contaminants (PAH, PCB), and metals on important resources. NOAA is cooperating with EPA and FDA on several components of these studies.

8. EPA's Strategic Plan

In response to a request from EPA Region I, NOAA staff provided comments on a new strategic planning process for

near-coastal waters. This effort is part of a new initiative by EPA Administrator Lee Thomas. NOAA comments emphasized several activities (marinas, dredging) which cause more concern to nearshore resources than represented in the draft EPA document. NOAA also provided EPA with a list of references for general environmental information about nearshore coastal waters in the Northeast and a list of NOAA program contacts.

9. Atlantic Coast Emergency Striped Bass Research Study: A joint study by NMFS and FWS

The harvest of anadromous stocks of striped bass in most estuaries along the Atlantic Coast is continuing to decline. The reduction in catch can be attributed to a decline in production of juveniles by the Chesapeake stock, possibly by the Roanoke stock, and to recently imposed management measures. Hypotheses for the decline in juvenile production include acidification of freshwater reaches of tributaries, toxicant inputs, bottom water anoxia, loss of submerged aquatic vegetation, diseases, and overfishing.

Studies conducted during the striped bass spawning season in recent years have examined one of these hypotheses. They indicated that environmental conditions were toxic to the early life stages of striped bass in the Nanticoke and Choptank rivers in Maryland in some years. Both of these tributaries are important spawning and nursery areas for the Maryland stock of striped bass. Water quality data collected in the field implicated aluminum toxicity brought on by episodic depressions of pH as the most likely cause of observed larval mortality. However, laboratory studies indicated that other, previously identified, inorganic contaminants also may be contributing to larval mortality at the low pH levels encountered in these two rivers. These results clearly suggest that pH and pH/contaminant interactions may in some years limit striped bass larval survival in the poorly buffered rivers on the eastern shore of the Chesapeake. However, the extent to which these factors may have contributed to the decline in the stock is not yet clear. Analyses of available information indicate that, regardless of the proximate cause of the stock decline, the population was being overexploited prior to the recently imposed Maryland and Delaware moratoria, fishing bans in Connecticut and New York, and the 33 inch minimum size limit in other states.

A model was formulated to protect future trends in egg production for the Maryland population of striped bass assuming that the survival rate is stabilized at an average level. The model indicates that, unless management measures like the Maryland moratorium remain in effect, the Atlantic coastal States will not be reducing the fishing mortality rate enough to increase juvenile production by

the Maryland population. If the decline in juvenile production by the Maryland population was caused by increasing mortality from sources other than fishing, then reducing fishing mortality may only reduce the rate of population decline.

Southeast Region

In the southeast Region, NOAA's emphasis during FY 1986 dealt with four major research areas: 1) factors influencing the distribution and recruitment of larval and juvenile fish; 2) research on habitat functions supporting fishery organisms (supported by enhancement monies), evaluation of procedures used in habitat mitigation, and determination of acreages of different wetland habitat types; 3) effects of metal contaminants on larval fish food webs, determination of mechanisms of metal accumulation and metabolism and the status and trends of metallic and organic contaminants in estuaries; and 4) development of conceptual models that relate pollution and habitat modification to stresses on fish population. Research was carried out by the Beaufort, Miami, and Galveston Laboratories, and was conducted in North Carolina, Florida, Louisiana, Texas, the Gulf of Mexico, and the Carribean.

Coastal research by NOAA is designed to provide general information about environmental and pollutant factors that influence fishery organisms and evaluate the nature and cause of population fluctuations. Experiments were carried out in the Laboratory on early life history stages of fishery organisms and on the influence of trace metals on their survival, and field studies assessed their spatial distribution, feeding, and growth in the ocean. Research was conducted in the southeastern Atlantic Bight on the meteorological and hydrodynamic mechanisms that influence the movement of the larval fish spawned on the continental shelf into estuarine nursery areas. The Beaufort Laboratory also has begun to examine mechanisms that might account for the spatial distribution of king and Spanish mackerel larvae over the southeastern continental shelf. During the year, research was conducted on the applicability of random walk, Markov chain models as null hypothesis in studies of vertical migrations of larval transport mechanisms.

Estuarine research by NOAA personnel was carried out in North Carolina, Florida, Texas, and the Carribean dealing with habitat values to fishery organisms, funded in part through enhancement monies. This research centered on utilization of wetland habitats, production and utilization of detrital material, development of procedures to assess the effectiveness of mitigation, effects of freshwater inflow on fishery organisms, and evaluation of the status and trends of coastal wetlands. Enhancement funding also is supporting research directed at developing conceptual and ecosystem models. In the conceptual modeling phase,

models of fish population dynamics are being developed to simulate and assess the impact of multiple stresses on estuarine-dependent fish stocks. In addition, ecosystem models are being developed to provide some general inferences on the food web relationships between primary production and fishery yield. These syntheses not only will be used to infer the probable consequences of changes in habitat quality and quantity on fish populations, but also will provide a feedback mechanism to guide prioritization of future habitat-related research.

Research was conducted in Everglades National Park by the Beaufort Laboratory which coupled patterns of estuarine recruitment to distribution of juvenile organisms, with particular emphasis on spotted sea trout and gray snapper. Marsh habitats in North Carolina also were sampled using block nets, fyke nets, flume nets, and pit traps to evaluate species composition, biomass, and numbers of transient and resident fishes foraging on the marsh surface. These studies were designed to quantify the value of natural wetland habitats. Research also was conducted to address mitigation follow-up procedures emphasizing seagrasses and marsh habitats. In both North Carolina and Texas, habitats under investigation traditionally are the most difficult to compare and quantify utilization by fishery species; they include: Spartina and Juncus marshes and eelgrass, shoalgrass, and turtle grass meadows.

In Texas, enhancement funds were used by NOAA's Galveston Laboratory to obtain information on why the abundances o. some species are consistently lower in propagated marshes that are 2-3 years old than in natural systems. Such differences appear to correlate with factors related to unstable nutrient conditions. Both physical and biological data suggest that after three years, the processes within transplanted salt marshes have not stabilized and that functional values of the marshes are not fully developed. Studies in North Carolina by the Beaufort Laboratory are showing similar trends for marshes with sediment development being a key parameter for some species. Research on transplanted seagrass meadows are showing that even after 250 days of growth in North Carolina, significant differences exist between faunal utilization and abundance in natural beds relative to the transplanted beds, indicating lack of functional equivalency.

A study of the impact of freshwater inflow on fishery habitats, supported by enhancement monies, was carried out at the Miami Laboratory, where modeling as well as sampling analyses continue. A predictive model was developed which suggested that reducing freshwater inflow from Faka Union Canal (near Naples, Florida) to about 40 percent of its present level (which is excessive during the rainy season) would increase the overall abundance of fishes in Faka Union Bay.

Research was conducted on the status and trends of wetland habitats in the United States. In one effort, thematic mapper imagery is being used to fine tune and validate a predictive model dealing with the disintegration of marshes in Louisiana, principally around the Barataria Basin. A collaborative investigation by the NMFS Beaufort Laboratory and NOAA National Ocean Service's (NOS) Ocean Assessment Division (OAD) has revealed that information on coastal habitat acreages for the conterminous 48 states is limited in both quantity and quality. Much of the available data are old and often misleading for those areas of the coast that have undergone development in recent years. A problem with using existing data to develop a national data base is the fact that there has been little consistency in the habitat classification scheme used by different state and Federal agencies. A second collaborative investigation was conducted by NOAA which evaluated the COE permitting program and NMFS input to that process. During the period of January 1981 through December 1985, NMFS made recommendations on over 23,000 requests to develop wetlands, over 5,000 of which involved the potential alteration of 184,000 acres of wetlands. The conservation of 136,000 acres was recommended, and 110,000 acres were recommended for mitigation to offset losses.

Research and synthesis efforts also were conducted through enhancement funding to NOAA's Beaufort Laboratory during FY 86 to develop analytical models that relate pollution and habitat modification to stresses on fish populations. These efforts are addressing both single and multi-species populations and are considering cumulative effects on productions and yield. Sensitivity analyses of population dynamics models were performed to infer the effects of pollution on population levels of selected species.

Trace metals research during FY 1986 focused on four major areas: 1) cycling of manganese in estuarine and coastal waters; 2) determination of free copper and zinc ion concentrations in estuarine waters; 3) bioassays of trace metal pollution in estuaries; and 4) the National Status and Trends Program. Experiments in trace metal buffers indicate that the toxicity of copper, zinc, and cadmium is inversely related to the soluble manganese concentration, indicating that the concentration of dissolved manganese is an important factor affecting the toxicity of these metals in estuarine and coastal waters. To better predict the toxicity of copper and zinc, a new technique was developed for measuring free copper and zinc ion concentrations in a number of east coast estuaries. In only one of seven estuaries sampled was free cupric ion concentration sufficiently high to be toxic to fishery organisms. Tests were carried out with zooplankton and phytoplankton in water with and without metal chelating agents. Addition of these agents increased survival of larval zooplankton in natural estuarine water samples that previously had been shown to be toxic. As part of NOAA's

National Status and Trends Program, the Charleston and Beaufort Laboratories are collecting and analyzing samples of fish and sediments from 18 sites along the southeast Atlantic and Gulf of Mexico coasts for organic and trace metal contaminants. Currently, an interpretive report for the entire first year's results is being prepared for each region and an analysis of the second year's samples is proceeding.

Southwest Region

1. The Current Status of California's Coastal and Estuarine Habitats

This report is a continuation of information provided in previous Annual Reports (1983 and 1984). While developmental pressures continue to threaten wetland areas, particularly in southern California, there has also been an increasing awareness of the value of these areas. As a result, considerable effort from Federal, state, and local agencies has been directed towards enhancing and restoring various wetland systems, particularly in San Diego County. The Los Penasquitos, San Diequito, Batiquitos, and Buena Vista wetland systems have all been targets of enhancement or restoration projects.

2. Interagency Eelgrass Investigation

An interagency committee has been established in the San Francisco Bay area to develop an information data base on the basic biology and ecology of eelgrass, assess the geographic distribution of eelgrass in the Bay, and to assess various eelgrass mitigation techniques. The committee consists of staff representatives of NMFS Beaufort Laboratory and Southwest Region, the California Department of Fish and Game (CDFG), the Fish and Wildlife Service (FWS), Corps of Engineers, the Bay Conservation and Development Commission, and San Francisco State University. The major goal of the committee is to develop a management plan to preserve and enhance eelgrass habitats throughout San Francisco Bay.

Thus far, two major activities are underway:

- o A Corps project to repair the Richmond Training Wall that employs an experimental eelgrass transplant to offset channel dredging impacts to existing eelgrass beds. NOAA and Corps of Engineers (COE) (Waterways Experiment Station Vicksburg) have developed the eelgrass transplant and monitoring plan. To date, the transplant units have not experienced good survival at Richmond; however, densities throughout the bay have experienced substantial declines.

- o A cooperative inventory of existing eelgrass beds is being conducted by boat and helicopter. In addition estimates of plant population/biomass and survival are being made. Observations are also being made on seed production, and germination and reproductive patterns of eelgrass in the Bay (annual versus perennial populations). Recently, we have noticed a dominance of seed (annual) reproduction and very little perennial vegetation reproduction. This may be an indicator of the overall stress that beds are experiencing -- chemical, turbidity, freshwater/salinity, etc.

3. Effects of freshwater diversion on the baitfish resources of Pearl Harbor, Oahu.

In response to information that the State of Hawaii had tentative plans to divert freshwater from Waikele Stream, the main source of inflow to Pearl Harbor, a planning session was convened involving pertinent state and Federal officials, and university scientists to address possible impacts of freshwater removal. Within 3 months of this session, a research program was developed with the main emphasis on determining the role of freshwater input in the life cycle of the nehu, an important baitfish for the skipjack tuna industry in Oahu. Using the techniques of the egg production method and taking concurrent physical data, estimates of biomass will be made and the distribution of nehu eggs and larvae relative to freshwater input will be determined. This study will provide important baseline information against which possible changes in the population will be assessed.

Northwest Region

Research continues to assess impacts of estuarine and coastal activities and development on anadromous and marine fish habitat. NOAA staff worked closely with other Federal and state agencies to improve habitat conservation research. A research plan to determine the impacts of expansion and operation of the Columbia River hydropower system on white sturgeon was developed for the Bonneville Power Administration (BPA). In FY 86, BPA contracted with NOAA, the Oregon Department of Fish and Wildlife (ODFW), the Washington State Department of Fisheries (WDF), and the U.S. Fish and Wildlife Service (USFWS) for a 5-year cooperative study on the habitat requirements of white sturgeon. This

study deals specifically with the highest priority elements designated in the BPA plan -- early life-history, stock assessment, population dynamics modeling, habitat requirements, and reproductive biology.

NOAA and COE extended, for a third year, a cooperative investigation into the effects of dredging and dredge-disposal on Dungeness crabs in the Columbia River estuary. These crabs are the basis of a valuable commercial and recreational fisheries ground for mid-age juvenile crabs. Studies by COE indicated that large numbers of crabs can be entrained during dredging. Based upon studies of the seasonal distribution of crabs, NOAA recommended changes in dredging schedules and techniques.

NOAA completed a 4-year assessment of the effects of industrial pollutants on salmon passage at John Day Dam (Columbia River). This study was supported in part by COE. Fluorides discharged by an adjacent primary-production aluminum plant were believed to be instrumental in adult-fish passage delays at that site. New discharge limits greatly reduced fluoride concentrations in the John Day Dam area, and salmon passage-times are now significantly improved.

In late FY 86, NOAA and EPA signed an Interagency Agreement to study industrially-polluted sediments near aluminum plants at other Columbia River sites. Besides possible direct effects of these pollutants on fisheries resources and their habitats, there is concern about the nature and extent of the pollutants because of future dredging and dredge-disposal actions.

NOAA, in cooperation with COE and EPA, conducted research on habitat and species distributions at several interim dredge disposal sites on the Oregon and Washington coasts. A concurrent investigation, in cooperation with COE, relates to possible effects of navigational improvements on the ling cod ecosystem of Grays Harbor, Washington.

Studies conducted by NOAA in the Southern California Bight identified high concentrations of aromatic hydrocarbons and chlorinated hydrocarbons and their derivatives in sediment and bottom-dwelling fish from the vicinity of Los Angeles and San Diego. White croaker from San Pedro Bay (near Los Angeles) had a variety of liver diseases, including liver neoplasms, and several fish species from both areas had high prevalances of fin erosion.

Results of NOAA investigation on the reproductive capacity of English sole from urban and non-urban sites in Puget Sound suggested that the reproductive success of females

with serious liver lesions was significantly lower than that of females without lesions. In another Puget Sound study, juvenile Chinook salmon from an urban estuary were found to have a ten-fold higher concentration of metabolites of aromatic compounds in their bile than did similarly aged Chinook salmon from a non-urban estuary.

Alaska Region

The impact of bark debris at log transfer sites (LTFs) in southeast Alaska was examined by NOAA. The cooperative research was aimed at developing a more quantitative and repeatable methodology for assessing proposed LTFs. A habitat rating index was formulated which incorporates terms for the amount of vegetative cover, the level of biotic heterogeneity, and the degree to which commercial species utilize the benthic habitat at the proposed LTF site. The index is being tested for its sensitivity to seasonal and inter-annual variability in the sizes of biotic populations at particular sites. Because Dungeness crabs support a large fishery dependent on estuarine habitats in southeast Alaska, data on an extensive set of variables related to the habitat preferences of Dungeness crabs are being collected for eventual incorporation into the habitat utilization function for that species. Multivariate analysis of the factors that determine the degree to which bark accumulates on the bottom near LTFs is in progress. The collection and analysis of data on one of these factors, bottom currents, is being undertaken in cooperation with the Alaska Department of Environmental Conservation.

A method for the analysis of tri-butyltin (TBT) compounds at a level of 25 parts per trillion sensitivity level has been developed by NOAA. Net pens treated with TBT are lethal to salmon being reared in them. Using this sensitive analytical technique, we demonstrated that salmon reared in net pens treated with TBT accumulate TBT in excess of 1,000 fold in muscle tissue.

NOAA conducts research on anadromous fish habitat with regard to streamside management to reduce adverse effects of logging. NOAA scientists completed a study of winter habitat requirements of juvenile salmon overwintering in streams and the effects of logging on their habitat. NOAA also finished a study on stream classification (channel typing) that will help forest managers to plan logging operations to minimize impacts on anadromous fish.

Salmon rearing and spawning studies were initiated by NOAA in cooperation with the State of Alaska on the Taku River -- a transboundary river. Provisions of the Pacific Salmon Treaty between the United States and Canada require that optimum escapements of salmon be determined. For the transboundary rivers, data are generally not available to adequately estimate optimum escapements. NOAA staff has developed a system of habitat classification for large rivers and estimated populations of juvenile anadromous salmonids rearing in various habitats in the Taku River. Information on the quantity and quality of spawning and rearing habitats can be useful in refining escapement estimates and defining the productive capacities of large rivers.

NATIONAL OCEAN SERVICE (NOS)

Office of Oceanography and Marine Assessment (OMA)

The OMA conducts the National Circulation Program which: carries out circulation observation programs; predicts currents and water levels; publishes data, information, compilations, and reports; and develops numerical models to support those activities. Applications of this data includes safe and efficient pilotage of ships and recreational craft, port and coastal engineering, search and rescue operations, environmental assessment capabilities, emergency planning, rapid forecasting of oil and hazardous waste spill trajectories, warnings of storm surges and hazardous currents, and cost-effective ship operations and planning.

During FY 86, the OMA continued to modernized its circulation data products and services. The goal is to improve the use of information products for uses by developing state-of-the-art circulation prediction models funded partly by the local user communities.

OMA continues to develop numerical circulation models for Delaware River and Bay, Miami Harbor, Columbia River, and Cook Inlet. The Delaware River and Bay and the Miami Harbor models are well into the validation phase and are starting to be used in production modes. The goal is to use the models to generate water level and circulation predictions. A line of new NOS products will result from the modeling.

The OMA Office has begun using the modeling capability to develop a new line of products. Preliminary work is

finished in the development of a Delaware River and Bay water level and circulation forecast atlas. This is the first of a series of atlases which will lead to tidal and non-tidal predictions of water levels and circulation, with emphasis on wind and runoff conditions. A black and white mock-up of the atlas, using tidal predictions, is finished and the final version should be ready for public distribution in 1987.

In addition to OMA activities in circulation studies, it has conducted a number of important projects related to estuarine science and management including:

1. The National Estuarine Inventory (NEI)

   The NEI is the framework in NOAA's efforts to assess the health of the Nation's estuaries. It identifies all large- and medium-sized estuaries within the contiguous United States; compiles a data base of their important physical, hydrologic, biological, and economic characteristics; and specifies a commonly-derived spatial unit, the estuarine drainage area, by which data are compiled. The 92 estuaries identified in the NEI account for approximately 90 percent of the estuarine water surface area along each of the three coastal regions of the contiguous United States, and 90 percent of the freshwater inflow. The National Estuarine Inventory Data Atlas has been produced to illustrate characteristics of the estuaries identified in the NEI. Volume 1 of the Atlas, physical and hydrologic characteristics, was completed in November 1985. Volume 2, land-use characteristics, was completed in January 1987. Addiional projects are being conducted by the Strategic Assessment Branch (SAB) of NOAA within the NEI framework or are being adapted to that framework. These projects are described below. When the NEI data base is completed, it will be used to make comparisons, rankings, statistical correlations, and other analyses related to resource use, environmental quality, and economic value among estuaries.

2. National Coastal Pollutant Discharge Inventory (NCPDI)

   The NCPDI is a data base and computational framework containing discharge estimates for all point, non-point, and riverine sources of pollutant discharges into the estuarine, coastal, and oceanic waters of the contiguous United States (excluding the Great Lakes).

Pollutant discharge estimates are for a variety of contaminants including nutrients, metals, petroleum hydrocarbons, PCBs, chlorinated pesticides, fecal coliform bacteria, particulate matter, sludge, oxygen-demanding materials and wastewater flow. The framework will enable nationwide assessments of the impact of pollutant discharges into these waters under different assumptions about economic conditions, pollution control options, meteorologic and hydrologic conditions, and the public policies. The NCPDI contains three components: the Gulf of Mexico (completed March 1981); the East Coast (completed January 1985); and the West Coast (scheduled for completion in March 1987). NCPDI data for pollutant categories of interest, such as nutrients and pesticides, will be compiled for the 92 estuaries of the NEI in 1987.

3. National Coastal Wetlands Data Base

In cooperation with the Beaufort Laboratory NMFS, the SAB is developing a national coastal wetlands data base by using a systematic grid sampling procedure on wetland maps produced for the National Wetland Inventory (NWI) of the n.S. Fish and Wildlife Service (FWS). Fifteen habitat types are recorded by 45 acres cells on 1:24,000 scale wetland maps. Acreage estimates and color maps for one or several NWI maps can be produced. Grid sampled data can be intersected with digitized boundaries such as counties and estuarine drainage areas, as defined in the National Estuarine Inventory, to produce acreage summaries and maps for specific units of interest. Approximately 3,300 of the 5,000 NWI maps required for complete coverage of the Nation's estuaries are currently available. Grid sampling of coastal wetlands from Maine to Connecticut began in late FY 86 and was completed in January 1987. As sampling is completed, these data will be integrated into the NEI and used in conjunction with other information such as coastal pollution, distribution of estuarine fishes and invertebrates, and the status of classified shellfish waters to develop a national estuarine assessment capability.

4. National Shellfish Register of Classified Estuarine Waters

This project compiles nationwide information on the classification of shellfishing areas by state authorities. Estuarine waters are classified primarily on the basis of coliform bacteria levels as approved,

prohibited, conditionally approved, restricted, or nonshellfish/nonproductive. The SAB and NMFS of NOAA, and the Food and Drug Administration jointly prepared the 1985 Shellfish Register during FY 86. NOS has begun to improve the data presented in the 1985 and previous Shellfish Registers. Classification data from 1971, 1975, 1980, and 1985 have been reorganized into the 92 estuaries on the east, west, and Gulf coasts that comprise the NEI. The data also have been corrected for areas that were classified for reasons other than water quality. They are summarized in a December 1986 NOAA report entitled National Estuarine Inventory Classified Shellfish Growing Waters by Estuary. The SAB, in cooperation with shellfish producing states, is now identifying the pollution sources of areas that are limited to the harvest of shellfish.

5. Living Marine Resources

This project develops information on the distribution and abundance of living marine resources in the Nation's estuaries. The information will be developed for approximately 150 species and will initially be organized by the three salinity zones depicted for each estuary in Volume 1 of the National Estuarine Inventory Data Atlas plus additional estuaries of biological importance. Data are being collected through literature reviews, consultation with local and regional fisheries experts, and sources of NMFS, U.S. FWS, and NOAA's Oceans Assessments Division (OAD). The project is being conducted in three phases. Phase one will cover the West Coast; phase two, the Gulf of Mexico; and phase three, the East Coast. A preliminary component of phase one, assessing the overall feasibility of the project, was completed in February 1986 and discussed in a NOAA report entitled National Estuarine Inventory, Living Marine Resources Component, West Coast.

6. Shoreline Characterization

This project develops information on shoreline characteristics for each of the 92 estuaries of the contiguous United States identified in the NEI as part of the effort to develop a national estuarine assessment capability. The project identifies two shoreline types, dredged channels, and dredge material disposal sites from NOAA nautical charts, and estimates the relative extent of each shoreline type along the estuary. These data will eventually be integrated into

an estuarine classification scheme to explore relationships between estuarine habitats and their susceptibility to anthropogenic inputs to the estuarine environment.

7. Water Quality Screening Model

A generalized, water quality "screening model framework" was developed for application to estuarine systems included in the NEI. This model framework was designed to use available data, and can be applied to most systems in a matter of days. It is based on 8 years of experience with an oil spill simulation model developed by NOAA's Hazardous Materials Response Branch. The model is a steady-state, two-dimensional formulation composed of a hydrodynamic component that estimates circulation based on system geometry, fresh-water inflow, and tidal action, and a water quality component that estimates pollutant concentrations based on advection and dispersion processes. It is now being applied to Pamlico and Albemarle Sounds and has already been applied to Breton Sound, Louisiana, and Long Island Sound.

Activities of OMA are also designed to measure and assess the consequences to marine environmental quality from human activities in coastal and estuarine areas. OMA has two major programmatic areas: National Status and Trends; and Consequences of Contaminants. Data are assessed and interpreted to provide information on whether environmental conditions are stable or are getting better or worse, to identify geographic areas with the most urgent environmental problems, to anticipate the nature of effective remedial actions, and to propose cooperative strategies to resolve use conflicts. Important projects under this activity includes:

8. The National Status and Trends (NS&T) Program

In 1984, the Ocean Assessment Division initiated the NS&T Programs to establish and maintain the information base required to quantify the current status and long-term temporal and spatial trends of key chemical contaminants and biological indicators of environmental quality in the Nation's coastal and estuarine environments. The questions this program intends to answer are: What are the current conditions of the Nation's coastal and estuarine environments; and, Are

these conditions getting better or worse? A nationally uniform set of measurement techniques will be employed to determine marine environmental quality parameters.

The NS&T Program has four major components: 1) Benthic Surveillance; 2) Mussel Watch; 3) test and evaluation; and 4) historical data base development. The Benthic Surveillance and Mussel Watch projects are carried out mainly in selected estuarine locations around the coastal United States. The 50 sites selected for Benthic Surveillance include urbanized, industrial areas, and a few pristine areas that will serve as reference points. Sediments and bottomfish are sampled at three stations located at each site. Surface sediments are analyzed for major and trace elements, PAHs, PCBs, chlorinated pesticides, coprostanol (a chemical sewage tracer), grain size, organic carbon, and carbonate. Widely distributed bottomfish that consume benthic and epibenthic invertebrates are also collected at each station using otter trawls. Necropsies are performed on at least 30 individuals from each of two species, and visible lesions are noted and tissues preserved for subsequent histopathological examination. Sampling cruises are conducted from the NOAA ship FERREL along the East Coast and Gulf of Mexico, and from the NOAA ship McARTHUR along the West Coast.

For the Mussel Watch component of the NS&T Program, mussels or other suitable bivalves are collected from 150 sites nationwide. Thirty-seven of these stations coincide with sites occupied by the former National Mussel Watch program supported by the U.S. Environmental Protection Agency from 1976 to 1978, and some sites are located within National Estuarine Research Reserves. Tissues from the mussels are analyzed for major and trace elements, PAHs, PCBs, chlorinated pesticides, size, weight, gonadal index, and percent lipids. Surficial sediments from depositional areas near each mussel watch site are collected and analyzed for the same group of toxic chemicals. Sediments serve as longer term integrators of contaminants, and sediment analysis will aid in the assessment of long-term contaminant status and trends in the sampling areas.

Field sampling for the Benthic Surveillance Project was conducted in the spring/summer of 1984, 1985, and 1986. Results from the 1984 effort were presented at the OCEANS 86 Conference in Washington, D.C., in September 1986, and in the NS&T Progress Report, issued

in January 1987. Field sampling for the Mussel Watch Project was conducted in the winter of 1985/1986 and again during the winter of 1986/1987. Results from the first sampling effort will be available in the fall of 1987. A report describing historical trends of chlorinated hydrocarbon levels in fish and shellfish tissue will be issued in February 1987. A test and evaluation project for measures of biological effects of contaminants will be conducted in San Francisco Bay during early 1987; a report is expected in early 1988.

9. Consequences of Contaminants to Living Marine Resources

The goal of this program is to determine whether existing levels of contamination in coastal or estuarine areas are sufficiently high to affect reproductive success among adult fish and shellfish or to affect the survival and development of their eggs and larvae. Determination of such levels would be of direct value to management of living marine resources and environmental quality in our Nation's coastal and estuarine waters. Since reproductive success is logistically difficult to monitor, a parallel objective of the program is to find surrogate measures that can be monitored routinely by the NS&T Program.

During 1986, reproductive success was measured in fish in Puget Sound (WA), San Francisco Bay (CA), and coastal Southern California. At the two sites in California, preliminary evidence indicated that reproductive success is diminished among more contaminated fish. It should be noted that none of the fish contained contamination in excess of FDA limits for seafood consumption. Surrogate measurements of reproductive success that show promise to date are the activity of certain enzymes in livers and the proportion of micronucleated cells in the blood. Each of these parameters is easier to measure than reproductive success itself. If they are shown to reflect validly reproductive success, they can be exploited in the national monitoring program.

Testing estuarine water for its ability to sustain the development of larvae was conducted in the Elizabeth River (VA), Raritan Bay (NJ), the St. Johns River (FL), the Cooper River (SC), Escambia Bay (FL), and the Newport River (NC). At the first three locations,

water was toxic to larvae of the copepod species Acartia tonsa. In all cases, the toxicity could be eliminated or significantly reduced by the addition of metal-chelating agents indicating that trace element contamination is responsible for the toxicity. Even though this very sensitive test may overestimate toxicity to larvae of valued fish species, the next logical step is to determine the spatial extent over which toxic waters can be found.

Fish eggs themselves were used to test the toxicity of the sea surface microlayer in Puget Sound (WA). The microlayer is the upper 50 micrometers or so of the sea surface. This very thin layer is known to be chemically distinct from bulk seawater and, since many fish produce eggs that float prior to hatching, it may present a toxic barrier to egg development. Eggs of sand sole were placed in breakers containing microlayer water samples collected in various parts of the Sound. There was a significant reduction in the hatching success of eggs in microlayers collected from discrete areas within urban embayments.

While it is not an objective of the program to assess the public health hazard of chemical contaminants in seafood, a survey was completed in 1986 on the amount of contamination consumed annually by urban fishermen in Puget Sound. This survey will serve as an example of how such information can be gathered by local agencies in other estuarine or coastal areas.

In cooperation with the EPA, the program has begun a study of indicators of hazards to humans from shellfish consumption. The hazards are due to microbes as opposed to chemicals. For many decades local agencies have judged the safety of shellfish on the basis of concentrations of coliform bacteria in the harvesting areas. This procedure has much to recommend it but still lacks a quantified relationship between the concentration of coliform bacteria (or any other possible indicators) and the likelihood of disease among shellfish consumers. In 1986, a study was begun in which the concentrations of a suite of potential indicators will be monitored and gauged against the frequency of disease among a controlled group of consumers.

10. Hazardous Materials (HAZMAT) Response Branch

The HAZMAT, which is located in Seattle, Washington, maintains a cadre of technically trained people to respond to releases of oil and hazardous materials in the coastal or estuarine environment. Response is effected through the provision of scientific advice to the agencies mandated to control, clean-up, and mitigate the effects of such releases. The program has evolved into two broad types of responses: those requiring immediate action associated with U.S. Coast Guard (USCG) spill response activities and those that allow a more measured approach and that are associated with the EPA's activities with "Superfund" sites.

In order to effectively support the lead agency, HAZMAT has placed (or will be placing) personnel in or nearby to the regional offices of EPA (only for coastal regions) or the district offices of the USCG. HAZMAT can thus become directly involved in day-to-day planning activities that are required for an effective response and can influence longer term clean-up and mitigation plans. Those personnel placed in USCG offices are termed Scientific Support Coordinators (SSCs) and those supporting EPA are called Coastal Resource Coordinators (CRCs). These regional HAZMAT people are supported through a nationwide communications network by an interdisciplinary group of chemists, ecologists, and oceanographers and a carefully structured information system, that enables timely, expert advice.

In order to respond more effectively, HAZMAT has developed several tools:

o Environmental Sensitivity Index Atlases

Environmental Sensitivity Index (ESI) atlases are a primary resource used by the SSC during a spill. These documents, prepared by HAZMAT contractors, depict the distribution of valuable coastal habitat and resources (scale of 1:24,000 except Alaska) and characterize the coast according to vulnerability to potential oil spills. Locations where booms or other mitigative actions might be deployed for most effective protection of estuarine habitat in the event of a spill are also identified. Since 1979, HAZMAT has funded more than 40 atlases. The St. Lawrence River, St. Mary's River, Virgin Islands, San Francisco Bay, and the Oregon/Washington coast were completed in FY 86.

- Trajectory Modelling

  HAZMAT routinely provides support for spill response for 150 spills each year. The most common support request is for pollutant trajectories and distribution on and in the water. Modeling of a spill is activated within a two to four hour response time for most incidents, with additional capability deployed on-scene, if required. Algorithms for beaching and weathering of spilled oil have already been completed, tested, and incorporated into the model. More recently, the model has been expanded to include an algorithm for wind-driven analysis of currents. During FY 87, the model will be adapted for use on a personal computer.

- Port Studies

  As an outgrowth of the ESI maps, HAZMAT has funded a series of port studies which summarize transportation patterns of oil and hazardous materials in a port; information on the facilities that use oil and hazardous materials; locations, causes, and types of past groundings and spills; ESI information; hydrological and climatological considerations; identification of hazardous materials most likely to be involved in a pollution incident; and pollution response strategies and recommendations for contingency planning. Eleven ports have been studied and atlases are available for the following: Portland, ME; Narragansett Bay, RI; Boston, MA; Philadelphia, PA; Hampton Roads, VA; Jacksonville, FL; Los Angeles, CA; Baltimore, MD; Tampa, FL; Toledo, OH; and Detroit, MI. Beginning in FY 87, port studies will be available in both hard copy and personal computer formats.

- Computer-Assisted Management of Emergency Operations (CAMEO)

  As a result of HAZMAT's frequent response to chemical spills and staff uncertainty regarding the identity of a spilled chemical (and thus its dispersion, effects, and protective measures to be taken for response personnel) HAZMAT developed a program to use a MacIntosh computer for expediting the time required for analysis of a spill situation. The program has three components: a

large chemical data base, that includes information from existing sources on physical properties, fire fighting measures, non-fire fighting measures, decontamination procedures, health hazard information, protective clothing data, synonyms, chemical formula, various placarding symbols, and numerical identification numbers; a graphic portion that allows maps of a city, facility, port area, etc. to be viewed in relation to areas of concern, such as schools and retirement homes, access routes, and high population areas; and an air plume model that is linked to both the maps and a chemical data base, thus allowing a plume for a specific chemical to be overlain onto a map of the affected area. This program can be used for responses, contingency planning, and response training. It was installed on the Seattle Fire Department's HAZMAT van in late FY 86 and has since been used successfully for real hazardous materials incidents.

11. Outer Continental Shelf Environmental Assessment Program (OCSEAP)

OCSEAP is managed by the Ocean Assessment Division's Alaska Office under a basic agreement between NOAA and the DOI's Minerals Management Service (MMS). The purpose of the program is to conduct environmental studies in Alaska OCS areas designated by MMS for potential oil and gas development. OCSEAP provides MMS and other agencies involved in OCS oil and gas leasing decisions with scientific data and information needed to predict environmental disturbances and to resolve multiple-use conflicts associated with offshore oil and gas development in Alaska. OCSEAP has carried out several ecosystem studies in coastal and estuarine areas of Alaska to understand the vulnerability and sensitivity of these systems to potential impacts from oil and gas development. During 1986, OCSEAP-managed estuarine studies focused on the following areas:

- Beaufort Sea: Electrophoretic techniques are being developed for use in stock separation studies of Artic chair, an important subsistence species, from the several river systems draining into the Beaufort Sea. During 1986, tissue samples were collected from the Hulahula, Canning, Coleville, Sagavanirktok, Kavik, Egaksrak, Firth, Babbage, Canoe Creek, Joe Creek, Aichilik, and Kongakut rivers for technique development and archival of genetic profiles.

- Peard Bay: This ecosystem study was initiated on the Chukchi Sea coast in 1983 to determine the processes that structure the biological utilization of Peard Bay and to contrast these with results of earlier studies in the Beaufort Sea. During 1986, three years of data was analyzed and a report was prepared which described physical processes; utilization of the bay by mammals, birds, fish, and invertebrates; outlined primary production, nutrients and trophic relationships; and refined the hypothetical food web which was initially developed from the first year's data.

- Kotzebue Sound: A study of ecological processes and habitat use by valued vertebrate consumers was begun during 1986. This study will describe ocean circulation, carbon flow, and sedimentological parameters, and discuss their importance to the biological productivity and pollution effects in the study area. This research complements and is conducted in coordination with the National Science Foundation-funded Inner Shelf Transfer and Recycling Study (ISHTAR) being conducted in the Bering Strait and southern Chukchi Sea. The initial field effort in September collected a comprehensive suite of data types from twenty stations in the southern Chukchi Sea.

- Yukon-Kuskoquim Delta: Physical oceanography studies, begun in 1985 to describe both the coastal and estuarine circulation features that could affect the transport of pollutants, were completed. During 1986, three field surveys were conducted to provide data on the timing of chum and chinook salmon out-migrations and on their residence in lower river and estuarine environments. Approximately 2,000 juvenile salmon were collected from 20 stations and preserved for trophic and otolith analysis. Waterfowl use of the coastal waters off the Yukon River Delta was assessed in a series of ten aerial surveys, supplemented by ground truth verifications of aerial bird identifications. Two intertidal surveys were conducted in the Yukon North Mouth tributary to evaluate the availability of beach food supplies to migrating waterfowl.

- North Aleutian Shelf: This ecosystem study was initiated in 1984 to describe the major processes and biotic relationships occurring along the north coastline of the Alaska Peninsula coastline. Particular emphasis was placed on investigations of fish, birds, mammals and their trophic relationships as well as on sources of organic carbon. Aerial

bird surveys were conducted early in 1986 with the major effort being directed toward data analysis and report preparation.

National Marine Pollution Program Office (NMPPO)

Sections 4 and 8 of the National Ocean Pollution Planning Act (NOPPA) of 1978 require NOAA to coordinate marine pollution research, development, and monitoring activities funded by the Federal Government and to disseminate information resulting from these activities to interested users. These responsibilities are delegated to NMPPO, a staff office to NOAA's Assistant Administrator of the National Ocean Service. This part of the report describes the interagency planning and coordination and the information dissemination activities which were conducted by NMPPO during FY 86 in response to Sections 4 and 8 of NOPPA.

The Omnibus Budget Reconciliation Act of 1986 (P.L. 99-272, enacted April 7, 1986) amended the NOPPA and significantly altered the level of coordination required by Congress among the agencies and departments that support research, development, and monitoring related to ocean pollution. The amendments formally established an interagency National Ocean Pollution Policy Board and specified that NMPPO is to serve as staff to the Board. This Board is similar to the previous Committee on Ocean Pollution Research, Development, and Monitoring (COPRDM) but with added responsibilities. Each agency represented in the Federal Plan for Ocean Pollution Research, Development, and Monitoring is now required under Section 4 of NOPPA to submit to the Policy Board their annual requests for appropriations in support of ocean pollution research, development, and monitoring programs. The Policy Board is to review these requests for appropriations and submit a report to the Office of Management and Budget and Congress discussing the extent to which the agency requests are consistent with the priorities established in the Federal Plan. Under NOPPA, OMB is to review the requests for appropriations as an integrated, coherent, multi-agency request and is to take into account the review of the Policy Board. The first budget review report was drafted by NMPPO and approved by the Board during September 1986. This report supplemented the FY 88 budget request submitted to OMB by the individual agencies and departments. The 1986 amendments also gives NMPPO the responsibility to coordinate the research necessary to support the preservation and protection of the environmental quality of the Great Lakes, Chesapeake Bay, Puget Sound, and other estuaries of national significance.

NMPPO is conducting various estuarine-related activities in support of its interagency planning and information dissemination responsibilities. They are as follows:

- Five-Year Federal Plan for Ocean Pollution, Development, and Monitoring

Section 4 of NOPPA requires NOAA to prepare a comprehensive five-year Federal Plan for the overall National Marine Pollution Program and to update this plan every three years. The last plan was completed in September 1985. Preparations are currently underway for the next update, due in September 1988. As the first step in the process to update the plan, a Workshop on National Marine Pollution Problems was scheduled for the summer of 1987, where high priority national marine pollution problems will be discussed by groups of experts. Progress by the Federal Government in resolving these problems will also be addressed. The results of this workshop will form a substantial basis for drafting the next five-year Federal Plan due in September 1988.

- Description of Ongoing Marine and Estuarine Pollution Research

NMPPO annually publishes descriptions of all marine and estuarine pollution-related research, development, and monitoring projects supported by the Federal Government. This report, the National Marine Pollution Program - Summary of Federal Programs and Projects, includes the following information on the projects: agency program title, program goals, accomplishments, and milestones, as well as specific project listing including principal investigators. All projects in this report are indexed by polluting activity, pollution, region of the United States, zone in the marine environment, and project purpose.

To complement the annual summaries of Federal programs and projects, NMPPO periodically summarizes marine and estuarine activities supported by sources outside of the Federal Government. These reports include a brief description of the project, geographic area of concern, funding source, and contact person. Presently, separate reports are available for the following geographic areas: Northeast and Middle Atlantic, South Atlantic and Gulf of Mexico, and the Great Lakes. A report summarizing projects on the West Coast and in Alaska is being prepared.

A large portion of the results and information generated by different components of the National Marine Pollution Program is available only through reports of the participating Federal agencies. To facilitate user awareness and accessibility of this "grey literature" that is not

widely available, NMPPO is developing an annotated, indexed, and automated bibliography. Publications from the 1979-1983 were entered prior to FY 86, and more recent publications are currently being listed.

NMPPO is developing a Compendium of Federal Laws and Regulations on Marine Pollution, to be published in FY 87. This document will be of value to the government and private sectors and will be invaluable in preparing the next Federal Plan by providing a review of the laws and regulations which establish the needs and priorities for marine pollution research.

o Development of a Periodically Published Report on the "State of the Marine Environment"

NMPPO is currently determining the feasibility of preparing and publishing a report to provide an indication of time trends and regional patterns in the quality of U.S. estuarine, coastal, and Great Lakes environments. The document will benefit industrial, municipal, and recreational users of the marine environment; environmental scientists from industry, academia, and government; and government decision-makers. It will be based on a number of indicators of environmental quality in marine systems. The following are examples of indicators that might be used: parameters that address human health aspects (i.e., shellfish bed closures, bathing beach closures and direct measurements of pathogens); aspects of bird reproduction; in situ contaminant levels in fish tissues; frequency and extent of low oxygen events; and wetland loss and modification. These and other possible indicators of marine pollution have been evaluated based on the following considerations: a literature review of past uses of the indicator; indicator reliability, natural variation, sensitivity, and ecological significance; accessibility of relevant data and any difficulties that might be encountered in data synthesis; and an analysis of the advantages and disadvantages of the indicator. The report will use only information and data that are already available; no new field or laboratory work will be performed.

o Coastal Information System

NMPPO is supporting the development of a personal computer-based system for packaging regional and/or site-specific multi-disciplinary information related to marine environmental issues. As envisioned, this system will allow direct interaction by coastal managers with a wide spectrum of scientific, land, and water use and other marine pollution-related information stored on spreadsheets and accessed through desk-top computers.

The intent is to provide a mechanism whereby resource managers, decision-makers, and others can access and manipulate significant regional marine pollution information sources, including those that are often not available (i.e., grey literature, data summaries, etc.)

A prototype Coastal Information System has been developed for the Hudson-Raritan estuary and is currently being evaluated and enhanced. Development of additional systems has begun for the Puget Sound and Chesapeake Bay estuaries.

o Estuaries Monographs

NMPPO is supporting the preparation of a series of reports that will focus on understanding man's impact on specific estuarine systems. The intent of these reports is to relate how changes in land and water use and increased pollutant loadings may affect ambient water quality and the living resources in these estuaries. Existing data will be used to describe the estuary setting and characteristics, historical trends of land/water use, pollutant loadings, trends in water quality, changes in living resource populations, and the implications of the changes occurring in the estuary to human health. Currently, monographs are being prepared for Lake Ontario, Indian River Lagoon (Florida), Narragansett Bay, Delaware Bay, Galveston Bay, and Pamlico Sound.

o Survey of Federal Wetland Habitat Assessment Activities

There is increasing interest within various Federal agencies and coastal states to compile and use new information on wetland acreage and loss over time. This is due, in part, to recently enacted Federal and state wetland protection legislation and a growing public perception that coastal wetlands are disappearing at an unacceptable rate. Many of these efforts are supported by Federal funds and fall under the purview of the National Marine Pollution Program. The purpose of this project is to prepare a description of current Federal and non-Federal wetland inventory activities, methods, and existing data bases.

Office of Ocean and Coastal Resource Management (OCRM)

The National Estuarine Reserve Research System is authorized by Section 315 of the Coastal Zone Management Act of 1972 (P.L. 92-583), as amended. The System is administered by NOAA's Marine and Estuarine Management Division (MEMD).

The mission of the System is the establishment and management, through Federal-state cooperation, of a national system of estuarine research reserves representative of biogeographical regions and estuarine types in the United States. National estuarine research reserves are established to provide opportunities for long-term research, education and interpretation. Scientific and educational programs are particularly focused on the development of information for improved management of the Nation's estuaries.

The designation of a national estuarine research reserve signifies a state's commitment to long-term management of an area in accordance with the System's policies and regulations (15 CFR Part 921).

NOAA has designated research reserves in 16 areas and several additional sites are progressing through the pre-designation process. During FY 86, Weeks Bay, Alabama was added to the Estuarine Reserve Research System. This 3,000 acre site consists of brackish marsh, bay/tupols/cypress swamp, and moist pine forest habitats.

In an effort to stimulate high quality research within designated sites, the NOAA Office of Ocean and Coastal Resource Management (OCRM) and MEMD provides limited financial support, on a competitive basis, for research in national estuarine reserves having approved final management plans.

The Estuarine Reserve Research Program was initiated in 1984 with a series of information syntheses on the environmental characteristics of various estuarine sites. The initial investment was approximately $80,000. The Program has grown rapidly and today, research funds are primarily used to support management-related research that will enhance scientific understanding of estuarine reserve environments, provide information needed by coastal zone and reserve managers and decision-makers, and improve public awareness of estuaries and estuarine management issues. Research projects are oriented to specific sanctuaries; however, some projects may be selected that would benefit other reserves in the national system.

In FY 86, cooperative agreement awards by the OCRM through the MEMD totaled $489,886. Table 1 presents a summary of funds expended by general topic area through the Program for FY 86.

Technical information and a brief description of the background, objectives, and methodology for estuarine research projects funded in FY 1986 and processed to date are available from MEMD.

TABLE 1.

FY 1986 ESTUARINE RESEARCH EXPENDITURES

MARINE AND ESTUARINE MANAGEMENT DIVISION

TOPIC	AMOUNT
Living Resource Management	$212,533
Water Management	134,281
Habitat Management	76,699
Pollution Management	29,190
Sediment Management	19,984
Cultural Resource Management	7,200
Other Management	9,999
TOTAL	$489,886

OFFICE OF OCEANIC AND ATMOSPHERIC RESEARCH

Environmental Research Laboratories

Great Lakes Environmental Research Laboratory

The Great Lakes Environmental Research Laboratory (GLERL) conducts integrated interdisciplinary environmental research in support of resource management and environmental services in coastal and estuarine waters, with special emphasis on the Great Lakes. The research program includes both basic and applied studies and combines experimental, theoretical, and empirical approaches. Field, analytical, and laboratory investigations are performed to improve understanding and prediction of environmental processes and their interdependencies with the atmosphere, land, and sediments in coastal and estuarine areas. GLERL places special emphasis on a systems approach to problem-oriented research to develop environmental service tools. Assistance is also provided to resource managers and others who wish to apply the information, tools, and services GLERL develops.

GLERL's multidisciplinary program supports the Ocean and Great Lakes Prediction Program of NOAA. It addresses: 1) the need for new and improved simulation and prediction models of ecosystem structure and function, and of the effects of stresses and proposed remedial options; and 2) the need to assess other options while taking system dynamics and dimensions into account. Two elements of the Ocean and Great Lakes Prediction

Research Program provide the focus for GLERL research: Marine Ecosystems Assessment, and Marine Hazards and Lake Hydrology.

1. Cycling of Toxic Organics

In lakes and estuaries, the adsorption of toxic organic contaminants onto particles, followed by settling and eventual burial, is commonly the major internal process controlling the residence time and concentration of these compounds in the water column.

Understanding the interactions between different types of suspended matter and dissolved organic contaminants, and understanding the processes that affect these interactions, are critical in modeling the behavior of such contaminants in the environment.

In 1984, experiments were performed to measure the equilibrium distribution (partitioning) of a suite of contaminant organics between the dissolved, the suspended-solid, and the dissolved-organic-carbon phases. The results, primarily from a nearshore station in Lake Michigan, revealed significant seasonal changes in the partitioning between these phases. During FY 86, similar experiments were initiated for offshore waters.

Bottom sediments and their sorbed contaminants are mixed by animal activity (bioturbation) and can be reintroduced into the water column by resuspension. GLERL has an ongoing program to measure and study the fluxes of new versus resuspended particulate matter and associated contaminants, using sediment traps moored in vertical arrays in the water column. The field portion of this research, completed during FY 85, included the collection of more than 200 sediment samples from the traps. During FY 86, processing and analyses of these samples were completed.

In a related field program, sediment traps of different size and design used by GLERL and Canada's National Water Research Institute (NWRI) were deployed in FY 85 in tandem arrays in the northern and southern basins of Lake Michigan to determine relative collection efficiencies over a wide-range of mass fluxes. During FY 86, these traps were retrieved, sampled, and redeployed.

During FY 86, work began on development of a stratified, single-lake contaminant-fate model, which will explicitly incorporate sediment resuspension as a parameter and make use of the trap data.

A second and apparently important process for remobilizing contaminants out of sediments involves the direct uptake of contaminant compounds by benthic invertebrates and transfer up the food chain to higher trophic levels. GLERL's toxicokinetics program has been studying the uptake, depuration, and biotransformation rates for various toxic organics in Great Lakes invertebrates.

Previous work involving the accumulation of PAH from sediments by benthic invertebrates such as Pontoporeia hoyi (P. hoyi) showed that the process is complex and is affected by a number of parameters. Experimental work on the environmental factors that affect the toxicokinetics of xenobiotics in P. hoyi was completed.

Experiments were initiated this year to examine the relative sensitivity of the predominant Great Lakes benthic invertebrates, P. hoyi and Mysis relicta, to a suite of well-documented toxic organics.

The usual measure of the toxicity of a chemical compound to a particular organism is the concentration that is lethal to 50 percent of the test population, known as the LC^{50}.

However, LC^{50} experiments do not provide any indication of what concentration level starts to produce toxic effects. GLERL developed a procedure to detect the initiation of toxicity to benthic organisms by measuring the rate of sediment reworking in a test cell under increasing concentrations of a particular toxic contaminant.

2. Ecological Succession and Trends

A major problem in developing and testing the effectiveness of ecosystem models is the limited amount of comprehensive long-term data available for aquatic ecosystems, upon which model development could be based and tested. Previously, GLERL took advantage of a 20-year data base from Lake Washington (near Seattle) to develop a generic heat-diffusion model for lakes, which was then adapted for Lake Michigan. This year, the generic one-dimensional vertical heat-diffusion model was compared with the observed vertical thermal structure and total heat content in Lake Washington for the period 1963-1976.

The Lake Michigan Heat-Diffusion Model was then modified and used to simulate 1985 epilimnetic thermal structure with emphasis on diel stratification. One laboratory and two field experiments were conducted during FY 86 to assess the effect of afternoon (diel) stratification on Lake Michigan phytoplankton.

GLERL conducted a major Lagrangian ecosystem in Lake Michigan during 1983 and 1984 (Lake Michigan Ecosystem Experiment) to define and quantify biological and chemical processes causing dynamic short-term and seasonal ecological changes in Lake Michigan phytoplankton. During FY 86, the data from that field experiment were used to complete and calibrate a long-term total-phosphorus model for Lake Michigan.

A related model that simulates Lake Michigan's summer pelagic food web (phosphorus, phytoplankton, zooplankton, planktivorous fish) was also constructed and calibrated against the concentrations and process rates observed during the Lake Michigan Ecosystem Experiment. The model was used to explore the hypothesis that Lake Michigan's summer food-web structure is sometimes controlled by fish dynamics.

Ecosystem dynamics involves the determination and study of the critical first-order processes that control the flow of nutrients and energy through the ecosystem and determine the composition and pattern of succession of biota in the lakes. GLERL has an established program to examine and evaluate the importance of various temporal and spatial aspects of the Great Lakes ecosystem.

Significant progress was made toward completing analyses of the data from the Lake Michigan Ecosystem Experiment. Comparisons of epilimnetic nutrient depletion rates with primary production and sinking rates were completed, and evaluations of the spatial and temporal variations of nine nutrients, temperature, and drifter movement during 1983 and 1984 were about 80 percent completed.

Seasonal studies of Lake Michigan phytoplankton previously documented long-term changes in both surface and deep phytoplankton communities. Surface-water population changes were attributed to food web modification resulting from a large decline in alewife populations. During FY 86, it was shown that recent changes in the fish communities have cascaded to affect the deep chlorophyll layer as well.

Previous studies have shown that bacterial production may account for a significant part of the total production in the Great Lakes. Analyses of the results of bacteria field experiments conducted during FY 85 were completed and preliminary findings were confirmed during FY 86.

GLERL scientists continued to use the new Microcinematography Laboratory established last year. FY 86 experiments examined the effects of algal morphology as a defense mechanism against capture.

Information on the population dynamics of organisms living under the ice during winters in the Great Lakes is scant. Studies in other parts of the world show that signficant biological activity can be present under marine ice. GLERL initiated a pilot study during FY 86 to evaluate the importance of under-ice ecology in the Great Lakes. Field projects involving winter phytoplankton sampling in Grand Traverse Bay and Lake Huron were initiated.

3. Food Web Dynamics and Pelagic-Benthic Interactions

Energy flows through an ecosystem by means of food web processes, starting with photosynthesis at the lowest trophic level and ending with large fish. An understanding of food web interactions is necessary before the effects of anthropogenic inputs and changes on the ecosystem can be predicted.

Previous results from a study on the effects of silicon limitation on phytoplankton species succession showed that diatoms have a phosphate uptake system that functions more efficiently than other algae at low substrate concentrations. However, under silicon-limiting conditions, the ability of diatoms to utilize phosphate was diminished, triggering a shift to blue-green algal dominance. During FY 86, new computer simulations were used with the data to determine the reason for the loss of efficiency under silicon-limiting conditions.

Silica and phosphorus fluxes were calculated from Lake Michigan sediment cores and revealed that dissolved silica fluxes are 3 orders of magnitude larger than dissolved phosphorus fluxes. Comparison with other sources of nutrients demonstrated that sediment fluxes are more important to the internal recycling of silica than to that of phosphorus.

During FY 86, the results from a seasonal study of nitrogen transformations and fluxes in Lake Michigan sediments at two stations indicated that denitrification is a major sink for mineralized nitrogen in silty Lake Michigan and that flux of ammonium or nitrate from the sediments into the overlying waters is minimal.

Lipids (fats) are the compounds organisms primarily use to store energy. Materials from a series of sediment traps collected from Lakes Michigan and Huron were analyzed for lipid content to provide information on the magnitude and mechanisms of biochemical energy transfer from the pelagic to the benthic systems in these lakes.

4. Benthic Ecology

A GLERL biologist who participated in the first exploration of Lake Superior with a research submersible completed his comparison of benthic samples to evaluate the sampling efficiency of Ponar grab samplers. Samples collected with the Johnson Sea Link II were compared with those collected using a Ponar grap sampler from the same locality. During FY 86, the field work using the submersible was extended into Lake Huron.

5. Water Movements and Temperature

Winter storms resuspended bottom sediments, causing a redistribution of materials deposited during the summer months. During 1986, GLERL recovered several arrays of current meters moored near the bottom of Lake Michigan. The arrays had been deployed during November 1985 to measure the vertical profile of horizontal currents in the bottom boundary layer during the winter storm season.

Accurate prediction of the movement of contaminants, nutrients, and suspended sediments in the Great Lakes depends on the accuracy of numerical lake circulation models in predicting currents. During FY 86, an alternative to the traditional method of testing model accuracy was developed and applied to GLERL's numerical lake circulation model.

6. Optimization, Uncertainty, and Risk Analysis Applied to Environmental Systems

Development of contaminant management plans that balance acceptable environmental risks against acceptable costs is a major goal of the Great Lakes community. Optimization, uncertainty, and risk analysis techniques are useful tools for achieving this goal, but have been used only sparingly to date. GLERL established a program in late FY 84 to explore the application of these techniques to improving the management strategies for Great Lakes natural resources.

During FY 86, we completed a first-generation optimization model that takes uncertainty into consideration when determining the cost-effectiveness of contaminant treatment strategies. Management of phosphorus loading was chosen as a test case because of the importance and cost of dealing with this problem, the availability of a large, reliable data base, and the existence of tested phosphorus mass-balance models for the lakes.

7. Surface Waves and Water Level Fluctuations

The primary driving forces of water movements in the Great Lakes are the wind acting on the surface, the exchange of heat across the water-atmosphere boundary, and the hydraulic flow through the system. Wind-generated surface waves can be a significant hazard to ships and recreational boaters, and storms can produce rapid short-term elevations of water level in the shallower bodies of water such as Western Lake Erie, Green Bay, and Saginaw Bay. The ability to predict wind-generated waves and seiching produced by storms is critical to the safety of marine users and shoreline property interests on the Great Lakes.

Some of the most heavily populated and most intensely used areas of the Great Lakes are also the shallowest (Lake St. Clair, Green Bay, and Saginaw Bay, and western Lake Erie, for example). Although wave forecast methods for deep water are well developed, shallow water wave forecasting is still in its infancy. During FY 86, GLERL initiated research on the effects of shallow water on wave dissipation and attenuation that includes both field experiments and development of applicable models.

GLERL staff continued to support the use of the GLERL Interactive Wave Prediction Model by marine forecasters at the NWS Great Lakes Weather Service Forecast Offices (WSFOs). This model, housed on the GLERL computer, was accessed more than 200 times by NWS forecasters during FY 86.

8. Great Lakes Ice

The seasonal ice and snow cover in the Great Lakes basin has a major effect on both the economic and social well-being of the community. It affects navigation, shoreline erosion and damage, hydropower generation, water supplies, fisheries, recreation, and local climate. Understanding, simulating, and forecasting the ice and snow cover require improved information on the formation, growth, movement, and decay of the ice cover; the extent, thickness, water equivalent of the snow cover; and a better definition of the characteristics of the snow and ice cover.

A menu-driven computer algorithm was developed during FY 85 for NWS to forecast ice conditions on the St. Marys River. The algorithm forecasts date of ice formation, ice growth, and date of ice loss. During FY 86, procedures to access and run the algorithm, data input requirements, and forecast limitations were demonstrated and documented. Access to and support of the algorithm on GLERL's computer were provided to both NWS and the Army COE for use in making (experimental) operational forecasts during the 1985-86 winter season on the Great Lakes.

An 81-year (1897-1977) degree-day climatology for the Great Lakes region was updated with the addition of data for 6 years (1978-1983). The cumulative frequency distribution of the seasonal maximum freezing degree-days at 25 stations for the base period of 1897-1983 was used to revise a winter severity index developed in an earlier study. Winter severity class limits were developed for each of the Great Lakes.

During FY 85, airborne spectral reflectance measurements (400-1100 nm) of old snow, open water, and several ice types were made on Saginaw Bay and were corrected for atmospheric attenuation and path radiance effects by using a combination of existing standardization techniques (light and dark secondary standards calibrated against a barium sulfate primary reference standard panel). During FY 86, the FY 85 data were corrected for errors in the primary calibration panel.

9. Hydrologic Properties

The availability of adequate supplies of freshwater is potentially one of the country's most serious long-range problems. The Great Lakes, with a total combined surface area of 247,000 km^2, contain 23,000 km^3 of water, or approximately 95 percent of the United States freshwater surface. This water is used for navigation, drinking, industrial processes, hydropower, irrigation, transportation, and wildlife and fish habitat. Major changes in water quantity are caused by annual and seasonal variations in the water supply, consumptive use, and interbasin diversions. The usual measure of water quantity is the lake level of the individual lakes. Over the past 120 years, the levels have fluctuated about 2 meters, and the normal seasonal fluctuation has been 35-50 cm between winter minimum and summer maximum. Superimposed upon the natural fluctuations are a number of anthropogenic changes which have or could have major effects on Great Lakes water quantity. During FY 85, high lake levels set records on Lakes Superior, Michigan, Huron, St. Clair, and Erie. GLERL's hydrologic research program is directed toward improving our knowledge of the hydrologic and hydraulic processes, improving methods of forecasting and simulating water supplies and lake levels, and improving large-river dynamic flow models.

Deterministic forecasts (outlooks) of accumulated net basin water supply are required in near-real time for use in regulating water levels of large lakes. This GLERL Large Basin Runoff Model was developed for this purpose several years ago. This general model has been modified and re-

fined to improve and apply it to the Great Lakes. Initial calibrations are completed for Lakes Ontario and Superior. During FY 86, the initial calibration, using daily computation interval, was completed for each of the sub-basins about Lakes Erie and Michigan.

During FY 85, GLERL completed a semi-automatic software package to predict water supplies to Lake Superior in near-real-time. During FY 86, monthly outlooks of Lake Superior basin moisture, runoff, and water supplies were issued to a select group of users. In addition to those monthly outlooks, the Army COE Detroit District was supplied with lake level outlooks for Lake Superior.

Development of a generic Thiessen weighting package was completed. The Army COE, Detroit District, and the NWS NERFC use it to make near-real-time areal estimates of snow water equivalents from aerial surveys of Lakes Superior and Champlain, respectively.

Analysis of thermal corrections to Lake Superior's monthly change in storage, based on Expendable Bathythermograph transects made during 1976, revealed that the thermal component of change in lake storage is an important factor in the water balance of that lake.

GLERL's Great Lake Hydrologic Response Model, developed several years ago, models the hydrologic water balance through the Great Lakes system. The model provides the resulting lake levels for each of the Great Lakes and Lake St. Clair, and the flows in the connecting channels. During FY 86, the Hydrologic Response Model was simplified, extensively documented, and recalibrated to reduce the error in modeled Lake Michigan-Huron levels. Analyses using this model provided several useful insights relative to the present high Great Lakes water levels.

The St. Clair River Winter Flow Experiment was extended through the 1985-1986 winter season. Five consecutive winter seasons have also been collected for the Detroit River (Detroit River Winter Flow Experiment). During FY 86, historical data were examined for evidence of possible flow reversals in the Detroit River during 1900-1985. Eight possible occurrences were identified and selected for further analysis, including one major episode that occurred in April 1984 (when GLERL had meters in the river) and coincided with a massive St. Clair River ice jam.

10. Upper Great Lakes Connecting Channels Study

The Upper Great Lakes Connecting Channels Study (UGLCCS) is an international (United States-Canada) and interagency multi-year study of water quality and ecosystem dynamics in the upper Great Lakes connecting channels. Study areas include the St. Mary's River, the St. Clair River, Lake St. Clair, and the Detroit River; all are designated by the International Joint Commission as "Areas of Concern" in which environmental quality is degraded, and beneficial uses of the water and biota are adversely affected.

11. Environmental Models of Lake St. Clair

A conceptual ecosystem model was developed for Lake St. Clair for the purpose of understanding the dynamics of shallow (near-shore) systems and how the dynamics will affect the fate and transport of contaminants.

The EPA model, TOXIWASP, was selected as the basis for a model to predict the fate, transport, and effects of contaminants in Lake St. Clair. During FY 86, TOXIWASP was adapted for use on both the GLERL VAX and Department of Commerce Consolidated Scientific Computing Service CYBER computers.

A phosphorus mass balance model for Lake St. Clair was completed. It was used to identify the relative importance of phosphorus loading sources.

An unsteady-flow mathematical model is being developed for the entire St. Clair River, including flow distribution around islands in the single upper river channel and separation of flow through the main channels in the river delta.

A prototype toxic contaminant fate-and-effects model was developed for plankton systems. The state-of-the-art framework developed in this model is being used to predict the effects of contaminants on plankton populations.

12. Field and Laboratory Experiments

Microcosm experiments for determining phosphorus release from Lake St. Clair sediments were completed. Inorganic phosphorus excretion by clams appears to be a very important process in Lake St. Clair.

Three one-week long synoptic current surveys were conducted in Lake St. Clair during FY 85 to observe and measure flow throughout the basin under calm and storm wind conditions. Analysis of these data was essentially completed during FY 86.

During late FY 85 and early FY 86, GLERL and NWRI (Canada) performed an extensive joint field measurement program in Lake St. Clair to measure wave dissipation and the effect of waves on resuspension in shallow water (WAVEDISS '85: Wave Attenuation, Variability, and Energy Dissipation in Shallow Seas).

Atlantic Oceanography and Meteorological Laboratory

The Atlantic Oceanography and Meteorological Laboratory (AOML) is organized to pursue basic and applied research programs in oceanography and tropical meteorology. Oceanography investigations center on fluxes of energy, momentum, and materials through the air-sea interface; the transport and composition (thermal and chemical) of water in the ocean volume; and hydrothermal processes of mineralization at sea floor spreading centers. Meteorological research is carried out to improve the description, understanding, and prediction of hurricanes. The research program is enlarged by the Cooperative Institute for Marine and Atmospheric Studies (CIMAS), a joint enterprise with the Rosenstiel School of Marine and Atmospheric Science of the University of Miami. CIMAS enables NOAA and university scientists to collaborate on problems of mutual interest, and facilitates the participation of visiting scientists. AOML's current research program concerns processes relating to climate, weather observation and prediction, marine observation and prediction, marine resources, and air quality.

Marine Observation and Prediction

AOML research in Marine Observation and Prediction is concentrated in the following areas: 1) improving the definition and measurement of the ocean bottom depth for charting, navigation, and bathymetric purposes; 2) potential operational system evaluation and demonstrations, including research aimed at improving the observational equipment and techniques used to collect data on the marine environment -- particular emphasis is placed on the use of new, advanced, high-technology systems; and 3) improving measurements of naturally occurring water column particulate distributions and the distribution of particulates produced through human activities (e.g. dumping in the ocean). The AOML bottom-echo-formation model was refined and further developed. When provided with a set of input parameters characterizing a bottom environment, the model will produce the echo signal to be expected from such a bottom. An experiment conducted in August 1986 in Chesapeake Bay provided field data for model evaluation.

Pacific Marine Environmental Laboratory

The Pacific Marine Environmental Laboratory (PMEL) is a mission-oriented government laboratory that conducts interdisciplinary scientific investigations in oceanography, marine meteorology,

and related subjects. The current PMEL programs focus on climate, marine environmental assessment, marine observation and prediction, and marine resources. Studies are conducted: to improve understanding of the complex physical and geochemical processes that determine the extent of human effect on the marine environment; to define the forcing functions and the processes driving ocean circulation and the global climate system; and to improve environmental forecasting capabilities and other supporting services for marine commerce and fisheries. Products of PMEL's research are environmental information and predictive models; these are disseminated by means of scientific papers, technical reports, and presentations at scientific and public gatherings.

Marine environmental assessment at PMEL emphasizes understanding the complex physical and geochemical processes that ultimately determine the health of the marine system and its ability to assimilate pollutants. Included are studies of suspended-sediment transport and geochemistry, distributions of hydrocarbons and synthetic organics, coastal and estuarine circulation, theoretical modeling of pollutant transport processes, and a program in marine sources of acid rain. Although the geographic focus of these studies has been Pacific Northwest and Alaskan coastal and estuarine waters, the scientific knowledge acquired and methodologies developed are applicable to other marine systems. Two major activities at PMEL are studies of the long-range rate of chronic pollutants in marine waters and oceanic precursors to acid rain.

For more than ten years, PMEL conducted research on the behavior of Puget Sound, the largest marine estuary in the lower forty-eight states. In recent years, considerable emphasis has been placed on the ability of fjord-like estuaries to assimilate pollutant inputs, using Puget Sound as a model system. The entire effort is being synthesized into a report for publication in FY 87. A number of specific activities were underway in 1986:

1. Circulation

   Empirical orthogonal function analysis was used to describe the spatial structure of current fluctuations. At subtidal time scales, three circulation modes are evident: 1) a near-surface (upper 20 m), wind-driven shear; 2) a near-bottom layer (150-200 m) dominated by density currents that propagate up estuary after generation during neap tidal mixing at the entrance sill to Puget Sound; and 3) an intermediate layer (25-75 m) influenced by partial refluxing of Colvos Passage water and modulated at fortnightly periods by nonlinear mixed tides.

The landward intrusion of higher-density seawater over the entrance sill is an important mechanism for deep water renewal in the estuary and for up-estuary transport of material in the bottom nepheloid layer. The intrusions can occur fortnightly on neap tides, depending on the strength of tidal mixing over the sill and the presence of a hydrostatic head of high-density water. The intrusions also drive the downward refluxing of surface water at the entrance sill. A late-summer intrusion was predicted from a tidal mixing analysis using the Froude number and its effect on bottom boundary layer processes was followed.

A linked channel model of tides and tidal currents in Puget Sound, Washington was developed and explored. A network of 79 channels was constructed in a linearized theory. Tidal height and cross-sectionally averaged tidal currents of 8 tidal constituents were computed at over 550 locations (1 km resolution) in the Sound. The theory was tuned to available observations of tidal height by adjusting the friction coefficients for the channels. When compared after tuning with cross-sectionally averaged tidal current measurements, the theory and the data showed agreement to within 5 percent. Results are useful in estimating tidal heights and tidal currents at a multitude of locations in Puget Sound for which no measurements are available.

An analytic model for vertical profiles of steady currents and suspended sediment in shallow water was developed using a simple form of turbulence closure to describe the vertical viscosity and diffusion. They also demonstrate the interaction between wind-driven and pressure-driven currents through the mutual generation of turbulence. A series of tests were run on time-dependent turbulence closure schemes to select an adequate scheme for the laterally-averaged model of density intrusions in Puget Sound. A Level II 1/2 scheme was selected which allows diffusion of shear-generated turbulence into the stratified water overlying the intruding bottom water.

2. Estuarine Chemistry

Accurate budgets for dissolved and particulate lead, zinc and copper, were completed, based on information from source functions, in situ concentrations and settling rates, for the first time in any estuary. In addition, lead, representing a non-conservation species, was incorporated into the steady-state refluxing model. The model is being extended to more of the conservate elements, zinc and copper.

Polyaromatic hydrocarbons in aged-dated cores are being examined. It appears that trace metals such as lead are winnowed and transported horizontally in the bottom boundary layer, whereas PAH remained close to their area of initial deposition. The hypothesis that metals and PAH adhere to particles of different sizes and entities is being examined.

3. Transport

An experiment was carried out in Puget Sound from August 4 to September 6, 1986 before, during, and after a later summer intrusion using the NOAA ship MILLER FREEMAN. Physical, sediment, and chemical observations were made sequentially to provide time series for models under development at PMEL. Analyses of water samples will also be used to identify the types and sizes of particles that scavenge manganese and toxic metals.

A special study was conducted for OAD/N to determine settling spectra for sewage sludge under oceanic conditions.

A special study was conducted for EPA, Region X, on the transport of contaminants out of polluted embayments in Puget Sound, particularly Elliot Bay. The tidal currents are weak and do not substantially resuspend bottom currents. However, surface plumes bearing contaminants from industrialized sites and combined sewer overflows transit the bays in a matter of days, transporting most contaminants to open water in the main basin.

National Sea Grant College Program

1. Environmental Studies

The Sea Grant Environmental Studies of FY 86 consists of 197 research projects conducted at 28 Sea Grant institutions. A total of $6,878,068 in Federal support and $3,567,929 in matching funds was made available for these efforts. Sea Grant environmental studies are grouped into seven topical areas: environmental characterization; nutrient and carbon dynamics; habitat utilization and dynamics; toxicants; human health; environmental management; and special projects. Of these, nutrient and carbon dynamics, environmental management, and toxicants are the largest, representing 36 percent, 17 percent, and 15 percent of the total number of efforts funded, respectively.

A major segment of the Sea Grant environment program (65 percent) relates to estuaries. In FY 86, 127 environmental studies dealt with estuarine questions. These, together with 33 projects sponsored by other Sea Grant divisions, constituted an estuarine program involving 24 Sea Grant institutions that had a combined funding level of $8,773,036 (Federal funds plus match).

The breadth of Sea Grant environmental and estuarine studies was enhanced in FY 86 by augumented cooperative endeavors, especially with NOAA components. For example, pass-through awards permitted the expansion of efforts to investigate the processes, dynamics and effects of oxygen depletion on living marine resources in Chesapeake Bay and in the northern Gulf of Mexico. In addition, pass-through funds enhanced Sea Grant comparative studies of estuarine environmental quality. The development of better-integrated environmental and estuarine studies within the Sea Grant network and the linking of these efforts to investigations being undertaken by other Federal and state agencies are high priorities for the Environmental Studies Division of Sea Grant in the coming year.

2. Fisheries

Research in fisheries consists of 144 projects funded at a level of $4.99 million in Federal funds and $2.99 million in state matching funds. The University of Southern California and Massachusetts Institute of Technology were the only programs which are not supporting fisheries research.

Last year, 69 percent of the projects supported conformed to the annual guidance document, but this year there was only 14 percent conformance. The decrease is attributed to an expected lag resulting from the issuance of a new set of priorities.

Continuing the practice begun last year, program highlights are identified and described. Those included this year are: time-series model improves fishery forecasts (MN); sonar methods accurately counts migrating fish (WA); simulation model of brown shrimp population dynamics developed (TX); young lobsters thrive on red algae (FL); heavy metal pollutants inhibit olfaction in Coho Salmon (OR); acid rain may be effecting salmon sense of smell (NH); urchin roe fishery (ME); selective harvesting methods developed (ME, MIT); scientists evaluate survival of undersized netted fish (ME); parasite leads to high flounder mortality (VA); and lobster disease controlled with antibiotics (ME).

During the upcoming year, a good deal of effort will be spent on developing a Program Development Plan (PDP) for recruitment research and an OAR Long Range Plan section on Fisheries Oceanography. Both planning efforts could benefit university fishery scientists. Two additional areas of focus are the identification of sampling devices needed to successfully pursue fisheries oceanography and evaluation of methods used to deliver information generated by fishery researchers to identified constituents.

3. Coastal Processes

During FY 86, more than $1,300,000 in Federal funds, matched by more than $1,100,000 from the grantees, was applied to research into the study of the motion of the ocean and the resulting form, manner, and rate of change of the coast and seafloor. Nineteen of the Sea Grant programs have one or more projects in this field. The California program has the greatest number of projects, and Delaware, Florida, Maine/New Hampshire, New Jersey, New York, Oregon, and Woods Hole Oceanographic Institute programs have combined dollar efforts exceeding $200,000. The direction of research is predominantly in the broad areas of motion and transport of sediment, covering topics such as waves and currents, geographic changes of the coast and sea floor, transport rates, and the development of predictive models.

The series of hurricanes and "northeasters" which strike the Gulf and Atlantic coasts point out the need for better understanding of seafloor motion responsive to the extreme event, a priority topic. Fifteen percent of total funds are directed to that priority topic this year. Scientists from the global weather and marine communities are increasingly concerned about a projected rise in sea level (as the "greenhouse" effect warms the earth) and the effects that will have on coastal and estuarine regions. Quantifying the role of rising sea level in terms of one to ten decades, and the implications for shore protection and management, are also priority research topics. Twelve percent of funds are directed at these priorities. Rising levels of the Great Lakes are an immediate concern to that coastal region, and on smaller time and space scales is a depiction of what may occur on the ocean coasts. In the Great Lakes, the cause of rising levels is increased precipitation, and because of long-term records, the prediction of future levels can be made to a high degree of accuracy for several months. Nevertheless, the real issue is how property owners (private or public) deal with that reality, and what alternatives are available. Related to coastal protection, for whatever cause, is research to improve the design of presently used standard structures. Eight percent of this current program is devoted to the study and evaluation of coastal protection structures.

Forty-five percent of total dollars in this year's program are directed toward topics identified in the annual guidance as priority. This level is judged to provide for a suitable mix of projects responding to stated needs with projects developed out of needs perceived by the university gene pool.