NOAA'S COASTAL OCEAN PROGRAM

An integrated systems approach to problems confronting our Nation's coastal waters

AN ACTION PLAN FOR

THE COASTAL OCEAN IN CRISIS: Science for Solutions

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
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TABLE OF CONTENTS

EXECUTIVE SUMMARY

The national economy, and especially the local economies of coastal communities, rely heavily on the environmental quality and physical stability of the coastal ocean. When beaches erode and are closed and people can't swim in coastal waters because of pollution, when fish and shellfish cannot be sold because of restrictions on their harvest, and when commercial and recreational fishing declines, the costs affect us all.

Coastal areas of the United States are developing at a rate that exceeds the capabilities of public and private institutions to make decisions that direct growth so that environmental quality and resource values are maintained or improved. This state of affairs affects both the coastal environment and the economy. The direct environmental effects include a pattern throughout the Nation of elevated levels of chemical contamination in coastal and estuarine areas and the living resources that inhabit them, closures of shellfish harvesting areas due to pollution, closures of marine recreational areas and loss of other recreational opportunities due to pollution, shoreline erosion, and loss of habitat (e.g., wetlands and seagrasses). Direct economic effects include the loss of revenues from fishing and marine recreation.

Over the next 10 years, Federal, State, and local governments will make decisions about the use of the coastal ocean that will determine whether this economically and environmentally important area will continue to be a valuable national resource that provides important goods and services to the Nation into the next century. Increasing the capabilities of these decisionmakers to predict and assess emerging problems is the most effective and efficient means for maintaining and improving the environmental quality of the Nation's coastal waters. The central thrust of NOAA's Coastal Ocean Program is to develop the scientific information base and the predictive tools that are needed.

The Coastal Ocean Program focuses NOAA's observational, research, assessment, and modeling capabilities on key problems in the coastal ocean and simultaneously directs the Agency's information management and delivery systems to assure that the findings of the program are accessible and communicated in ways that are meaningful to decisionmakers. The program integrates technical capabilities and resources across all of NOAA's major line organizations to: 1) assure that we are making the best use of the data and information that is already available; 2) carry out research and related long-term observational programs directed at developing a sufficient understanding of the natural system function and variability for assessing and predicting the effects of human activities; 3) deliver information generated by the program in the form of data (and data analysis), predictions, warnings, and advice and comments on proposed actions affecting the coastal environment.

NOAA initiated its Coastal Ocean Program in 1988 with management initiatives toward revitalizing and refocussing its activities to support the three program elements:

1. **Prediction of coastal ocean degradation and pollution**
2. **Conservation and management of living marine resources**
3. **Protection of life and property in coastal areas**

The President's FY 1990 budget request, presently under review by the Congress, includes $5.46 M to fully fund the National Status and Trends Program and $12.4 M to enhance NOAA's Coastal Ocean Program activities focussing on **Program Element 1**.

Major problems to be addressed by the program in FY 91 are:

- Excessive algal growth and associated oxygen depletion, related to nutrient overenrichment and other factors --**Nutrient Overenrichment Program**
- Cumulative effects of environmental change on estuarine habitat structure and quality and its consequences to early life stages and fish community structure -- **Estuarine Habitats Program**
- Cumulative degradation of coastal organisms, sediment, and water by mixtures of toxic chemicals -- **Toxics Program**
- Episodic and persistent physical alteration of coastal systems -- **Physical Impacts Program**
- Effects of varying natural forces on coastal and estuarine living marine resources -- **Coastal Ecosystem Program**
- Impacts of plastic debris on survival and reproductive rates of marine mammals -- **Marine Debris Program**

The FY 91 budget request will enhance elements of the program initiated in FY 90 to address the first two problems and develop new integrated Agency programs to attack the latter four problems. These problems and the programs described to address them span the three Coastal Ocean Program Elements listed above, The actives form major steps toward achieving the overall program goals.

Much of the ongoing and proposed research to address these problems relies on similar sets of basic ocean observations. To meet these needs NOAA is enhancing its coastal ocean observation network of buoys, ships, and other platforms, and is developing the capability to acquire and rapidly disseminate remotely sensed sea-surface temperature, ocean color, and synthetic aperture radar data. CoastWatch, which began in FY 89 as a pilot project to provide near-real time analysis of satellite imagery for anticipating and tracking unusual environmental events, will be expanded to additional coastal sites.

NOAA information delivery systems are being enhanced to support the intent of the Coastal Ocean Program to provide a full and timely mechanism for moving program findings to where they are most needed. These systems serve the needs of the problem-oriented sub-programs and will improve the transfer of data to the scientific community, the transfer of information to the decisionmaking community, and communications within the ocean community.

NOAA must implement this program in concert with other Federal, State, and local programs to maximize the utilization of our scarce resources for dealing with these problems. The spectrum of research and operational capabilities within or directly accessible to NOAA provide the Agency with a unique capability to mount a national coastal ocean program.

I INTRODUCTION

THE COASTAL CRISIS

The Great Lakes and coastal oceans are magnets for living and recreation. These areas frequently are crowded during the summer as a more affluent and leisure-oriented society turns to the Great Lakes and the ocean's edge. The Nation's major industrial centers and urban population concentrations also are centered in coastal areas. Over half of our people now live and work within an hour's drive of the coast. About 40% of American industry and almost half of Canadian industry is located in the drainage basin of the Great Lakes alone. The population density of coastal counties is 5 times greater than non-coastal counties nation-wide; coastal counties of the Atlantic coast are 10 times more densely populated than non-coastal counties.

Our understanding of the ecological importance of the coastal ocean as an important habitat for living resources is also increasing. More than 70 percent of the economically valuable species of fish and shellfish depend on near coastal waters for important habitat. Each year commercial and recreational catch of species dependent on these areas contributes over $13 billion to the U.S. economy. Additionally, recreational fisheries in the Great Lakes alone support a $4 billion industry. The Nation's stake in the coastal ocean, including the Great Lakes, is increasing in both economic and environmental terms, and it is likely to expand.

Hundreds of thousands of people directly derive their incomes from working on or near the coasts. Their environments touch the lives of millions who buy goods transported on their waters, who visit coastal areas for recreation, and who consume products developed from its resources.

Unfortunately, population stress has led to environmental strain. While as a Nation we have obtained significant reductions in the discharge of the "conventional" pollutants from major point sources, population growth and related coastal development continue to place a disproportionate strain on coastal and estuarine areas. The coastal ocean, especially coastal waters around the nation's urbanized estuaries, is suffering from declining health. The summers of 1987 and 1988 brought dramatic pollution events to the Atlantic coast. New Jersey and New York beaches were closed when medical and municipal wastes rode in on the surf. Millions of dead fish were found on the shores of Long Island. Public concern rose after hundreds of dead or dying dolphins washed up on Atlantic beaches from New Jersey to Florida and after accusations of contaminated seafood. We are now at a point where we find it necessary to impose restrictions on where we swim, and on the fish and shellfish we eat. These restrictions heighten public concern and cost U.S. fisherman lost income.

These problems are not new. We continue to lose wetlands at a rate that is harmful to marine life. And despite 15 years of efforts to clean contaminants from the Great Lakes, nursing mothers, pregnant women, and children under 15 are still advised not to eat lake trout and other fish over a certain size because of toxic contamination

Harvest restrictions, potential seafood contamination, and declining stocks of finfish and shellfish in the United States pose serious economic concern. In the Gulf of Mexico, 61% of the shellfishing waters that have been classified have some restriction on harvest, primarily due to inadequate septic systems, sewage treatment, and urban runoff.

Restrictions on shellfish harvest are both serious environmental and economic problems. Maryland's oyster harvest from the Chesapeake Bay has declined 90% from levels 100 years ago. Columbia River Basin salmon and steelhead have declined approximately 75-84% from estimated pre-development levels. In California, chinook salmon spawning habitat has been decreased by 90%, and striped bass populations have decreased 60-80% from their peak introductions in the early 1900's.

Our coasts can also be physically hostile environments. Each year, over a hundred lives are lost and millions of dollars of property are damaged by storms and other natural coastal hazards; in some cases, whole towns have been destroyed. Approximately 50% of the Nation's shorelines experience significant and almost constant erosion at enormous economic and ecological costs. Flooding, beach erosion, habitat modification and loss, structural damage, silting and shoaling are all driven naturally and all pose major adverse economic and public safety consequences. The potential for loss of life and economic devastation grows significantly year after year as coastal populations escalate.

A critical element in the solution of coastal environmental problems is the development, delivery, and use of scientifically sound information. Reliance on fragmented, imprecise, and inaccurate information has often led to environmentally unwise and economically costly decisions. NOAA plays a vital role in the Nation's decisionmaking pprocess by ensuring a solid foundation of facts, findings, and information and by making that information readily available.

NOAA'S ROLE IN IMPROVING ENVIRONMENTAL DECISIONS

Over the next 10 years, Federal and State governments will make decisions about the use of the coastal waters that will determine whether this economically and environmentally important area will continue to be a valuable national resource that provides important goods and services to the Nation.

For example, billions of dollars of both public and private funds will continue to be invested to enact legislation and develop regulations, develop and implement management plans, install and operate pollution control equipment and other measures, conduct waste disposal operations, modify the physical environment, monitor, respond to emergency events, and assess and compensate for damages.

The frequency at which coastal problems now occur and affect the coastal ocean is increasing. A significant time lag exists between the recognition of problems in the coastal ocean and their consequences, the ability of Federal and State decisionmakers to take action, and a measurable change in the condition of the environment resulting form that action. Consequently, decisionmaking at all levels remains after the fact -- addressing yesterday's problems today. Increasing the capabilities of Federal and State decisionmakers to predict and assess emerging problems before they occur -- to address tomorrow's problems today -- provides an effective and efficient means for maintaining and improving the environmental quality of the Nation's coastal waters.

Data and information management, from data collection to information transfer, is an integral component of the complex process that generates new knowledge and understanding. Efficient and effective management of data and information is especially critical in a world in which satellites and computers generate each day mountains of data about selected coastal conditions, but at the same time, which lacks some of the most basic information and fundamental knowledge needed to solve serious problems.

Three user communities require access to NOAA data and information:

(1) scientific community,

(2) decisionmaking community, including NOAA and other Federal, state, local governments and the private sector,

(3) marine operations community.

Each of these groups has different requirements for data and information depending on the time and space scales of the coastal ocean problems they address. For example,

dealing with emergency situations such as toxic chemical spills or red tide outbreaks requires near real-time information with detailed spatial resolution about a particular place. At the other extreme, writing national legislation and implementation strategies to address coastal wetland problems requires information about conditions over longer time periods throughout the United States.

The information currently available to make these decisions remains incomplete and often inadequate and inaccessible to appropriate levels of government and the private sector. Most decisionmakers and scientists continue to address specific problems in selected parts of the coast on a piece-meal basis.

As a result, Federal and State policies for managing coastal waters remain fragmented and disjointed. A great deal of information is available for the Great Lakes and several of the largest and most "visible" estuaries, but much less is known -- as a whole -- about the other ones, or about adjacent coastal waters that comprise the Nation's "coastal ocean".

NOAA plays a vital Federal role in developing and implementing solutions to many of the problems confronting the Nation's coastal waters. That role includes legislatively mandated responsibilities as the Nation's steward for living marine resources such as allocating fish harvests, responding to hazardous spills, protecting of coastal habitats and marine mammals, and formal commenting on permits to allow actions effecting living marine resources and their habitats. The role also includes providing information, advice, and the sound scientific basis for environmental decisions made by other local, state, and Federal agencies. Simply stated, NOAA's role is providing information for effective environmental decisions.

This focus on developing information for the Nation's coastal ocean is enhancing the nature of the traditional role of the National Oceanic and Atmospheric Administration. It requires fundamental changes in the types of products developed; services provided; data collection, research, and assessment activities undertaken; and the timing and manner in which these products, information, and services are developed and delivered.

NOAA initiated its Coastal Ocean Program in 1988 with management initiatives toward revitalizing and refocussing its activities in support of three program goals:

1. Prediction of coastal ocean degradation and pollution

To predict changes in the quality of the coastal environment and its living marine resources to help prevent further habitat degradation and to recommend mitigative measures.

2. Conservation and management of living marine resources

To predict the influence of fishing, habitat degradation (pollution and alteration), and natural forces on living marine resources to ensure optimal productivity today and for the future.

3. Protection of life and property in coastal areas

To predict the occurrence of natural physical hazards, for both short-term warnings and long-term planning, to prevent or minimize adverse effects of storms and erosion on coastal communities.

The President's FY 1990 budget request, presently under review by the Congress, includes $5.46 M to fully fund the National Status and Trends Program and $12.4 M to enhance NOAA's Coastal Ocean Program activities in **Program Element 1.**

The FY 1990 Coast Ocean Program enhancements specifically provide funds for the following activities:

- **Expand the existing NS&T program** to encompass new sites, measurements, and organisms; to evaluate historical pollution trends, including nutrient overenrichment; to assess pollutant levels in fish muscle; and to determine biological responses to pollutants in areas such as Chesapeake Bay, Boston Harbor, Delaware Bay, the Hudson-Raritan Estuary, Long Island Sound, Tampa Bay, Galveston Bay, San Francisco Bay, and southern California.

- Focus **research on sea-grass and tidal-wetland estuarine habitats** to examine their function under natural conditions and their support of important marine life. Of special concern will be the effects of nutrient enrichment, diversion of freshwater flows, wetland habitat loss and alteration, and chemical contamination. This information is essential to develop models to predict cumulative impact.

  The habitat studies, together with another element of the FY 1990 program that uses satellite data to repetitively map the Nation's tidal wetlands to determine their rates of change or disappearance, form a critical basis for implementing the President's "no net overall wetland loss" goal.

- Explore the **effects of nutrient enrichment** associated with human activities on the primary production and water quality of the Nation's coastal oceans, and examine the implications of enhanced production to the global marine carbon cycle. The first study area will be the Mississippi River plume and the adjacent Louisiana Continental shelf.

- Expand our ability to deliver timely information though enhancement of NOAA's new prototype geographic information systems, **GeoCoast** and **COMPAS**. We will examine correlations among contaminant loadings, pollutant concentrations, distribution of living marine resources, and habitats and land use patterns. Prototype demonstrations with selected coastal states will allow users to employ state-of-the-art GIS systems to support their coastal environmental decisionmaking.

  A **CoastWatch** project for the Southeast Atlantic region will continue and one for the Chesapeake Bay will be expanded to include remote sensing to increase spatial and temporal resolution of spring algal blooms thought to be linked to the Bay's oxygen depletion.

  A prototype **Interactive Marine Analysis and Forecast System (IMAFS)** will increase NOAA's ability to access and combine rapidly changing observations with model output and archived data. Aspects of IMAFS database management will become operational, software enhancements will allow display of additional satellite imagery, and additional physical, chemical, and biological historical data sets will be added.

To increase the value and effectiveness of NOAA's input to coastal ocean decisionmaking, in FY 1991 we will continue to improve both 1) the QUALITY of the information and products being delivered (see Chapter II) and 2) the methods of information DELIVERY (see Chapter III).

The information delivered to decisionmakers, both within and outside of NOAA, falls into four categories:

1. **Data** and findings on critical properties, synthesized spatially and temporally and presented in ways meaningful to environmental decisionmakers (e.g., regional maps of annual wetland loss, living marine resource distributions),

2. **Predictions** of environmental change resulting from human activities relative to change expected due to natural forces alone (e.g., interannual trends in important fish stocks, estuarine response to nutrient and toxic loads),

3. **Warnings** of impending danger or damage to humans, property, or living marine resources due to the combination of natural and society's actions (e.g. storm-surge inundation of coastal wetlands and urban areas, land-fall of spilled oil),

4. Formal **advice** and comments on permits allowing actions that effect living marine resources and the habitats upon they depend (e.g., advice to Fishery Management Councils, comments on dredge-and-fill permit proposals).

The effectiveness of information for environmental decisions is highly dependent on three closely related properties:

The quality of the environmental data bases,

The accuracy and precision of predictions and warnings,

The sophistication of the knowledged upon which the predictions, warnings, and advice is based.

Improving the quality of NOAA's products requires focused and purposeful research and model development, both to increase understanding and to improve predictions and warnings (Chapter II).

NOAA will use its observational, research, and modeling capabilities, integrate them with historical data, and provide the information required by individuals, agencies, and institutions responsible for decisions on the following priority coastal issues:

- Excessive algal growth and associated oxygen depletion, related to nutrient overenrichment and other causal factors,

- Cumulative effects of environmental change on estuarine habitat structure and quality and its consequences to fish community structure, particularly to early life stages,

- Episodic and persistent physical alteration of coastal systems,

- Cumulative degradation of organisms, sediment, and water by mixtures of toxic chemicals,

- Effects of varying natural forces on coastal and estuarine living marine resources, and

o Impacts of plastic debris on survival and reproductive rates of marine mammals.

The FY 91 budget request will enhance elements of the program initiated in FY 90 to address the first two problems and develop new integrated Agency programs to attack the latter four problems. These problems and the programs described to address them span the three Coastal Ocean Program Elements listed above, The actives form major steps toward achieving the overall program goals.

The effects of these impacts can be predicted and eventually controlled only if they are understood within the context of natural variability. Because this variability is driven by combinations of processes (e.g., storms, circulation, ecosystem dynamics) controlled predominantly by natural forces, we include complementary research and model development focussing on understanding the natural structure and function of estuarine and marine ecosystems and on predicting change caused naturally.

Finally, the ongoing and proposed research and model development efforts, as well as many of the required data synthesis products, depend on a common suite of observations and delivery mechanisms. Thus, cross-cutting observing and information delivery systems are also planned for initiation or expansion (Chapter III). The common observations include surface and subsurface data gathered from buoys, ships, and other platforms, as well as from space. The delivery systems for improved communication, synthesis, and display of information use state-of-the-art computer technology.

The Program creates flexibility in product generation in response to the relatively rapidly changing suite of coastal problems. These flexible products derive from the six impact-focussed assessment, research, and model development activities that are longer term in nature. The context for the impact-driven research and products lies in NOAA's efforts to observe, describe, understand, and predict natural variability. The overall strategy (Figure: the crown) creates a stable, scientifically rigorous foundation underlying focussed efforts on major persistent coastal problems and a capability to produce and deliver information in response to rapidly changing problems.

The following is a concise lsit of the suite of problems being addressed - some immediately, some over time - within the six sub-programs.

Toxic Contamination	o	Habitat degradation
	o	Closed shellfish beds
	o	Contaminated fish and shellfish
	o	Contaminated sediments
Nutrient Overenrichment	o	Hypoxia/anoxia effects on ecosystems and stocks
	o	Increased primary productivity
	o	Global climate effect
Physical Impacts	o	Coastal flooding
	o	Coastal erosion
	o	Evacuation planning/prediction/preparedness
	o	Pollution transport
	o	Global scale sea-level change
Estuarine Impacts	o	Wetland habitat loss and degradation
	o	Pollution impacts
	o	Overenrichment
	o	Declining estuarine stocks
	o	Contaminated estuarine stocks
Coastal Ecosystems	o	Unpredictable fish abundance
	o	Lack of understanding of critical recruitment processes, especially those related to: - transport processes - ecosystem processes - ocean frontal processes
Marine Debris	o	Marine entanglements
	o	Effects on marine life
	o	Long-term impacts
	o	Plastics

NOAA'S COASTAL PRODUCTS

Specific products, delivered through NOAA's Coastal Ocean Program efforts in FY 1991, include:

TOXICS PROGRAM:

- An expanded National Status and Trends (NS&T) data base of the kinds and levels of toxic organic compounds and associated biological effects in U.S coastal and estuarine waters.
- Reports and articles describing various aspects of the present status and developing trends relative to toxic organics in coastal and estuarine environments.
- An new data base of organic contaminants in fish muscle.
- New methods for monitoring bioeffects in marine biota.
- New methodology for determining the effects of sublethel amounts of contaminants on individuals of key living marine resources and relating these effects to changes in populations and ecosystems.
- New methodology for determining the effects of complex mixtures of toxic compounds on marine species.
- Models to predict the fates and biological effects of toxic organic compounds from physio-chemical structure and biological activity

NUTRIENT OVERENRICHMENT PROGRAM:

- The development of a NS&T data base that will provide the basis for an assessment of the severity of overenrichment problems in the areas studied and on a national basis.
- Annual reports on the status and trends of nutrient overenrichment and its impacts on biological productivity and water quality.
- An understanding of the impact of nutrient overenrichment on the productivity of our coastal and estuarine waters.

- o A capability to predict the impact that nutrient control strategies are likely to have on productivity.
- o A capability to predict the likelihood of hypoxic/anoxic events as a function of physical, chemical, and biological parameters in our estuaries and coastal waters.
- o Understanding of the role that the coastal oceans play in the marine carbon cycle and an estimate of the flux of biogenic carbon to the deep sea from these oceans.
- o The development of new measurement and modeling capabilities in NOAA and in the oceanic community as a whole.
- o Early warning and tracking of noxious algae blooms along U.S. coastal waters.

PHYSICAL IMPACTS PROGRAM:

- o Improved and more complete data sets and models of coastal inundation resulting from tsunamis and hurricane storm surge.
- o A measurement capability for determining the spatial and temporal variability in long-term coastal ocean forces required for interpreting and predicting the response of coastal regions and ecosystems to extreme short-term events and global change.
- o An understanding of the impact of coastal storms on the water levels, circulation, mass transport and energy gradients of the coastal ocean.
- o Improved models of coastal ocean circulation, storm surge, and wave generation/transformation processes.
- o A data base for use by research and management agencies to develop improved prediction and analysis procedures.

ESTUARINE HABITATS PROGRAM:

- o Expanded estuarine assessment capability by inclusion of salinity and bottom sediment profiles in NOAA GIS systems.
- o Development of user-friendly pollutant load estimation and water quality screening models for estuaries.

- Synthesis of understanding of the fundamental processes controlling primary and secondary production in salt marsh and sea grass habitats.
- Determination of the effect of toxics on habitat functioning.
- Assessment of mitigation techniques for sea grass and salt marsh habitats
- Development of methodology to assess cumulative habitat alteration and loss.

COASTAL ECOSYSTEM PROGRAM:

- Identification of the factors that control variability of living resources in ocean ecosystems.
- The ability to distinguish between changes in population abundance or community structure caused by nature and man.
- The capability to predict the consequences of human activities on the living marine resources of coastal environments.
- The capability to forecast the abundance of fishery resources interannually and interdecadally.
- To link ocean physics and climate to economically important biological resources.
- Provide a scientifically sound basis for designing and modifying monitoring programs assessing the impacts of man on coastal ecosystems.

MARINE DEBRIS PROGRAM:

- Chemical evaluation and standard toxicity testing of the natural "degrade" products of new degradable plastics being developed.
- An understanding of pathology and toxicology of plastic debris and degradable plastic products ingested by marine birds.
- An understanding of the effects of mortality caused by persistent plastic debris on populations of affected endangered species.

- o New technology to minimize mortality of fish and shellfish resources due to "ghost fishing" by lost fishing gear.

- o Economic models of the costs of the problems and solutions posed by persistent marine debris which can be adapted for use world-wide.

- o National public service education programs and videos addressing the marine debris issue to stimulate public awareness.

- o Transfer of appropriate new information and technology (e.g. vessel waste handling, toxicity testing, use of degradable plastics to reduce mortality in ghost fishing, etc.) to user groups and industry.

- o A more concerned and aware general public which is the ultimate goal in control of marine debris.

The products outlined above and described more fully in the following chapter do no good unless they are put in the hands of the those that need them. Individuals and institutions requiring and depending on NOAA's data and information are diverse. They include laboratories and programs within NOAA and within a wide range of other Federal agencies (e.g., EPA, MMS, COE, Navy) that have regional and national responsibilities for protection and restoration of the Great Lakes and marine environment. Users of NOAA products also include state and local units of government. These decisionmakers are much closer to the coastal problems and therefor closer to their solutions. One of NOAA's roles in the many Federal-state partnerships (e.g., the Coastal Zone Management Program) is to provide consistency in the intent of state and local regulations and in the data and information upon which those regulations are based. Federal and academic researchers also depend on access to NOAA's data, information, and infrastructure. The nature of research in the Great Lakes and coastal oceans is large-scale, interdisciplinary, and complex. Only NOAA has the capability to provide the researcher with the required suite of multidisciplinary data on time frames ranging from real-time to decadal.

To increase access and quality control of NOAA data and information, we focus specific attention on its delivery mechanisms. Specific products deriving from FY 1991 efforts include:

INFORMATION DELIVERY SYSTEMS:

- A real-time data synthesis, analysis, and delivery system capitalizing on remote imagery;

- An interactive and integrated marine analysis and forecasting system, designed to manipulate, display, and superimpose relatively rapidly changing data and model-derived distributions of critical physical, chemical, and biological ocean data;

- A user-friendly, micro-computer based geographical information system (GIS) designed for routine coastal ocean assessments at the Federal, state, and local level;

- An ability to access bay and harbor physical oceanographic data and model output in real time to improve efficiency and safety of maritime commerce;

- Improved ocean communications by connecting national hubs together to form the backbone of NOAA's ocean communication network.

II THE PROBLEMS AND NOAA'S RESPONSE

The problems confronting the Nation's coastal waters are not simple ones. They are complicated by dynamic and complex ecosystems and their interactions with man. To poise the Nation in a position to solve today's crises, but also to anticipate and optimally prevent tomorrow's problems, NOAA plans a set of coordinated assessment, research, and model development projects focused on critical issues. These issues and the associated programs are:

- Toxic contamination of coastal and Great Lakes' waters and its impact on living marine resource development and use - **Toxics Program;**
- Nutrient overenrichment of coastal and estuarine waters and its impact on algal overproduction and subsequent potential impact on for dissolved oxygen depletion and the global carbon cycle - **Nutrient Overenrichment Program;**
- Physical impacts of storm-induced coastal inundation and shoreline erosion and its influences on coastal development and wetland habitat loss - **Physical Impacts Program;**
- Alteration of estuarine habitats and its influence on living marine resources - **Estuarine Habitats Program;**
- Distinguishing natural ecosystem change from that induced or exacerbated by human actions - **Coastal Ecosystems Program**; and
- Persistent marine debris and its impacts on marine life, the coastal environment, and the economy of the coastal zone - **Marine Debris Program.**

While these research and model development efforts have several common themes, particularly with respect to data requirements and the understanding and description of underlying natural physical and ecological processes, each are described separately below.

TOXIC CONTAMINANTS

Background

U.S. coastal (particularly estuarine and Great Lakes) waters provide essential spawning and nursery habitat for many important living marine resources of commercial and recreational importance. Human activities adversely affect these resources through the release of many different contaminants to the coastal, estuarine, and Great Lakes ecosystems including polychlorinated biphenyls, chlorinated dioxins, petroleum hydrocarbons, and heavy metals. Contaminants degrade essential habitats of important living marine resources and may affect entire ecosystems, including human consumers and other apex predators. NOAA's Status and Trends program has shown that toxic organic compounds are widespread in the coastal and estuarine environment.

The Federal Plan for Ocean Pollution Research, Development, and Monitoring: Fiscal Years 1988-1992 specifies six major research goals of the national marine pollution program. The goal for toxic materials is:

> Understand the sources, fates, and effects of toxic materials entering the marine environment as a result of human activities.

Key management questions to be addressed are:

1) What is the distribution, both spatially and quantitatively of toxic contaminants?

2) What are the mechanisms that influence exposure patterns and bioavailability of toxic contaminants in the marine environment?

3) What are the effects of toxic contaminants on marine organisms and populations and how are these effects connected to the organism's exposure?

4) What is the toxicological risk to top level consumers, both aquatic and human?

The Program

NOAA's program in toxic contaminants must address assessment, a definition of the current and continuing problem, while developing models to predict future events and provide options for management and remediation. The research program is a coupled

program of simulation and prediction modeling combined with research in ecosystem processes and is focused on the issues of loads, transport and fate, exposure, and effects on populations, communities, and ecosystems.

Ongoing research in NOAA and other agencies has focused primarily on acute and sublethal effects of toxic chemicals on individual organisms. The next level of complexity that needs to be addressed is the effects of complex mixtures of contaminants on individuals and the impacts of these effects on growth and reproduction and on the integrity of populations and ecosystems. In addressing this need, it is necessary to understand the biogeochemical processes that affect the chemical structure and bioavailability of the toxicant. Similarly, it is necessary to understand the synergistic or antagonistic effects of mixtures of contaminants.

The NOAA program will significantly advance our understanding of the levels and impacts of toxic organic compounds in the marine environment. A major advance in the capability to predict the fates and impacts of toxic organics in the marine environment will result.

A. Assessment

The purpose of the toxics assessment, carried out through NOAA's Status and Trends (NS&T) Program, is to determine the current status and detect changes in the levels of toxic contaminants and their effects in the coastal waters of the United States. This assessment is structured in a three-tiered design which provides a cost-effective method for collecting information at varying levels of detail.

The first tier is design to obtain field measurements of contaminant concentrations in biota and sediments at a national network of sites to provide warnings as to which regions are of greatest concern. The second tier involves using all available historical data and information to assess the present state of knowledge of conditions in the regions indicated by the first tier as having the highest level of contaminants and associated effects. The third tier includes detailed field studies in the regions indicated by the first two tiers as having substantial environmental degradation. Intensive multi-year sampling programs are carried out to determine the magnitude and extent of degradation in these regions.

INSERT NS&T 3-TIER FIGURE

To improve the ability of this program to assess degradation due to toxics and to detect trends in these conditions, it is proposed to expand the program in several ways:

(1) The number of second and third tier surveys will be increased. This will provide an expanded capability to assess the magnitude and extent of environmental degradation in regions where there are first tier indications of substantial problems.

(2) Measurements of contaminants in fish muscle will be added in both the first and third tiers to augment the presently measured concentrations in livers. These measurements of fish muscle concentrations will provide a greatly improved ability to evaluate environmental degradation in terms of measurements of immediate concern to the public.

(3) A research program to identify and evaluate improved measures of the ecological effects of toxics will be conducted. This program will develop methods that can be carried out as part of the NS&T program to provide inexpensive and efficient indicators of the environmental conditions at the sampling sites.

NOAA, because of its existing expertise in bivalve monitoring programs, will represent United States interests in International Mussel Watch. In addition to expanding the NOAA National Status and Trends Program into the U.S. areas of the Caribbean region, NOAA will assist in the development of overall program protocols and procedures to ensure international compatibility with the U.S. program.

B. Effects-Contaminants Data Base

The NOAA National Status and Trends (NS&T) Program and other past and present monitoring programs have extensive documentation of chemical contamination of the marine environment. High concentrations of toxic organic contaminants may give warning of possible biological effects but the interpretation of contaminant data is hampered by the lack of an organized database indicating contaminant levels that are never, sometimes, or always associated with bioeffects.

NOAA will assemble information on end-points of unacceptable contamination such as criteria, standards, action levels, EC 50s, AETs, SLCs, and NOELs from available sources. Where these end-points have not been derived, but where the data to do exist, synoptically-collected biological and chemical data from field studies and laboratory experiments will be identified and gathered into an effects-contaminants database. These data will be evaluated through various analytical methods to determine effects-contaminants relationships.

The database initially will consist of three files: one each for sediments, bivalves and fish, the three media presently analyzed in the NS&T Program. Each will accommodate both measures of chemical contamination and bioeffects and include results of field

studies and laboratory experiments. Data from NOAA-conducted or -supported studies will be entered first and serve as the prototype in developing file formats. Data from studies performed by others in areas sampled by the NS&T Program will be given high priority.

In FY 1991, the relationships between the synoptically-collected bioeffects data and the chemical data will be determined through iterative manipulations of the data. The relationships observed in each data set will be compared with those observed in other data sets to establish a preponderance of evidence. Estimates of the contaminant levels never associated with contaminant-induced effects would be made along with estimates of the ranges in which effects are sometimes observed and always observed. Estimates such as AETs will be made and compared with estimates made through other manipulations of the same data. The resulting estimates would be compiled in large tables in which the no, low, and high effects concentrations are compared. Effects-contaminants relationships for individual regions will initially be kept separate, but may be merged in the second year of the effort.

Estimates of AETs and other similar concentrations that are based upon data from field studies of chemically complex mixtures have an inherent weakness of not accounting for additive and synergistic effects. The estimates made from these field studies will be compared with those made with single chemicals in laboratory bioassays.

The resources requested in FY 1991 will be used to compile data files, analyze the data, and synthesize the results in a form useful to coastal decisionmakers. For measures of environmental quality to be used effectively in decisionmaking, they must include indications of ecological consequences to the market and non-market values of coastal resources. In FY 1992-93, NOAA will use the results from toxicant research, simulation, and modeling, from coastal and estuarine ecosystem studies, and from NOAA's robust coastal ocean characterization and living marine resource databases to synthesize, assess, and deliver information through the scientific literature, reports and presentations, and its Coastal Ocean Management and Assessment System (COMPAS See Chapter III).

C. Research

NOAA's research program in toxic organic compounds will address the management questions presented in the Federal Plan cited above. A research program in simulation and prediction modeling will be coupled with research on ecosystem processes focussing on transport, physical fate, transformations, and uptake of toxic organics. Additional programs will develop an understanding of the effects of mixtures of toxic organics on key marine species and develop an understanding of the sublethal effects

of toxic organics with emphasis on the relationship between the effects on individuals and the integrity of populations. The research will focus on those organic compounds of major concern in the marine environment such as halogenated compounds (e.g., dioxins and polychlorinated biphenyls), polycyclic compounds (e.g., aromatic hydrocarbons), and a variety of pesticides.

The research program consists of the following four elements, each closely tied to the Estuarine Ecosystem research efforts described later in this chapter.

(1) Simulation and Prediction Modeling - Because of the large number of toxic organic compound in the aquatic environment and the diversity of sources, it is impractical to expect complete studies of all polluted areas with all chemicals and biological species present. It is therefore important to develop an understanding of the processes that can affect a chemical's fate and transport and, through the use of structure-activity relationships, develop and verify models to predict such fates and transport for important classes of compounds. A similar use of structure-activity relationships, once developed, will assist in predicting effects and performing risk assessments.

The modeling research will validate existing models for sediment mixing, particle resuspension, and physical and food chain transport. A hierarchy of physical and biogeochemical models will be developed, calibrated, tested, and improved through application to coastal, estuarine, and Great Lakes ecosystems categorized in terms of dominant processes and characteristics (physical, biological, chemical, and geological). The transferability of these models from one aquatic system to another will be tested in selected coastal systems.

(2)eEcosystem Processes - The data to support the modeling effort is based one developing an improved understanding and numerical formulations for major ecosysteme processes related to the behavior of toxic organic contaminants. The first-ordere processes important to these models include sorption/desorption, degradation, biologicale uptake, biotransformation, and transport, including the basic ecosystem functions ande hydrodynamics. The major processes are identifiable, experimentally manageable, ande generic to most aquatic ecosystems. The mathematical formalisms for many of thesee processes already exist, but these numerical hypotheses have been tested on only ae limited basis. A laboratory and field program will interact with the modeling studies toe develop and measure rates of these key physical, chemical, and ecological processes.e

(3)eSublethal Effects and Populations - Although a wide range of sublethal stresse indices have been proposed for evaluation of chronic responses of organisms toe contaminants, few have been linked to the survival potential of the individual or thee reproductive potential of the population. The research program in this sub-area will 1)e

conduct experimental studies directed at determining sublethal effects of mixtures of contaminants on individuals, including changes in energy metabolism; at evaluating the influence of these effects on growth and reproduction; and at determining links between effects on individuals and effects on higher levels of organization, (2) develop an understanding of the relationship between bioavailability, bioaccumulation, and the pharmacological and toxicological effects of organic contaminants, and (3) determine the physiological and molecular processes involved in uptake, retention, and loss of lipophilic contaminants; the toxicity and transformations of lipophilic contaminants; and the interactions between developmental, reproductive, and energetic abnormalities;.

(4) Interactive Effects Studies - Multivariate statistical techniques will be combined with laboratory mechanistic studies of the mode of action of classes of compounds as a method to understand the interactions of complex mixtures of compounds on test organisms. In this way, instead of dealing with many compounds, the effects of several classes of compounds could be studied. A knowledge of the mode of action and relative potency of each compound in a class of chemicals is needed to do this. Therefore, NOAA will conduct a research program to investigate the relationships between sublethal effects observed in field and laboratory studies and exposures to complex mixtures of chemicals, and will use the results in models to predict the relative toxicity and interactive effects of important classes of chemicals.

D. Products

Products of the NOAA Toxics program will include:

* An expanded data base of the kinds and levels of toxic organic compounds and associated biological effects in U.S coastal and estuarine waters.

* Reports and articles describing various aspects of the present status and developing trends relative to toxic organics in coastal and estuarine environments.

* An new data base of organic contaminants in fish muscle.

* New methods for the monitoring of bioeffects in marine biota.

* New methodology for determining the effects of sublethal amounts of contaminants on individuals of key living marine resources and relating these effects to changes in populations and ecosystems.

* New methodology for determining the effects of complex mixtures of toxic compounds on marine species.

* Models to predict the fates and biological effects of toxic organic compounds from physio-chemical structure and biological activity

* Development of a data base which relates contaminant levels with bioeffects.

E. Benefits and users.

The assessment program will define the extent of the current contaminants problem in coastal and estuarine environment as well as evaluate the success of remedial actions. The research will result in the development of cost effective methods for the prediction of fate and effects of new chemical compounds from a minimum of chemical, physical, and biological data. The data base relating contaminants and bioeffects will serve to alert managers to potential and actual impacts of toxics in the environment.

Major users of the products of the program would include the EPA, the F&WS, state and local regulatory agencies, NOAA's Habitat Conservation Program, industry, and the scientific community.

F. Participants

The toxics program will involve the Status and Trends program of NOS, Environmental Research Laboratories and academic investigators of OAR, and laboratories of the NMFS.

NUTRIENT OVERENRICHMENT AND ENHANCED PRODUCTIVITY

Background

Evidence is mounting that society is adding very large quantities of nutrients to coastal waters with subsequent impacts that can be deleterious to the quality of our estuarine and coastal waters. A worldwide comparison of riverine nitrogen inputs from areas of high population density and development versus areas of low population density and development shows that nitrate nitrogen can be greater by a factor of 10 to 30 in rivers flowing through developed regions. In the U.S., the concentration of nitrate in the Mississippi below New Orleans has increased from about 1 mg-atm/l in the late 50's to 2.2 mg-atm/l in the early 80's. In fact, even in less well developed U.S. coastal regions, nutrient inputs to our coastal oceans are steadily increasing. For example, in the Althamaha River of North Carolina, the nitrogen concentration has tripled from 10 to 30 ug-atm/l since 1960.

Our understanding of the effects of such increases in nutrient input and consequent stimulation of biological primary productivity is limited and their full impact can not be predicted. Episodes of hypoxia (low dissolved oxygen) and anoxia (no dissolved oxygen) in our coastal waters appear to be developing in areas such as the Louisiana continental shelf and the New York Bight region. Hypoxia and anoxia can lead to the death of the benthic marine biota within the impacted area and the displacement of mobile, or migratory, species. In addition, depending on the severity and duration of the event, drastic chemical changes can occur in coastal waters with concurrent changes in biology and trophic structure.

Aside from hypoxia/anoxia events, the stimulation of the biological primary production of our coastal oceans by anthropogenic nutrient inputs may well have other serious consequences. This stimulation, or eutrophication, may impact our coastal ecosystems by altering species distribution and abundance of phytoplankton. This change in food supply could have serious impacts on the herbivorous species that form the base of our commercial fisheries. Unwanted plant materials accumulate on beaches and in the water and interfere with beach use, swimming, and other recreational activities. Blooms of noxious algae result in fish kills and are often a danger to human health.

Finally, the input of significant amounts of anthropogenic nutrients may play an important role in climate and global change. We do not have an accurate estimate of the degree to which the oceans remove fossil fuel CO2 from the earth's atmosphere by photosynthetic fixation followed by transport to deep ocean waters and ultimate burial in sediments. This information is necessary if realistic predictive models of climate change are to be developed. Biological removal of carbon requires the utilization of

new nutrients rather than those released by the decay and recycling of marine organic material. Input of large quantities of nutrients into the coastal oceans may be a major source of the required new nutrients on a global basis.

On a national scale, then, nutrient overenrichment is one of the most serious problems in our coastal marine environment, with impacts on fisheries, the recreational uses of the seashore and coastal waters, and global change.

The Program

A. Assessment

The National Status and Trends Program will be expanded to include a national assessment of the severity of nutrient overenrichment problems in U.S. coastal and estuarine waters. A preliminary study has identified 12 areas of high concern with respect to nutrient overenrichment and 12 additional areas of less but still substantial concern.

As an initial step in this expansion, a more detailed evaluation of existing and potential overenrichment problems will be conducted. Based on this survey, a program to monitor the conditions associated with nutrient overenrichment and potential hypoxia/ anoxia problems will be initiated in the areas where substantial existing problems are identified. It is estimated that this will involve 20 to 25 areas. These efforts will rely on cooperation with existing local and regional efforts wherever possible. Measurements will be conducted a number of times throughout the spring and summer to follow nutrient concentrations, biological productivity, and associated changes in water quality parameters such as dissolved oxygen levels.

The assessment program will be conducted as follows:

1) Periodic cruises in each of the areas of concern will be conducted to measure key physical, chemical, and biological parameters that are indicative of trends in eutrophication and nutrient overenrichment.

2) Remote sensing from aircraft and satellites to provide wide areal and temporal coverage of biological productivity and water quality.

3) Utilization of buoys and other platforms to provide continuous time series measurements of dissolved oxygen and key physical parameters such as temperature and salinity.

C. Synthesis Activities

NOAA will gather information to develop a consistent characterization of problems associated with eutrophication (e.g., algal blooms, anoxia, hypoxia, fish kills, and species shifts). This effort will initially use existing data but will be continually updated with new data from the assessment and research programs. The data will be combined with existing nutrient susceptibility analysis to assess the potential impact of reducing nutrient loadings.

NOAA will define a consistent set of measures (e.g., dissolved oxygen, turbidity, primary production, chlorophyll) that can be compared across estuaries. These data, when coupled with systematic problem identification, will be used to characterize the present extent and potential increase of eutrophication. By using standard protocols for data gathering and synthesis, criteria will be established and used to classify each of about 120 estuaries and coastal ecosystems based upon existing levels of eutrophication. Project results will be entered into NOAA's GeoCoast GIS system and the Coastal Ocean Management Planning & Assessment System, COMPAS (see Chapter III).

The characterization of eutrophication problems, coupled with ongoing nutrient susceptibility analysis will be used by water quality and resource managers to evaluate the extent of current and potential eutrophication problems and the ability to achieve alternative water quality objectives through nutrient load reductions.

C. Research

Two main areas of research on nutrient overenrichment will be undertaken in FY91. First, the program initiated in FY90 to investigate the impacts of nutrient enhanced coastal ocean productivity will continue in the Mississippi River Plume/ Louisiana Shelf region and will be expanded to initiate a study in the Southeast Atlantic Bight. A second research effort will focus in determining the importance of the atmosphere in transporting nutrients to east coast coastal waters. A preliminary study by the Environmental Defense Fund suggests that one-third of the nitrogen supplied to Chesapeake Bay may come through the atmosphere.

1. Nutrient Enhanced Productivity

NOAA will, in FY91, continue and enhance the study of the causes of hypoxia on the Louisiana shelf approved for initiated in FY90. A detailed implementation plan has been developed to reach the stated goals and develop the specified products within the 5 year time frame of this program.

In addition, NOAA will expand its nutrient enhanced productivity studies to begin a project focused on the South Atlantic Bight. As with the Mississippi River / Louisiana Shelf Project, the emphasis will be on the impact of added nutrients on the productivity of the Bight's waters. NOAA will cooperate closely with the Department of Energy in thise program. DOE has an existing program on the outer shelf which complements NOAA'se proposed program nicely.The key objectives of this research program are to: 1)e Determine if there has been significant enhancement of coastal primary productivity ine areas impacted by anthropogenic nutrient input, 2)Determine the impact on water qualitye (especially dissolved oxygen content) by this enhanced productivity, and 3) Determinee the fate of the carbon fixed in these areas of enhanced productivity and its impact one productivity of the upper trophic levels and the global marine carbon cycle.e

The coastal ocean productivity research program contains the following major technicale components:e

1)e A physical oceanographic program to determine the coastal ocean structure ande circulation that provides physical forcing and responses that control nutriente distributions and primary production.e

2)e A chemical/biological program to measure the distribution of nutrients in the coastale ocean areas and the primary and secondary productivity of the study areas as ae function of space and time.e

3)e A remote sensing program utilizing satellite and aircraft AVHRR and ocean colore measurements to provide coverage of coastal ocean productivity over extendede space and time periods. Additional remote sensing activities utilizing optical ande acoustic systems will be deployed on buoys and drifter platforms to complemente the observations from satellite systems.e

4)e A modeling program to develop or adapt a variety of models needed as part of thee research effort and to provide predictive capabilities for management.e

2.eAtmospheric inputs of Nutrientse

It has just been recently recognized that the atmosphere can be a significant source of nutrients, especially nitrogen, to the estuaries and coastal waters of the U.S. A recent evaluation of nitrate input to Chesapeake Bay suggests that 30-40% of the total nitrogen input to the Bay may come via the atmosphere through deposition directly to the Bay's waters or its watershed. If confirmed, this input represents a previously unrecognized non-point source of nutrients to U.S. coastal waters.

Prevailing wind patterns suggest that the waters of the U.S. east coast are most likely to be impacted by nutrients delivered via the atmosphere. Many bodies of water along this coast show signs of eutrophication and the development of effective nutrient control strategies is a priority task. This cannot be accomplished without a thorough understanding of the nutrient source functions including atmospheric deposition.

The research program will focus on: 1) Quantifying the deposition of nutrients in selected test areas with emphasis on the east coast sites, 2) Determining the seasonal variation of nutrient transport, 3) Developing and modifying models of atmospheric transport and input to coastal waters, and 4) identifying source regions of these nutrient fluxes.

Specific elements are:

1. Analyze Existing Data. Available deposition data from coastal sites will be analyzed to give a gross estimation of nutrient deposition to coastal watersheds.

2. Field Studies. Intensive field studies will be made to test the ability of models to assess deposition to extensive water areas and to develop methodology for relating catchment deposition with inputs to coastal waters.

3. Construction of New Atmospheric Transport Models. Based on the research program, improved models will be constructed. These models will provide estimates of nutrient transport and deposition, catchment efficiency, and the identification of nutrient sources.

D. CoastWatch Water Quality Applications

Blooms of noxious algae (red and brown tides) and episodes of anoxic/hypoxic waters are occurring on a global basis at increased frequencies. While the causes of these noxious blooms are not well understood, inputs of large amounts of nutrients to coastal ocean waters are strongly suspected to be a major factor. NOAA's Coastwatch capability will be used for early detection of these blooms in U.S. coastal waters. Two prototype CoastWatch areas are currently being developed, one covering the central North Carolina coast, and another covering the Chesapeake Bay. Requirements analysis, research, product development, sample product production, personal computer (PC) image display software development, and prototype demonstrations will be conducted for these areas during FY89. During FY90, products for these regions will be operationally implemented, including automated products, archive creation, and high-speed communication of products and data. In subsequent years, similar activities

will be developed for other NOAA CoastWatch regions. A more detailed discussion in Chapter III illustrates prototype CoastWatch regional boundaries for the southeast, the Chesapeake Bay, the Gulf of Mexico and the West Coast.

E. Products

* An understanding of the impact of nutrient overenrichment on the productivity of coastal and estuarine waters.

* The development of The NS&T data base that will provide the basis for an assessment of the severity of overenrichment problems in the areas studied and on a national basis.

* Annual reports on the status and trends of nutrient overenrichment and its impacts on biological productivity and water quality.

* A capability to predict the impact that nutrient control strategies are likely to have on productivity.

* A capability to predict the likelihood of hypoxic/anoxic events as a function of physical, chemical, and biological parameters in our estuaries and coastal oceans.

* Understanding of the role that the coastal oceans play in the marine carbon cycle and an estimate of the flux of biogenic carbon to the deep sea from these oceans.

* The development of new measurement and modeling capabilities in NOAA and in the oceanic community as a whole.

* Early warning and tracking of noxious algae blooms along U.S. coastal waters.

F. Benefits and users

The NOAA program on nutrient overenrichment will provide the first comprehensive study of the impact of man's addition of large quantities of nutrients to our coastal and estuarine waters. The products listed will be of use to the EPA and state regulatory agencies, public health officials, and the scientific community.

G. Participants

Participants will be NS&T, Ocean Observation, and Strategic Assessment programs of NOS, the ERL and academic scientists of OAR, NMFS laboratories, and NESDIS.

EXTREME EVENTS: PHYSICAL IMPACTS

Introduction

This component of the Coastal Ocean Program outlines a two-phase effort to: 1) enhance existing research and modeling efforts to provide immediate benefits related to short-term coastal flooding and 2) develop a longer term effort to conduct rational, progressive investigations of extreme events affecting coastal ocean resources, particularly those very near the shoreline. General concepts are presented as well as specific initial steps which build upon existing NOAA capabilities and plans. A minimum 10-year effort is envisioned in order to obtain sufficient data and knowledge of the variability and interactions associated with episodic coastal weather phenomena.

A. Background

Unlike its deep ocean neighbor, the shallow coastal ocean responds rapidly to numerous atmospheric and oceanic forces. These forces drive the exchange of a wide range of materials derived from natural weathering of the continent and man's use of rivers and estuaries, and control to a great extent the distribution of drifting life forms. Extreme events such as hurricanes and extra-tropical storms generate winds, waves and currents which are particularly effective in rapidly altering water column, coastal margin, and sea bed regimes. Coastal populations and property are also threatened by flooding associated with earthquake-generated tsunamis, a very real hazard on the U.S. Pacific Coast. Although short-lived, these episodic processes, integrated over the long-term, profoundly affect the character and populations of coastal environments. As important as these events are to man-made and natural coastal resources, very little is known about the quantities of mass and energy that are exchanged across the boundaries of the coastal ocean. This program addresses the data and research needs which must be met before our understanding and prediction of the impacts of severe events can be enhanced sufficiently to develop preventive measures.

B. Rational and Applications

NOAA has an historic interest in and a national responsibility for measuring and predicting the physical processes of the coastal ocean and providing early warnings against hazardous natural conditions. Its component organizations possess the wide-ranging capabilities needed to address the three conditions necessary for effective decisions regarding physical forces: high-quality, comprehensive data; simulation techniques for predictions and warnings; and fundamental understanding. Within the past few years, NOAA has made three major long-term commitments: 1) modernization

of weather services, 2) predicting climate and global change, and 3) predicting coastal ocean change.

This physical oceanography component is the critical link necessary to unify NOAA's new capabilities and interests with historic missions related to coastal hazard mitigation, for it is the long- and short-term physical processes which manifest the most dramatic impact upon our coastal citizens and their commercial activities. Every resource and discipline (chemical, biological, and geological) relies upon a fundamental understanding of the physical boundary conditions and transport processes to explain the distribution and ultimate fate of their components. The rationale for enhancing NOAA's efforts in coastal physical oceanography is expanded upon briefly in the following paragraphs.

Coastal Hazards. In one way or another U.S. coastal populations, resources, and environments are periodically impacted by extreme natural phenomena, often with resulting loss of life and extensive property damage. Whether they are East Coast northeasters, Gulf of Mexico hurricanes, Great Lakes frontal systems, or Pacific coast tsunamis, mitigation of and recovery from the effects of flooding, shoreline erosion, channel and harbor sedimentation, and wave action costs U.S. interests billions of dollars each year. Our understanding of these phenomena and their impacts has been hindered in past years by a paucity of reliable, sophisticated instrumentation with which to obtain the data necessary for determining their spatial and temporal variability. As a result, NOAA's marine hazards work has focused on development of models for predicting hazardous conditions for marine warning and forecasting services. Further improvement of such models, as well as the development of engineering and management alternatives to mitigate the costs of storm damage demand not only more information on the magnitude and distribution of the forces, but a commitment to greatly improving our fundamental understanding of how these forces interact across the shore face to transport sediment, water, pollutants, and organisms.

Global Change. If the scenarios for global change are even partly correct, large-scale changes in atmospheric forcing (e.g. increased storminess) and ocean characteristics (e.g. temperature and sea level rise) will produce a disequilibrium between the short-term processes and their interaction with the coastal boundary. Nature abhors disequilibrium, and the restoring forces of the coastal ocean will not necessarily be kind to man's interests. In order to plan for and/or mitigate against the undesirable aspects of nearshore responses to global change, we must have improved regional numerical models, firmly grounded in field observations, which accurately reflect our increased knowledge of atmospheric and oceanic interactions.

Water Quality and Cross-shelf Exchanges. Weathering of the continental landmass produces large quantities of fine-grained sediments, some produced by erosion of the

adjacent beaches, bluffs, and cliffs, but much derived from interior regions. Rivers deliver these and other particulates (the byproducts of man's industrial and societal activities, including toxics, nutrients, and bacteria) to the coastal ocean, where they are distributed both alongshore and across the shelf, most effectively by storm-induced waves and currents. Based on surveys and sediment cores, we know that much of this material is deposited on the shelf, while significant quantities cross the shelf and are eventually deposited on the continental slope. We do not know how rapidly these processes occur, nor the pathways taken. In order to reduce the economic losses associated with erosion of the nearshore and the extreme costs of removing sediment from navigation channels, we must develop improved engineering models founded upon a basic understanding of the processes.

Because of the potential importance of the coastal sea bed to future mineral explorations, NOAA and the US Geological Survey have established a joint office for mapping and research in the Exclusive Economic Zone (EEZ). An additional NOAA/USGS mapping initiative has been established for the Great Lakes. This physical oceanography component of the Coastal Ocean Program will provide the scientific basis necessary for proper interpretation of maps and related products, since the cost-effectiveness of marine explorations and mining can be significantly enhanced when the exchange processes controlling material distribution and deposition are known or can be predicted.

Objectives

The primary objective of this physical-impacts component of the Coastal Ocean Program is to develop quantitative understanding and time-dependent dynamical models of the severe atmospheric and oceanic processes impacting coastal resources and controlling the cross-shore exchange of matter and energy within the coastal ocean. As discussed in more detail below, the improved models will be used in part to meet NOAA mission requirements for early warning of marine hazards (storm surge and flooding, shoreline erosion, and extreme waves) such that threats to lives and property are reduced. **A second objective is to provide other components of the Coastal Ocean Program with the physical data necessary to interpret and predict the complex biological and chemical processes affecting man's interests and activities in this region.**

C. The Program

The major elements of the program are 1) long time-series measurements of forces and response, 2) process-oriented research on severe atmospheric forcing of the coastal ocean, 3) pilot projects to enhance ongoing NOAA efforts and take immediate

advantage of recent technological advances to mitigate costly impacts of coastal hazards, and 4) long-term development of improved models for predictions and warning. A critical assumption is that coastal ocean and boundary responses to severe weather phenomena and other hazards can be characterized on a regional basis. This will allow process and time-series measurements made in "representative" portions of the region to reflect the predominant set of conditions affecting a much larger area. However, neither all conditions nor all areas can possibly be investigated. Verified, comprehensive models are required to transform the results of the regional field analyses into predictive tools for the wide range of catastrophic forces affecting coastal areas.

This program will focus on developing a quantitative understanding and modeling capability for processes affecting the following regions: Great Lakes; Gulf of Mexico; Mid-Atlantic coast (Delaware to Georgia); and Pacific Coast. Pilot projects for improved early warnings and prediction of tsunamis and hurricane surge will be initiated immediately. The framework for the long-term measurement and research programs will be established concurrently. Following establishment of the long time-series measurement systems, an ordered set of process-oriented large-scale experiments will be conducted to address an increasingly complex set of hypotheses regarding the physical nature and interactions of coastal oceanographic processes.

1. Long Time-Series Measurements. Building upon NOAA's existing capabilities and data networks for measuring lake and ocean water levels and currents, and designed in concert with the Enhanced Coastal Ocean Observation Network (described in Chapter III), a series of long term measurements will be initiated to meet two fundamental program requirements. The first is for sufficiently long and complete data sets such that the temporal and spatial variability in forces and response can be statistically quantified, and thus provide accurate data for input to local and regional models. The second need relates to the follow-on set of process experiments, which will use the data to plan the location and spacing of more dense arrays and integrate the long-term instrument capabilities into the short term measurement suites. **The data will also meet the needs of investigators from other disciplines who need to understand the physical processes affecting chemical and biological variability.** Additional benefits derived from these measurements include sea-truth data for satellite observations and opportunities for testing and calibrating new oceanographic instruments. The long-term measurements concept includes:

- Cross-shore arrays of fixed instrument packages extending from the shoreline to the edge of the continental shelf. Instruments include an anemometer, a directional wave gage, water level recorder, remote acoustic doppler current meter (for vertical profiles of storm-induced currents), near-bottom suspended sediment sensors, and

bottom mounted video camera. Measurements will be obtained within each region identified for future process research studies, and must be located on "representative" cross-shore transects which will reflect regional environmental response to large-scale forcing.

- Sequential satellite sensor overflights and interpretation of atmospheric and oceanic storm phenomena controlling large-scale circulation and wave generation in the coastal ocean regions of interest.

- Sufficient bathymetric and side-scan surveys to accurately determine seasonal changes in bottom topography resulting from the impact of coastal storms in the regions of interest.

- Integration of the measurements and observations into a database management system featuring highly-automated data editing and processing functions and on-line data and information dissemination to research investigators and management agencies.

A long-term measurement plan will be developed by the joint-agency steering committee described in a later section. It is imperative that both science and management-driven requirements be fully incorporated into the final design. Responsibility for technical design and installation of the measurement system will be shared jointly by the Office of Oceanography and Marine Assessment, National Data Buoy Center, NESDIS, and other line organizations as appropriate.

An added benefit of these measurement arrays is envisioned. Like tires and reefs attract fish, these state-of-the-art instrument systems will draw investigators from a wide range of disciplines who will utilize the fundamental information to complement their more detailed studies of coastal phenomenon. This synergism will provide significant intangible benefits to the nation as a whole, and increase the cost-effectiveness of the NOAA Coastal Ocean Program dramatically. Such a response to large, long-term measurement systems is not conjecture. Many studies have been planned around NOAA data buoys and water level recording stations, and the Army Corps of Engineers coastal research facility at Duck, N.C. attracts several non-Corps science and operational groups each year.

2. Research. Research investigations of storm-induced physical processes of the coastal ocean will be conducted in the following major topical areas: 1) air/sea interactions, 2) water column circulation and mass transport mechanisms, and 3) bottom boundary layers.

o Air/Sea Interactions. Atmospheric forces provide much of the energy to coastal ocean large scale flow fields, and the mechanisms of energy transfer are important to the direction and magnitude of the resulting flows. Winds are responsible for rapid and often extreme changes in ocean water levels which produce coastal flooding. They also generate surface waves which strip sediment from the shoreline and deposit sand in navigation channels and harbors. Research investigations will address the mechanisms of energy transfer to the surface, as well as the ultimate dissipation of this energy through the spectrum of waves and near-surface currents, as well as the attendant storm surge and wave setup which contribute greatly to coastal change.

o Water Column. Large scale circulation is responsible for distributing many of the dissolved and particulate constituents in the water column. Therefore, developing an understanding of the characteristics and variability in this flow is crucial to predicting the fate of these materials, drifting organisms, and fine-grained sediments. An NSF report on the Coastal Physical Oceanography planning meeting in 1988 notes that recent measurements off the U.S. east coast during the GALE experiment have shown that dramatic changes in shelf circulation can be driven by rapid changes in strong wind forcing. Qualitative understanding of the importance of wind-driven circulation has also been developed for Great Lakes storm systems, yet much remains to be discovered about the cross-shore vertical distribution of such flows. The role of astronomical forcing in determining coastal water levels and currents must be included in any large-scale investigations.

o Bottom Boundary. Bottom boundary layers are extremely important to coastal ocean flows, since the bed roughness determines the dissipation of nearshore flow and in this way controls their direction and magnitude. To date, however, much of the boundary layer theory and data are based upon one-dimensional representations of the roughness/flow interactions. Advanced 2- and 3-dimensional experiments at a number of coastal locations are required before accurate models of boundary layer response and forcing can be developed.

Specific Research Efforts in FY91

Two major research thrusts having quite different time-scales will be pursued. The first concerns an accelerated research effort (pilot project) to establish more reliable predictions of tsunami and storm surge inundation which will immediately lessen hazards to U.S. coastal resources and populations. The second relates to the longer term effort required to design, plan, and conduct a more diverse program in coastal ocean exchange processes.

Coastal flooding Pilot Project. The National Weather Service (NWS) storm surge prediction program has been very beneficial in warning the public of damaging coastal floods during hurricanes, since 90 percent of hurricane related deaths and damage are due to storm surge flooding. In response to this need, the NWS developed the Sea, Lake, and Overland Surges from Hurricanes - SLOSH - model in the 1970's. In FY81, Congress funded a 5 year program to: a) adapt the generalized SLOSH model to vulnerable coastal areas and basins based on their particular physical characteristics and b) run model simulations for numerous hypothetical hurricanes to profile the possible surge flooding in a given basin. To date, basic models have been developed for 31 of 37 basins and hurricane simulations have been completed for 17 of the basins.

Since completion of the 5 year congressional initiative in FY85, a minimal effort to continue the needed SLOSH work has been supported primarily through funding from Army Corps of Engineers and the Federal Emergency Management Administration (FEMA). FEMA relies on model results to determine the siting of evacuation shelters and the segment of a basin's population that is at risk from hurricane surge flooding, and its studies depend on the completion of the SLOSH models. Thus, a continuing effort will be established in FY91 to develop improved storm surge models and apply them to the remaining six vulnerable locations. In addition, basin models more than 5 years old need to be modified to reflect local physical changes such as addition of sea walls, raising of road beds, etc. and improvements in model physics which allow for a better description of small scale basin characteristics. These models will therefore be updated and results made available to federal and state agencies.

NOAA's tsunami warning system presently provides only one product: time of arrival. Communities that react to such a warning have based their evacuation plans on estimates of the land area expected to be flooded. These estimates are derived from a variety of models whose accuracies are unknown, which has led to confusion and lack of confidence in the warning system. This situation is in sharp contrast to NOAA's storm surge program, which has provided more reliable estimates of flooding potential and supplementary information useful to disaster planning groups. Inaccuracies in the existing tsunami modeling techniques result exclusively from the lack of accurate observational data for calibration and verification. Recent advances in tsunami measurement technology have demonstrated that small tsunami can be detected in the open ocean and near the coast. Since these occur annually, collection of additional data would allow development of a new generation of more reliable inundation models.

In FY91, the existing tsunami observational project presently funded by NOAA, the USGS, and the Army Corps of Engineers will be enhanced by expanding and upgrading the existing observational network and acquiring the additional expertise of academic scientists. Guided by a NOAA advisory panel to insure that operational needs are met,

these individuals will utilize the more comprehensive data sets to improve models of tsunami inundation.

Storm-induced Processes. Before any comprehensive plan for research and modeling in the coastal ocean can be developed, a clear understanding of what is known and what can accurately be predicted must be obtained. Therefore, the first major effort of FY91 will be a set of technical conferences to define the present state of knowledge and identify the level of knowledge required a decade hence. Leading researchers in the field will be invited to present a series of papers on critical strengths and weaknesses within each of the three major research areas. Just as important, management agency program leaders will outline their informational needs. Thus, a mechanism for enhancing communication between the data collectors and synthesizers and the resource managers will be created. Requests for proposals will be issued for a number of review reports summarizing the highlights of the presentations and outlining specific recommendations to the Storm Processes leadership team (see below) regarding research and informational needs.

Modeling. Improved models reflecting our increased understanding of the physical processes are imperative if the data from the series of site-specific experiments are to be accurately extrapolated to other locations subject to different combinations of forces. Existing numerical models can reproduce some oceanic interactions at this time, and these can be used to suggest initial experimental design. However, as with the research effort, FY91 modeling work will concentrate on defining the existing capabilities of models in each of the three major areas and defining the steps required for fundamental improvements in modeling of storm-induced processes. However, as additional data become available, more advanced model development will be possible. Thus, through an iterative process involving both modelers and field investigators, more accurate simulations of real world conditions will be developed and applied. A few examples of known coastal modeling needs are cited below.

o Air/Sea Interaction Models. As discussed earlier, as expanded National Weather Service storm surge effort will provide to the public more reliable warnings of damaging coastal flooding during hurricane events and more detailed information for evacuation planning to emergency action officials. However, hurricanes are not the only cause of severe coastal flooding brought on by storm surges. Some of the most damaging storms are of extra-tropical origin, and the forces producing these increased water levels differ significantly from those of hurricanes. Modification and application of existing NWS models to such storms will be accomplished following the initial review process. However, in preparation for that review, existing data sets will be compared to results from operational models to determine model capabilities and limitations for predicting extreme wave heights, storm surge, and surface currents. Of particular interest are data

collected at 6 towers in Lake St. Clair by NOAA and the Canadian Center for Inland Waters during a 1985 experiment. Data are available to confirm model predictions of generation, propagation, and dissipation of shallow water waves in the Great Lakes.

An improved prediction technique for determining marine wind fields from routine marine meteorological observations will be evaluated by NOAA scientists using the Great Lakes data base. A two-step Barnes technique will be used for 3-dimensional interpolation of the wind field to a regular grid compatible with typical measurement location spacing. Results will be compared to observations from open water measurement sites to define model limitations and future development requirements.

o Coastal Circulation and Sediment Transport Models. Models of coastal ocean flows developed to date generally rely on a two-dimensional (i.e., vertically averaged) representation of velocity. Yet it is known that much of the cross-shore flow is vertically segregated, either by wind-driven upwelling and downwelling, or by wave-induced mass-balance inequalities. Thus in FY91, to evaluate the existing capabilities of NOAA models to accurately represent water column transport processes, a three-dimensional model will be operated using an existing set of input and output data.

o Bottom Boundary Layer Models. Models of wave and current driven near-bottom transport are necessary to predict the fate of sediment and large particulate materials, whose movement across the shelf during storms is either as bedload or as highly concentrated suspended sediment. Research proposals will be solicited from academic investigators to define the capabilities and limitations of existing transport models and develop recommendations for future model development and complementary field investigations.

D. Products

Products resulting from this program will include:

* Improved and more complete data sets and models of coastal inundation resulting from tsunamis and hurricane storm surge.

* A measurement capability for determining the spatial and temporal variability in long-term coastal ocean forces required for interpreting and predicting the response of coastal regions and ecosystems to extreme short-term events and global change.

* An understanding of the impact of coastal storms on the water levels, circulation, mass transport and energy gradients of the coastal ocean.

* Improved models of coastal ocean circulation, storm surge, and wave generation/transformation processes.

* A data base for use by research and management agencies to develop improved prediction and analysis procedures.

* Improved understanding and models of the coastal erosion process.

* Improved design criteria for coastal structures and shoreline erosion mitigation procedures.

* Fundamental understanding of processes contributing to navigation channel deposition and guidance for more effective channel maintenance operations.

E. Benefits and users.

Benefits resulting from the measurements and research of this component include enhanced commerce at U.S. ports through the design of more efficient dredging techniques and cost savings of dredging operations; reduced damages to coastal property and reduced threat to public safety through more timely and accurate warnings of extreme event impacts such as flooding and wave action; long term data sets for assessing the impacts of global climate changes on the circulation of the coastal oceans; reduced property damage from coastal flooding and shoreline erosion through a better understanding of the design and engineering requirements, and, finally, a major increase in our scientific understanding of the behavior of our coastal oceans.

Users of the research products include federal agencies (NOAA, Corps of Engineers, NASA, Minerals Management Service, FEMA, National Park Service, NSF, USGS, and ONR) along with state and local governments and the scientific community.

F. Participants.

NOAA participants include the Environmental Research Laboratories and university scientists of OAR, the National Weather Service, several parts of NOS, and NESDIS.

G. Interagency Cooperation.

Studies of storm-induced physical processes in the coastal ocean are of vital importance to a large number and wide variety of NOAA mission requirements. However, several other federal agencies maintain an active interest in coastal oceanographic information and research to meet immediate and long-range objectives. A prime example is the

recent Coastal Physical Oceanography (CoPO) research plan developed by a number of academicians under the auspices of the National Science Foundation. Complementary Federal efforts include ongoing work by MMS and DOE in the deeper reaches of the coastal ocean, while at the shoreline the USGS is rapidly developing its shore erosion research program. The National Center for Atmospheric Research recently completed a series of experiments addressing the mechanisms of formation and propagation of coastal storm systems, but complementary information on the circulation and waves these storms produced were lacking. In order to optimize results and cost-effectiveness for all, a coordinated approach and joint experiments are mandatory.

ESTUARIES, OUR MOST CRITICAL COASTAL RESOURCE

A. Background

Estuaries and their associated coastal systems are valuable, yet vulnerable, components of the marine environment. They provide the biological foundation for much of our productive coastal waters and are a venue for recreation and commerce. Two-thirds of the nation's commercial fisheries harvest is estuarine dependent. Yet as coastal populations grow, estuaries are coming under increasing pressure. Of our nation's coastal waters, estuaries are the waters most affected by man's activities. They are fringed with cites and attendant industries, they serve as transportation corridors, recreational sites, and dumping grounds for society's waste products. Their waters and the coastal habitats that surround them are impacted by nutrient over-enrichment, chemical pollution, and alterations due to dredging, erosion from the surrounding watershed, alteration of fresh water inflows, and pathogenic organisms from untreated sewage. Because of their importance, special attention is being paid to them in NOAA's Coastal Ocean Program. This section describes a suite of activities that provide basic assessment of estuarine characteristics, fundamental understanding how the major habitats of our estuaries function and how their functions are altered by both natural variability and man's impacts, an estimate of the rate of loss of estuarine habitats, and the impact of habitat alterations and losses on the living marine resources of our coastal oceans.

No other component of the Coastal Ocean Program is addressing the functioning of estuarine habitats and the impacts of environmental stress on the habitats and their primary and secondary productivity.

B. Estuarine Assessment and Characterization

A targeted estuarine assessment and characterization program is proposed. The objective of this program will be to provide information to those involved with making critical decisions related to the Nation's estuarine waters. The program will produce needed characterization products, develop useful computer software and models, and provide a framework for synthesis of these and other sources of information on critical estuarine issues.

Proposed program activities include:

(1) Characterization Products - Variations of salinity is one of the most important physical parameters that can be related to the health and character of a specific estuarine system. In the National Estuarine Inventory, NOAA has identified three generic

salinity zones for each of 92 estuaries based on average annual conditions. As a follow-on to this useful product, NOAA proposes to develop, for each estuary on the Pacific and Atlantic Coast, a characterization of its salinity regime over a range of physical environmental conditions. The results of this analysis will be made available to users through the GeoCoast GIS system and the Coastal Ocean Management Planning and Assessment System (COMPAS). This product, when coupled with living marine resource characterizations, will permit water quality and resource managers to better understand the relationship between salinity and stress on the marine environment.

Bottom sediment is a second important parameter that can be related to the health and character of an estuary. NOAA proposes to develop a unique set of products that will characterize the spatial distribution of bottom sediments for the Nation's estuaries. A sediment classification method will be developed, tested, and implemented. These results will be made available through the GeoCoast GIS system and COMPAS. This information, coupled with other available NOAA estuarine characterization products, will permit water quality and resource managers to better understand critical biological/chemical processes and relate them to their specific management needs.

(2) Computer Software/Models - Two assessment tools are proposed to be developed as an aid to forming management alternatives. The first is a PC-based, pollutant load estimation software package. The program will be designed with the capability to test different management strategies using various pollutant load scenarios. The project will produce a "user friendly" interactive computer-based system that operate in conjunction with the National Coastal Pollutant Discharge Inventory.

The second assessment tool is a water quality sreening moel for selected estuaries. The proposed project will refine a generic screening model originally developed to assess water quality in estuaries. The resulting micro-computer models will be applied to selected types of estuarine systems. The models are being developed specifically for use by state or regional planners who may be charged with developing and justifying specific pollutant reduction goals as part of the management strategy for a particular estuarine system.

C. Research Activities FY 1990

Estuarine habitat studies, initiated in FY 1990 as part of the NOAA Coastal Ocean Program, have instituted regional and national research whose purpose, ultimately, is the development of an ability to predict the effects of environmental quality changes on estuarine systems and the organisms they support. Five central issues were identified for study:

- What are the key trophic pathways within and linkages among estuarine habitats?
- What are the functional relationships between habitat structure (including habitat type, size and shape, and location within an estuary), habitat productivity, and secondary production?
- How does chronic exposure to toxic contaminants affect the productivity and health of living marine resources, and the functioning of estuarine habitats?
- Are the ecological functions of "restored" habitats (i.e., modified, created, or enhanced) equivalent to those of natural habitats?
- What are the long-term effects of cumulative estuarine habitat alteration on habitat functions and secondary productivity?

Understanding the nature and magnitude of variability in estuarine habitats, the relative importance of natural and human-associated perturbations on the functioning of these systems, and their interactions in regulating habitat productivity, especially secondary productivity, are major underlying themes.

FY 1990 research offers a blend of "fundamental" and "applied" investigations. Basic studies of trophic interactions, habitat dynamics, and toxic effects provide the foundation for improved mitigation procedures and decisions regarding the suitability of proposed remedial actions. Early results may lead to more precise and powerful tools for assessing the extent of environmental degradation, and the nature and degree of environmental stress in estuaries. A start also will be made in examining the cumulative effects of environmental change. This issue lies at the heart of virtually every permit application and regulation pertaining to estuarine systems.

Emphasis in FY 1990 will be placed on the study of seagrass and salt marsh habitats, and on changes associated with altered estuarine hydrology and physical modifications to estuarine systems. Toxics research will focus on the effects of contaminants on biological factors that control the reproduction of selected species.

Building upon the FY 1990 efforts

Continued research in the above areas is proposed for FY 1991, with some expansion of effort. Specifically, investigations of estuarine productivity will be extended to a third habitat--the water column. Of special concern are the roles of density surfaces (e.g., pycnoclines) in mediating water column secondary production, and the significance of shifts in water column trophic dynamics that appear associated with reduced water

quality. Greater emphasis will be placed on exploring the implications of toxic pollutants to estuarine structure and productivity, as described in the Toxic contaminants section above. Changes at the population- and systems-levels of organization will be of special interest, as will the development of models for examining the cumulative effects of habitat loss and habitat degradation associated with pollution. Assessment and synthesis activities initiated in FY90 will continue to draw together information directed at habitat management needs.

Habitat Requirements

Another new activity for FY 1991 relates to the habitat requirements of estuarine living marine resources, and involves developing a more comprehensive understanding of the roles of habitat availability and habitat quality in controlling the productivity and well-being of estuarine species. Documenting these features also is essential for understanding why some estuarine habitats are more productive than others, and what the effects of cumulative habitat loss or alteration might be on estuarine-dependent organisms valued by man. Specific objectives include (1) defining the nature of and benefits gained from interactions among living marine resources and the estuarine habitats they occupy, and (2) quantifying variations in living marine resource populations and habitats, and relating these to natural and human-associated environmental alterations.

Species to be studied include those of ecological importance (e.g., those that play major roles in shaping trophic dynamics), as well as those for which NOAA has mandated responsibility (i.e., commercial and recreational species of fish and shellfish, and protected species of mammals, turtles, and fish). Conventional wisdom suggests that the ecological importance of estuarine habitats relates to their roles as spawning and nursery areas. In this regard, considerable effort will be devoted to research directed at early life history stages of key organisms.

Investigations and analyses will be conducted both from the point of view of habitats (i.e., the roles played by individual species as components of habitats), and from the point of view of estuarine-dependent populations (i.e., the roles played by various habitats in the life cycle and overall productivity of individual taxa). Information will be gathered on topics including (1) food/energy requirements, food availability, and predator-prey interactions within estuarine habitats, and (2) the relationship of physiological requirements and behavioral characteristics to environmental characteristics of estuarine habitats.

Studies will be conducted by NOAA scientists, working in cooperation with researchers from the academic community (via the National Sea Grant College Program) and from state fisheries agencies. Efforts will be regional/national in scope.

D. Habitat Mapping: NOAA Coastwatch

Quantifying changes in land use and vegetation cover in the coastal zone is critical to the linking of land-based human activities to the productivity of the coastal ocean. Change in the coastal zone due to human population growth and attendant impacts on the physical habitat, water quality and living marine resources is occurring faster and more pervasively than we have been able to monitor. On time scales appropriate for national and regional decisionmaking no appropriate monitoring of change in land cover and fisheries habitat (i.e. wetlands and seagrass beds) for the coastal zone of the United States exists. Therefore, a NOAA program is proposed (using land remote sensing and supplemental aerial photography) to monitor land cover and habitat change in the coastal zone of the United States to provide information needed to determine the impacts of wetland and estuarine degradation on the abundance and distribution of fish. Land/habitat vegetational coverage in the coastal zone of the continental United States (including Alaska), Hawaii, and trust territories will be mapped every two to five years and monitored annually in regions of significant change.

The activity, described more completely in Chapter III, will emphasize the use of remotely sensed data from the Landsat Multispectral Scanner (MSS) and Thematic Mapper (TM) or the SPOT (HRV) instrument as well as supplemental aerial photography. Data from wetland and estuarine ecologists, and from biologists will also be used. Aerial photography is best for simple vegetation inventories of small test sites. However, for repetitive observations of vegetative changes and biomass of areas larger than 10,000 hectares (24,700 acres), use of MSS or TM is better suited for rapid analyses with considerable cost savings. This initiative directly supports NOAA legislative responsibilities in estuarine and marine science, monitoring and management contained in the Fish and Wildlife Coordination Act, the Coastal Zone Management Act, and the Magnuson Fisheries Conservation and Management Act.

E. Impacts of Habitat Loss - Models of Cumulative Stress

Plans to alter or develop large tracts coastal property receive considerable attention from regulatory authorities; however, the bulk of development plans pertain to small- or medium-size projects that alone are likely to produce few, if any, detectable ecological effects. The same may be said for point- and nonpoint- source pollution discharges. Summed across an entire embayment or watershed, these changes may be of great consequence. In this regard, NOAA will develop a capability to predict the effects of

incremental changes (both small and large) in the extent and quality of estuarine and coastal habitats on the abundance and distribution of economically valuable living marine resources (LMRs). The model will link human demographic patterns, including shifts in coastal land use, with assessments of coastal habitat functioning, and information on LMR population dynamics, reproductive success, and growth rates. The goal is to partition reduced secondary production (including LMR mortality) among natural factors, fishing, and habitat degradation.

F. Information Synthesis Teams

A series of synthesis documents, will be developed utilizing teams of NOAA and academic experts to address pressing estuarine scientific and technical issues. These will include "white papers" on such topics as the effects of specific environmental perturbations, pollutants, and natural events on living marine resources and water quality, the implications of management strategies of key estuarine species and their habitat, and trends in water quality and habitat degradation.

G. Products

* Expanded estuarine assessment capability by inclusion of salinity and bottom sediment profiles in NOAA GIS systems.

* Development of user-friendly pollutant load estimation and water quality screening models for estuaries.

* Synthesis of understanding of the fundamental processes controlling primary and secondary production in salt marsh and sea grass habitats.

* Determination of the effect of toxics on habitat functioning.

* Assessment of mitigation techniques for sea grass and salt marsh habitats

* Development of methodology to assess cumulative habitat alteration and loss.

H. Benefits and users

NOAA's research and assessment activities concerning estuaries and their habitats is essential if the national goal of "no net wetland loss" is to be met. The success of conservation and mitigation programs will be dependent on the results of this estuarine research and assessment program. Users of the information include the EPA Office of

Wetlands Protection, NOAA Habitat Conservation specialists, the F&WS, the Corps of Engineers, and State and local agencies, along with the private sector and scientific communities.

I. Participants.

Major NOAA participants in this program include OAR, NOS, NMFS, and NESDIS.

J. Interactions with Other Elements of the Coastal Ocean Program

1. Chemical and Biological Surveys

Information developed through the National Status and Trends Program documents the existence of pollutants in estuarine and coastal environments and provides a measure of associated fish pathology. Such information is essential for successful interpretations of laboratory findings and modeling activities on the effects of toxics, which are to be undertaken as part of the estuarine habitat program. Other interactions include assessments of the relationships between habitat productivity and environmental pollution, and evaluations of toxics and food-web dynamics.

2. Nutrient Overenrichment and Enhanced Coastal Productivity

Among the aims of the coastal productivity effort are determining the roles of anthropogenic nutrient inputs in enhancing the primary production of coastal waters, and determining the fate of excess production. Estuaries often determine "boundary conditions" for coastal productivity, influencing the nature and quantity of the nutrient flux from upland watersheds into coastal systems, and serving as a potential sink for carbon, particulates and associated materials. Proposed estuarine habitat investigations of water column primary production, nutrient dynamics, and trophic interactions may be of special relevance in this regard.

3. Toxic Contaminants.

A major focus of the Toxic Contaminant Program described above is on the transport, fate, and effects of those contaminants on estuarine ecosystems and the living marine resources they support. The Estuarine Ecosystems research program, described here, will be coordinated closely with these efforts. Any toxics research undertaken by Estuarine Ecosystems program will be focused on determining the impacts of toxics on habitat function and productivity.

COASTAL ECOSYSTEMS

A. BACKGROUND

The coastal environment of the United States is the most varied of any nation on the planet. In no other nation does one find environmental conditions that range from arctic to tropic and from broad continental shelves to coastal fjords, islands & reefs. Each of these broad categories can be subdivided into hundreds and perhaps thousands of coastal ecosystems making a study of each virtually impossible. Evidence to date suggests that living marine resources have evolved reproductive strategies to conform with or use dominant ocean features. An analysis of the living marine resources most important to the nation indicates that these are found or intimately associated with five major (or principal) generic types of coastal ecosystems: upwelling systems, riverine and pelagic fronts, shelf and bank systems, major ocean currents, and large lakes. Each species responds differently to local oceanographic features, but such differences are minor when compared with the overall reproductive strategy of the species. It is these coastal ecosystems and associated living resources that are most affected by man-made perturbations. Even estuarine species are directly influenced by events taking place in coastal waters. The majority of the species that are identified as "estuarine dependent" are spawned and spend the early stages of their life in the waters overlying the continental shelf.

One of the most important characteristics of the living resources of coastal ecosystems is that they are highly variable with respect to abundance and species make up. This variability is a natural phenomenon and is believed to be a consequence of a host of environmental factors. The magnitude of this variability in both the short-term (interannual) and long-term (interdecadal) is so great that it is currently impossible to distinguish between changes in abundance that are natural from those that can be attributed to man. In many of the world's and the nation's fisheries, one cannot attribute declines in abundance simply to fishing mortality.

The ultimate question confronting resource managers and decision makers with respect to coastal ecosystems is how to distinguish the effects of man's activities (pollution, eutrophication, habitat destruction, and fishing) from natural fluctuations. Such information is also critical to the design of monitoring programs and risk assessments of human activities in the coastal environment. At present, decisions of many resource managers are being made on the basis of worst case scenarios (that is assuming an activity will have maximum adverse impact) or on the basis of the best case scenario in which no impact is assumed. Decisions based on either of these extremes ultimately result in litigation where decisions are based on legal rather than ecological principles.

It has been well established that variability is an intrinsic component of coastal ecosystems, and this variability, particularly as manifested in populations and communities of living resources, poses one of the most important problems confronting decisionmaking in the coastal ocean.

B. THE PROGRAM

The program is a research effort which will provide fundamental understanding of the processes and mechanisms that control the productivity of living resources in coastal ecosystems. Because of their importance to the economy and their susceptibility to man's activities, the program will focus on fish and shellfish populations and communities.

1. Assessment

The National Marine Fisheries Service (NMFS) presently conducts extensive assessment programs aimed at determining the status of important fishery resources in most of the nation's coastal ecosystems. These assessments are pursued in response to the National Oceanic and Atmospheric Administration's fishery management responsibilities under the Magnuson Fishery Conservation and Management Act of 1976 (P.L. 94-265, as amended). Information from fishery programs will be very useful by providing information on the long-term status of some stocks (many stocks have been monitored for decades), and the degree of variability to be expected when working with different species or communities. Ongoing stock assessment efforts will also provide the data required to verify the conclusions and models developed in the course of the research component of the program.

Although there is a need to expand the assessment programs, such expansion does not fall within the purview of the Coastal Ocean Program.

2. Research

The program stresses use of the comparative approach on early life history stages of representative fish and shellfish species in upwelling systems, riverine and pelagic fronts, shelf systems, major ocean current systems, and the Great Lakes. Emphasis on early life stages is based on the preponderance of evidence indicating that factors influencing variability operate on larval and/or juvenile stages. By comparing within and among ecosystems and across species, it may be possible to derive some generalizations regarding the interaction of mechanisms controlling variability in abundance and community structure. To best achieve this, it will be necessary to better understand and

model the physical processes, both atmospheric and oceanographic, that account for a major source of variability in these ecosystems.

Two sets of questions will be addressed by this research, one dealing with issues related to interannual variability, the other with interdecadal variability. Interannual questions include:

- What is the role of abiotic environmental variation in controlling survival of eggs, larvae, and juveniles?
- What is the role of food availability in controlling survival of larvae and juveniles?
- What is the role of invertebrate and vertebrate predation in controlling survival of eggs, larvae, and juveniles?
- What is the role of physical factors in transporting eggs or larvae to appropriate juvenile habitats or in controlling predator-prey interactions?
- How do the above factors interact to affect total survival to recruitment?
- Does the relative importance of various survival mechanisms change within or among years?

Questions of interdecadal significance include:

- How are large-scale atmospheric and oceanic processes linked to major changes in fish community structure?
- Does the exploitation process itself effect major changes on fish community structure and under what circumstances?
- Are community shifts primarily due to responses of individual populations to environmental change, or are more subtle food web interactions important?

There is general agreement among researchers that the program should focus equally on short- and long-term time scales and seek to determine factors promoting survival rather than accounting various sources of mortality.

Over the past 10 years, NOAA has supported a number of research activities focused on understanding the causes of variability in fish stock abundance. Initially, these activities were supported by the NMFS and Office of Oceanic and Atmospheric

Research (OAR); however, in 1982, NMFS and OAR initiated a joint program, the Fisheries Oceanography Cooperative Investigation (FOCI) aimed at understanding the physical environmental controls regulating Gulf of Alaska walleye pollack population abundance. This program and the Sardine Anchovy Recruitment Program (SARP), supported by NMFS, have produced many of the tools and fundamental concepts upon which this research topic is being studied.

Research on upwelling systems is underway, and, though more work is still necessary in this area, major efforts are needed to expand research on shelf systems and initiate a major program on fronts and the Great Lakes.

SHELF SYSTEM INVESTIGATIONS

Findings to date from the FOCI in the Gulf of Alaska suggest that we must expand that investigation into the Bering Sea, one of the nation's most important environments and site of the world's largest shelf fishery. Linkages between off-shelf (Aleutian Basin) and on-shelf components of the Eastern Bering Sea pollack resource are poorly understood.

Hypothesis: Transport of larval pollack from the deep Aleutian Basin to the continental shelf enhances survival into the U.S. fisheries.

Program: A 5-year effort will be initiated to determine the inter-relationship of pollack aggregations in the Bering Sea, with particular emphasis on U.S. stocks. The expanded program has two components: (1) determine migratory patterns of walleye pollack through description of Aleutian basin physical oceanography, understanding of shelf-slope exchange processes, and determine through biochemical and morphological studies if aggregations represent distinct stocks, and (2) understand the simultaneous biological and physical processes which occur in egg and larvae patches, with an emphasis on mortality and dispersion. The first component consists of large-scale physical and biological surveys and investigation of the largely unknown processes of shelf-slope exchange by establishing long-term oceanographic moorings. The second component consists of patch-size ocean drifter experiments combined with in situ biological and doppler profiler current measurements.

ICE EDGE ECOSYSTEMS

Closely associated with shelf systems in the higher latitudes are the ice edge ecosystems found in such areas as the Bering Sea and Prince William Sound. Sea ice exerts a primary control over Arctic marine ecosystems. Its extent, formation, and melt are critical factors for the annual primary production cycle of the Bering Sea shelf, a platform and habitat for mammals, and a substrate for the tiny plants that form the base

of the food chain supporting fish, shellfish, birds, sea mammals, and man. The ice melt water stabilizes the sea and allows a unique spring pulse of food production. Shallow depths keep this biological energy available for use by higher trophic levels, especially the benthos. The retreat of the ice edge through the Bering and Chukchi Seas is equal to fertilizing an area from Texas to the Canadian border and the Rocky Mountains to the Mississippi River. Yet the critical pathways of energy flow from solar radiation to bottom organisms and fish and mammals are poorly understood; the biological capacity of the American Arctic marine ecosystem is unknown.

Hypotheses: Interannual variation of maximum ice extent and seasonal ice retreat account for the major year-to-year variability in the biological productivity of the Bering and Chukchi Seas.

Program: The study consists of the following elements:

- Re-evaluation of existing physical and biological data sets from the point of view of causal linkages.
- Use of coupled sea ice/ocean models to design sampling strategies.
- Process-oriented investigation of how abundant biological environments such as the ice edge oceanographic front, polynyas and the Anadyr current are maintained through a combination of oceanic and atmospheric mechanisms.
- Examination of the relation of ice edge primary production and nutrient/trace metal recycling to the occurrence and timing of the secondary production of zooplankton, larval fishes, and crustaceans.
- Investigation of the role of benthic populations as an intermediate part of the food chain.
- Interpretation of fisheries data sets in a manner consistent with the expanded information base on weather and climate, sea ice, and oceanography.

This program requires application of space-based observations to assist the mapping of secular changes, in all weather and seasons, of ice cover affecting the cycles of productivity on subarctic and arctic waters. These analyses are critical to the planning and staging of field observation and sampling programs. The analyses also will become an essential element of the descriptive physical time-history needed for studies of climate and global change over time intervals spanning decades. For a more detailed

description of the sensor data characteristics and data processing and communications issues, see the section on Space-Based Observations (Chapter III)

PELAGIC FRONT SYSTEM INVESTIGATIONS

Over the past 5 years, cooperative investigations have been conducted by the Atlantic Oceanographic and Meteorological Laboratories of ERL and the Beaufort Laboratory of NMFS on the trophic environment of the South Atlantic Bight. These preliminary studies suggest that the frontal system of the Gulf Stream is an especially favorable environment for the growth and development of larvae of the so called "estuarine dependent" fish and shellfish species. The onshore surface currents from the Gulf Stream appear to act as the transport mechanism by which larvae and juveniles migrate to estuarine nursery areas. Thus events occurring in coastal waters play a significant role on the biological productivity of estuaries.

Although many species make use of this ocean system, the Atlantic menhaden is probably the best experimental organism to study recruitment processes in frontal systems.

Hypotheses: 1) Larval menhaden survival is dependent on the trophic environment of the Gulf Stream Front. 2) Survival of late larval and early juvenile stages is dependent on onshore transport. 3) Juvenile survival is dependent on transport to and the environmental quality of estuarine nursery areas.

Program: A 5-year effort will be initiated to determine the physical and biological processes of the Gulf Stream Front and adjacent coastal waters in the areas of the South Atlantic Bight influential on the recruitment of Atlantic menhaden. The study includes four critical components: 1) the abundance and distribution of eggs; 2) the abundance, distribution, and feeding environment of early larvae; 3) the migration of late larvae onshore; and 4) the survival of juvenile menhaden in their estuarine habitats.

To be successful, the study must be built on a quantitative understanding of physical oceanographic factors influencing shoreward migration and frontal processes. Therefore, both surface and subsurface circulation must be measured at sea and within the estuaries. The circulation and hydrography of the region is complex, but have been the focus of a number of recent and ongoing studies. Simultaneous sampling of both physical and biological conditions is essential. Biological sampling systems utilizing photographic and acoustic technologies have been developed at AOML. These have been successfully integrated with in-situ physical sampling and shipborne-remote sensing. Because this effort focuses on an estuarine/coastal system complex, it will be coordinated with the Estuarine Ecosystem work described above.

GREAT LAKES

Current research of the Great Lakes ecosystem and fish community indicates that the time is ripe to initiate a program on the relationship between physical processes and fisheries productivity of the lakes. Evidence has been obtained over the past 10 years which indicates that variability of the forage base fishes is controlled by a combination of extreme weather events, turbulent transport, food web interactions, and commercial fishing. These processes are similar to those affecting ocean fishes but lend themselves to more facile examination because boundary conditions are more easily defined in lake systems.

Hypothesis: Variability of Great Lakes fishes is controlled by the degree of overlap between the onset of fish hatching and the seasonality of food web production.

Program: A 5-year effort will be undertaken to determine how the thermal regime experienced by developing eggs and the timing of the spring plankton bloom effects survival of larval coregonid white fish and alewife. The program consists of two projects: a comparison of Lakes Michigan and Ontario; and a Lake Michigan recruitment study. The first study will quantify the temporal and spatial patterns of plankton, fish larvae and juveniles, and lake-wide circulation, and temperature structure. The second study is to identify the linkage between physical, biological, and chemical processes as they effect the pelagic ecosystem and young fishes.

WEST COAST CoastWatch

Work on the Pacific Coast will concentrate on establishing capabilities for monitoring and evaluating the impacts of unusual environmental events on west coast fisheries. The most notable example of an anomalous environmental event that affects west coast ocean waters is the El Nino. This large-scale event occurs at varying time intervals and with varying intensities and impacts on west coast fisheries. Red tide outbreaks also take place occasionally at diverse locations along the coast of California, and appear related to variations in the upwelling regime in response to atmospheric forcing.

Support will be provided to Federal and state regulatory agencies offering the information they need to make environmental systems management decisions. There will also be a heavy research component to the activity. Efforts in this area will capitalize on capabilities and experience of NOAA Fisheries staff and the NOAA Center for Oacean Analysis and Prediction, resident on the west coast, and take advantage of the lines of communication that exist among NOAA Fisheries and other Federal and state regulatory agencies.

Research will center on applying satellite remote sensing technology to understand the affects of varying ocean conditions on recruitment and abundance of west coast fishery resources (see Chapter III). Case studies will be conducted on selected groundfish and coastal pelagic species and will emphasize quantitative evaluation of environmental change on fishery resources. The research process will involve the development of methods and approaches using both current and archived fishery and environmental data. Field studies will be conducted to help test findings. Satellite data will play an important role in planning and guiding field study operations on vessels at sea. The techniques and methods resulting from the research should have application to other NOAA CoastWatch locations around the United States.

PHYSICAL OCEANOGRAPHIC MODEL DEVELOPMENT

Since marine invertebrates and fish stocks are cold-blooded, and thus are perfect integrators of their physical oceanographic climate, it is necessary to account for the natural variations in the physical oceanographic climate in addition to other processes. As ecosystem models begin to show predictive skill, they must in turn depend more heavily on predictive models of ocean circulation and thermal structure.

The current state of knowledge of ocean circulation is improving rapidly as our observational information base expands. The coming generation of super-computers now makes feasible the development and operation of large-scale ocean circulation prediction models. These ocean models must be "spun-up" using a continuously-inserted atmospheric forcing data base over a long period of time. These models must be evaluated over long time intervals at a central computing facility, such as at the NOAA Center for Ocean Analysis and Prediction (COAP), where the historical global atmospheric and oceanographic data sets both reside and are readily available for routine operational assessment and evaluation.

Once the large-scale, ocean basin models begin to show predictive skill, smaller regional models need to be developed to support specific fishery ecosystem assessments. The large-scale models must provide the initial boundary conditions for the regional models. Consequently, these initial efforts must be conducted simultaneously at the outset in a major center such as COAP.

In FY 1991 a research, development, testing and evaluation effort will be initiated. A series of planning sessions will be conducted along with one or more workshops where the state of the physical-dynamical ocean modelling art will be assessed. Initial efforts in the regional modelling area will address the Pacific Coast upwelling region, as well as the Atlantic Coast shelf region inside the Gulf Stream, because these areas have a

good observational time history, as well as considerable model experimentation already underway.

PRODUCTS

* Identification of the factors that control variability of living resources in ocean ecosystems.

* The ability to distinguish between changes in population abundance or community structure caused by nature and man.

* The capability to predict the consequences of human activities on the living marine resources of coastal environments.

* The capability to forecast the abundance of fishery resources interannually and interdecadally.

* To link ocean physics and climate to economically important biological resources.

* Provide a scientifically sound basis for designing and modifying monitoring programs assessing the impacts of man on coastal ecosystems.

C. RELATIONSHIPS TO OTHER PROGRAM AREAS

This program element is an essential complement to the other components of the COP. As stated, this effort provides the basis upon which meaningful impact analyses can be made and monitoring schemes can be designed. The information on early life history of estuarine dependent species is critical to understanding the relationship of estuarine habitat to fish productivity, a major element of the Estuarine Ecosystems Program. The report of the U.S. Arctic Research Commission to the President and Congress strongly urges priority support for the ice edge ecosystem study, since it addresses critical issues confronting the nation in the subarctic and arctic regions' seacoasts.

In order to pursue this effort effectively, there is a critical need to employ satellite remote sensing and data buoys capable of providing oceanographic and weather information in as close to real time as possible. These tools will provide the temporal and spatial coverage required to conduct large scale ocean experiments, and to describe the relevant processes within individual ecosystems.

D. RELATIONSHIP TO OTHER FEDERAL PROGRAMS

This program is being coordinated with the National Science Foundation's (NSF) developing Global Ecosystem Dynamics Program (GLOBEC) and could be pursued as a joint effort. Line Organizations participating include NMFS, NOS, OAR (ERL and ORP) and NESDIS. The NSF, Office of Naval Research, and National Aeronautics and Space Administration have new Arctic research programs that total a $15 M commitment for FY 90. NOAA has the opportunity to coordinate its ice edge program such that all agencies benefit. Research to correct the neglected information base and promotion of cost-effective programs through interagency and international cooperation is necessary to fulfill national objectives as set forth in the National Arctic Research Plan as part of the Arctic Research and Policy Act of 1984.

MARINE DEBRIS

A. Background

Recent adoption of recommendations of the Interagency Task Force on Persistent Marine Debris, which was chaired by NOAA, by the White House Domestic Policy Council (DPC) commits appropriate Federal agencies to a combined program of Federal leadership, public awareness and education, research and monitoring, clean-up, and enforcement. The implications for economic and biological losses from the marine sector as a result of persistent debris are enormous and this DPC report provides NOAA with responsibility for research and educational programs related to protection of marine habitats and populations.

In passing the Marine Plastic Pollution Research and Control Act of 1987 (MPPRCA), the Congress charged NOAA with undertaking a wide range of research related to the effects of plastic materials on the marine environment. The MPPRCA specifically requires NOAA to identify and quantify the effects of plastic materials on Marine resources and to analyze plastic materials which are claimed to degrade to environmentally benign subunits under the action of natural environmental forces. This Act further charges NOAA with the development and operation of a national public education program on the marine debris problem. The recommendations of the DPC compliment the expectations of Congress in MPPRCA and support NOAA's role in addressing the marine debris issue.

Current Program

The only current NOAA program which directly addresses the problem of persistent marine debris is the Marine Entanglement Research Program (MERP), which is administered by the National Marine Fisheries Service (NMFS). MERP was originally established to measure the effects of commercial fisheries-generated debris on fish and wildlife, but as that issue has been somewhat clarified, its efforts have broadened to more generic issues concerning persistent debris as a water quality and habitat issue.

MERP is a small program but its contributions in documenting effects of plastics on marine biota have been significant. Derelict and discarded fishing gear has been shown to be a cause of mortality among seal populations, especially the northern fur seal, and may be contributing to declines of the endangered Hawaiian monk seal. Impacts on other marine mammals including whales and porpoises have been documented. Ghost fishing by lost and discarded fishing gear continues to trap unknown numbers of many species of fish and wildlife. Floating plastic wastes are commonly ingested by a variety

of fish, seabirds, and endangered sea turtles. Birds and turtles have experienced mortality as a result of ingestion or entanglement, and some seabirds pass their load of plastic on to their young during feeding.

MERP also provides leadership in developing programs for mitigation of debris problems and for increasing public awareness, especially among significant debris source groups such as the plastics industry, offshore oil and gas operations, commercial fishing and other maritime industries. It has developed educational materials for these groups and provided fora for international discussion and focus through its sponsorship of several conferences, working groups and workshops. Its assistance in the development of a national marine debris database has been instrumental in characterizing the enormity of the problem and in identifying the major debris sources.

MERP has sponsored activities focusing on the practical implementation of MARPOL Annex V in the U.S., as embodied in MPPRCA. Guidelines for the Implementation of MARPOL Annex V were prepared by MERP and subsequently adopted by the International Maritime Organization. These international guidelines establish a broad set of goals and options for nations, including the U.S., to consider in their programs to control marine debris. Modest efforts to review technology related to marine debris reduction have included shipboard waste handling systems, degradable plastics, and recycling of plastics. These reviews have often raised more new questions than they answered, pointing to the need for continued leadership in these areas.

To date MERP has been successful in showing that marine debris impacts exist on many marine species and resources over which NOAA has management responsibility, including many endangered, threatened, or otherwise protected species. It has also successfully begun to make the marine community and the public aware of the nature and scope of the problem and its potential solutions.

B. Proposed Program

In responding to the charges to NOAA from the Domestic Policy Council and in the MPPRCA, NOAA proposes to conduct a coordinated program of research, monitoring and education. The objectives of this expanded marine debris program are:

1) To broaden the scope and depth of research on the impacts of marine debris and marine debris solutions on wildlife and maritime commerce.

2) To develop and coordinate a national education and awareness effort among federal agencies, state agencies, industry and the public to inform and provide options for

changes in public behavior as part of the long-term solution to the marine debris problem.

1. Marine Debris Research

Current research into the interactions between marine life and persistent debris have clearly shown that individual animals are disabled and killed. This proposed program will undertake long-term research to elucidate the population level impacts of chronic and possibly increasing exposure to debris. Species that are afforded special protection under the Endangered Species Act, the Marine Mammal Protection Act, and the Migratory Bird Act that are known to be at risk to marine debris will be special subjects of these studies. The northern fur seal, the Hawaiian monk seal, and all species of sea turtles will be included. In the case of fur seals and sea turtles, this research involves combinations of laboratory and pelagic research activities coordinated with State agencies, Universities and foreign research entities. The Hawaiian monk seal project will include the careful cleaning of all entangling materials from important pupping and haul-out beaches on a regular basis.

The issue of whether the documented levels of plastic ingestion by seabirds and turtles in particular are reducing survival and reproductive rates will be thoroughly investigated under the proposed program. Very limited research to date has shown widespread ingestion of plastics by seabirds but has failed to demonstrate physical damage leading to death. Biologists and veterinary pathologists are recommending controlled experiments to carefully examine these findings. This research will be combined with extensive physiological chemistry analyses to assess the toxicological consequences of ingestion of plastics by seabirds and turtles. The range of plastics utilized in these important analyses will include the "degradable" plastic formulations currently available on the consumer market as well as a suite of polymer products commonly found in the digestive tracts of wildlife. Completion of these research projects will establish a clear understanding of the biological consequences of ingestion of plastic debris and set the tone for appropriate management and regulatory response.

The suitability of adopting "degradable" plastic formulations as alternatives to current plastics in many applications has not been addressed. The chemical evaluation of the processes of enhanced disintegration by a number of methods (photo-, bio-, hydro-, etc.) must be evaluated to insure that their products and by-products are "environmentally benign". This research will be undertaken as part of NOAA's proposed program and will be incorporated into the toxicological studies discussed above.

Even under fullest implementation and compliance with the requirements of MPPRCA, fishing gear will still be lost in the legitimate act of fishing. This ghost-fishing gear may

be destroying valuable commercial as well as non-commercial marine resources. Current fisheries technology has yet to fully address this class of problems. Under this proposed program, an active research project will evaluate the nature of the ghost-fishing problem in the United States and, in a series of prioritized research and development projects with industry, investigate practical, economical methods and gear technology to minimize gear loss and maximize its recovery. This project will also evaluate practical means for reducing the ghost-fishing power of non-recoverable gear (including testing of "degradable" materials.)

Economic evaluations of the impacts of marine debris on wildlife as well as other marine and coastal resources have not been within the scope of the NOAA marine debris program (MERP). To place solution strategies for the marine debris problem in reasonable perspective, both the cost(s) of the solutions(s) as well as the cost(s) of the problem(s) should be understood. This proposed program will utilize the unique economic research capability in NOAA to develop a prioritized series of investigations that will provide useful cost information about marine debris impacts. This will include assessments of the aesthetic value of clean beaches, the economic cost associated with wildlife deaths, the commercial losses associated with ghost-fishing and vessel disablement, and the cost of cleaning up debris. The economic circumstances associated with various solution strategies will be established to further rationalize the management process.

2. Education and Awareness

The ultimate solution to the marine debris problem is source reduction. This can be accomplished by changing human littering and disposal behavior through increased public awareness, education, and law enforcement. This proposal will support NOAA activities to develop and coordinate public and private sector educational campaigns worldwide. These will include stimulation of national public service programs, which will transmit information generated by the research program to large segments of the general public as well as appropriate selected target audiences (e.g. the plastics industry with regard to toxicity testing). Appropriate technology relative to degradable plastics, ghost fishing, port and vessel waste handling, development of significant volunteer programs, as well as significant results of all research will also be transferred and communicated to all appropriate users.

3. Strategy

MERP provides an ongoing infrastructure to support expanded research opportunities in marine debris, however, the intrinsic capabilities of NOAA research laboratories and

the Sea Grant Program with their resources in outreach and multidisciplinary research provide appropriate mechanisms and resources to complement MERP activities. Capability in toxics, population dynamics, and ecology in the NOAA laboratories coupled with special expertise in Sea Grant in resource economics, population ecology, public outreach, and technology transfer provide the components for a successful multidisciplinary team approach which will be managed by an advisory committee made up of members from each subunit.

C. Products

* Chemical evaluation and standard toxicity testing of the natural "degrade" products of new degradable plastics being developed.

* An understanding of pathology and toxicology of plastic debris and degradable plastic products ingested by marine birds.

* An understanding of the effects of mortality caused by persistent plastic debris on populations of affected endangered species.

* New technology to minimize mortality of fish and shellfish resources due to "ghost fishing" by lost fishing gear.

* Economic models of the costs of the problems and solutions posed by persistent marine debris which can be adapted for use world-wide.

* National public service education programs and videos addressing the marine debris issue to stimulate public awareness.

* Transfer of appropriate new information and technology (e.g. vessel waste handling, toxicity testing, use of degradable plastics to reduce mortality in ghost fishing, etc.) To user groups and industry.

* A more concerned and aware general public which is the ultimate goal in control of marine debris.

D. Benefits and Users

Information on the impact of debris on marine life will be used by regulators and U.S. negotiators in international meeting to address marine debris problems. Industry will benefit from evaluations of the degradability of biodegradable plastics in the marine environment. The public will benefit from a cleaner, safer coastal environment.

E. Participants.

OAR's Grant Program and the NMFS Marine Entanglement Program are the major participants in the marine debris program.

F. Program relationships.

The current limited NOAA marine debris program is coordinated with the activities of other agencies and organizations. Close working relations exist with the Coast Guard, who have responsibility for the issuance of regulations. Both the plastics and the fishing industry interact regularly with NOAA's current research and public education programs. The public education program activities have especially close ties with the Center for Environmental Education, the leading organization is beach cleanup programs.

III COMMON PROGRAMS

The Coastal Ocean Program has many activities in common and with other NOAA programs. Two important elements are Information Delivery and Observations. Described below are enhancements within both suites of activities that support each of the elements of the Coastal Ocean Program described in Chapter II.

PROVIDING THE RIGHT INFORMATION AT THE RIGHT TIME

Timely and easy access to data collected by various NOAA platforms, including satellites, aircraft, ships, buoys, and other in situ field measurement systems, is essential if the scientific community is going to accelerate the development of predictive models of environmental change in the coastal ocean. Improvements in the telecommunications capabilities among NOAA research laboratories and data centers and the development of an Interactive Marine Analysis and Forecasting System (IMAFS) workstation are examples of current projects that could improve access to data by NOAA scientists and users in the research community.

NOAA CoastWatch and new geographical information systems (GIS's), such as the Coastal Ocean Management, Planning, and Assessment System (COMPAS), are all examples of projects that are improving the transfer of scientific information to decision makers at various levels of government. NOAA will improve the products developed, services provided, data collection and assessment activities undertaken, and the time and manner in which these products and services are delivered to Federal agencies, state agencies (especially state coastal management agencies), environmental interest groups, and the scientific community.

NOAA proposes to improve its links with local and state governments by making available the full suite of information delivery mechanisms and products currently operational and those to be developed through this program expansion. Several NOAA efforts are underway to make data and information available in a more timely and effective manner:

A. Improving the transfer of data to the scientific community:

   1. **IMAFS**, an interactive marine analysis and forecasting system and a mini-computer based workstation;

B. Improving transfer of information to the decision making community:

2. **CoastWatch**, a near real-time capability to provide remotely-sensed selected characteristics of the coastal ocean;

3. **COMPAS**, a user-friendly, micro-computer based GIS for coastal ocean assessment at the state and local level; and

4. **PC-PORT**, micro-computer based software that allows marine operators to use real time information on currents, water levels, and meteorological conditions.

C. Improving communications within the ocean community

5. **NOCN**, the NOAA ocean communications network

1. **IMAFS** - NOAA's Interactive Marine Analysis and Forecast System

The Interactive Marine Analysis and Forecast System (IMAFS) is an operational spin-off of prototype workstations produced by the Program for Regional Observing and Forecasting Services (PROFS). The system has been implemented by the Office of Ocean Services to meet various new program requirements, including the Coastal Ocean Program, the Global and Climate Change Program, and the Marine Weather Program. The IMAFS will (1) store, process, and display conventional observational data, gridded fields of data, digital satellite data, and climate data, (2) permit the overlay, animation, and integration of multiple data and product sets, and (3) provide interactive processing and applications capabilities.

In July 1988, IMAFS was demonstrated to illustrate and emphasize the utility and necessity of having the rich NOAA data sources presented together in an integrated manner, to demonstrate the potential capabilities of an IMAFS workstation, and to explore the requirements for IMAFS beyond the demonstration period. The data and products brought together on the IMAFS display included the Navy's Fleet Numerical Oceanography Center (FNOC) model output fields, NOAA's National Meteorological Center (NMC) model output fields, GOES East/West satellite imagery, quality-controlled ship and buoy reports of NOAA's Ocean Products Center (OPC), COADS (Comprehensive Ocean-Atmospheric Data Set) climatological fields, and bathymetry/elevation fields from NOAA's National Geophysical Data Center (NGDC). Graphics, imagery, and point data representations derived from these data sources were presented for geographic areas ranging in size from global to coastline scale.

In FY 1989, two major activities were completed. A Program Development Plan and Implementation Plan to establish multi-year requirements for the IMAFS

Development/Implementation Program was completed during the summer. The second effort interfaced the IMAFS VAX mini-computer workstations with various microcomputer systems for easy access to data. This latter activity was an essential effort to demonstrate the "interconnectability" of various mini- and micro-computer workstations, as envisioned for the 1990s.

In 1990, the IMAFS will be made operational and incorporate (1) database management capabilities for specific data sets, e.g., winds, waves, temperature, and other oceanographic parameters, (2) reformatted data and gridded fields to be work-station compatible, (3) subsets of data that allow the system to "zoom" into specified regions and to "re-map" data to specified scales and projections. The IMAFS software was modified to incorporate both GOES-VISSR and POES-AVHRR imagery. Selected physical, chemical, and biological data sets e.g., selected data from the California Cooperative Oceanic Fisheries Investigation (CalCOFI), were installed on the system.

For FY 1991, the existing quality assurance component of IMAFS will be upgraded to include "expert system" capabilities. Specific quality assurance software will be developed and included in model verification. In addition to the quality control enhancements, application software for analysis of specific scientific investigations and events will be integrated into the system. Off-the-shelf software, such as statistical analysis packages and new system software (e.g., "X.Windows") will be incorporated to make the system accessible to a wider range of fisheries scientists, oceanographers, and meteorologists. Communication software will be improved to provide better handling of errors and to increase speed. Continuation of the data base management capabilities will provide for data management customized for both the area under study and for the specific investigator(s).

2. **CoastWatch** - an integrated remote-sensing and conventional data program to provide critical environmental information to coastal scientists and decisionmakers.

NOAA CoastWatch rapidly monitors coastal water and land to support environmental science and decisionmaking. Focussed on specific regional and national requirements NOAA CoastWatch takes advantage of observing capabilities in the National Marine Fisheries Service, National Environmental Satellite, Data and Information Service, the National Weather Service, the National Ocean Service and the Office of Oceanic Atmospheric Research.

NOAA CoastWatch recently began (August 1988) producing prototype regional near real-time data products using its environmental satellites along with oceanographic and meteorological data for the southeast coast. Weekly summaries of sea surface

temperature, wind drift, Ekman transport, and other information are integrated and distributed to a network of federal scientists and state and local agencies in the southeastern US concerned about outbreaks of noxious algal blooms.

A pilot Chesapeake Bay CoastWatch is being conducted in 1989 in conjunction with the multi-state/Federal agency Chesapeake Bay Program, to improve spatial and temporal resolution of algal blooms during the spring season. It is anticipated that an operational Chesapeake Bay CoastWatch will continue to provide improved estimates of total spring algal biomass, thought to be closely linked to the Bay's oxygen depletion problems. CoastWatch programs for the Gulf of Mexico, the West Coast, the Northeast, and the Great Lakes are envisioned for the near future.

The Land Use, Habitat Change and Fish component of NOAA CoastWatch will monitor national coastal zone changes in upland cover and gains and losses of coastal wetlands repetitively every 2 to 5 years. Remote sensing imagery coupled with ecological data and information will be used to quantify and assess the impact of upland modification and habitat degradation and loss on fish. This portion of the project will begin with the Chesapeake Bay in FY 90 and extend to remaining coastal areas of the US over the following three years.

3. **COMPAS** - NOAA's Coastal Ocean Management, Planning, and Assessment System

COMPAS (Coastal Ocean Management, Planning, and Assessment System) is a relational data base and set of analytical capabilities for identifying and evaluating management strategies to improve environmental quality in the Nation's coastal ocean. It is an inexpensive, extremely user-friendly, desk-top system that is available from NOAA in the form of a set of disks for use on an Apple Macintosh micro-computer and HyperCard software. It permits easy access by decisionmakers to information summaries of large NOAA data bases. COMPAS provides a "browsing environment" in which to explore simple relationships among, for example, pollution sources, "pollution susceptibility" of coastal ocean areas, ambient concentrations of pollutants in the environment, resources exposed to pollution, and effects of pollution, such as restrictions on shellfishing.

COMPAS brings a wide range of information to the desktop of coastal ocean managers and decision-makers. It is designed to meet the information needs of coastal states, although users include Federal and local governments, as well as the academic community. Its objectives are to (1) bring existing, but disparate, coastal resource information into a single, user-friendly computer environment, (2) simplify the transfer of management information to and from state-level decisionmakers and the Federal government so that accurate and consistent resource assessments can be made, and

(3) improve the environmental quality of the Nation's coastal ocean. Over the next several years, COMPAS will include simple, but eloquent, water quality "screening models" with which to evaluate management strategies and report-writing capabilities to comply with Federal reporting requirements such as section 305b reports under the Clean Water Act.

NOAA will work closely with state and federal agencies to develop, demonstrate, and evaluate the COMPAS capability during FY1989-90. An operational prototype will be demonstrated at the CZ89 Conference in Charleston, SC. A fully operational system will be available for distribution by the fall of 1990.

NOAA intends to add analytical and predictive components to COMPAS in FY 1991. A significant effort in system design and computer programming is required to create modules for a wide range of coastal resource parameters, to link these modules, to add analytical and predictive capabilities, and to allow users to add their own information and to specify and generate their own reports.

Efforts in FY91 will complete COMPAS for four regions, 22 states, approximately 100 estuaries, and about 330 coastal counties.

4. **PC-PORT** - PC based Physical Oceanography in Real Time

The coastal ocean is a highway for commerce that links America's ports and harbors that are so critical to the Nation's transportation network, and play a key role in economic vitality of the Nation. Through them flow the bulk of U.S. exports, interstate commerce and imports from abroad. Making the most effective and efficient use of ports and harbors requires accurate and up-to-date information on water levels and circulation. With the aid of the best available water-level and current measurement systems and computers, NOAA is preparing to solve that problem by providing "real-time" data.

Special sensors, with data transmission capabilities, have been tested in port and harbor waters to provide up-to-the-minute information on water levels and current regimes. A ship's pilot, with access to a personal computer system, and with appropriate computer software programs, can find out what water-level and current conditions are at the moment of arrival or departure. Real-time systems alone, however, can only go so far. Improvements can also result from accurate short-term forecasts that are based on these real-time data. The forecasting techniques can be included in microcomputer-based software packages.

PC-PORT will disseminate to state, regional, and local decisionmakers, technical information and guidance to improve predictions for marine operations and warnings of coastal hazards. This includes forecasts of water level, circulation, and meteorological effects, all based on real-time data. The methods of dissemination will include microcomputer-based systems and appropriate training.

For FY 1991, NOAA will develop microcomputer-based software programs that allow marine operators to use real time information on currents, water levels, and meteorological conditions in important decisions regarding commerce, navigation, and natural hazards to vessels and personnel in the coastal ocean.

5. **NOCN** - NOAA'S Ocean Communications Network

NOAA's Ocean Communications Network (NOCN, or "notion") is an expansion of the existing area-wide communications capabilities of the NOS Office of Ocean Services (OOS) to service the needs of the coastal ocean scientific user community, including IMAFS, CoastWatch, and geographical information system users. The existing network, established in 1986, provides a two-way data distribution capability at 9.6 kbps between the NOAA Ocean Products Center (OPC) and the National Meteorological Center in Camp Springs, MD, the Navy-NOAA Joint Ice Center in Suitland, MD, the NOAA Center for Ocean Analysis and Prediction (COAP) and the Navy's Fleet Numerical Oceanography Center (FNOC) in Monterey, CA, and the OOS Ocean Observations Division in Rockville, MD.

In FY 1989 NOCN is being expanded to include telecommunications capabilities with NOAA's fisheries laboratory in Beaufort, NC, NOAA's environmental research laboratory in Boulder, CO, the National Oceanographic Data Center in Washington, DC, and the NOAA Central Computer Facility (NCCF) in Suitland, MD. The network operates at the 9.6 kbps level, except for the OPC-NCCF link and the COAP-FNOC link which are T1-Ethernet lines, or their equivalent. In addition, the communications computer capabilities of the COAP in Monterey were upgraded to handle increased traffic of observational data sets and gridded fields of data to network users.

In FY 1990, NOAA's NOCN will be expanded to connect the distributed databases of selected NOAA national centers, additional fisheries laboratories, and environmental research laboratories to support IMAFS, CoastWatch, and geographical information system data exchange. The OPC-COAP and OPC-NODC links will be upgraded to 19.2 kbps to provide the required baud rates to support expected requirements for observational data sets, gridded fields, and satellite data exchange. Phased implementation of local area networks at the regional NOCN nodes now provide

regional two-way access to coastal ocean databases for other Federal, state, and local decision-makers.

In FY 1991, the main communications facility at the Center for Ocean Analysis and Prediction (Monterey, CA) will be upgraded. In addition, disk storage upgrades will be installed at both the Monterey facility and the Ocean Products Center to handle satellite data (GOES-VISSR, TIROS-AVHRR, NIMBUS-CZCS, LANDSAT, and ERS1-SAR). Recurring costs include maintaining wide area and local area network communications, and monitoring to ensure integrity of the networks.

COMMON OBSERVATION SYSTEMS

Much of the research and information development activities described above rely on similar sets of basic ocean observations. These include conventional surface and subsurface data gathered from buoys, ships, and other platforms, as well as from space. Below we describe enhancements required for several of those systems to provide the support required in the research, model development, and data synthesis projects described above.

ENHANCED COASTAL OCEAN OBSERVATION NETWORK

BACKGROUND:

NOAA will develop and operate the enhanced network, relying on in-house capabilities where appropriate for the benefit of the Coastal Ocean Program. For example, the National Status and Trends Program, the NOAA CoastWatch, and the Coastal Ocean Productivity Program will require temperature and other physical and meteorological data, as well as a suite of chemical and optical parameters including, dissolved oxygen, turbidity, and total chlorophyll. Eventually sophisticated sensors for dissolved carbon dioxide and high spectral resolution optical measurements will be required as well to support these programs. Current, water level, and meteorological data will be needed to support NOAA's CoastWatch and coastal hazard warning efforts. Data from unattended in-situ sensors can be obtained at time and space scales impractical by other means (e.g. from ships) and can provide the "sea-truth" needed to calibrate satellite data. A proven integrated in-situ observation network would be of interest to other Federal agencies (i.e. DOE, ONR, EPA, NASA) and data streams should be valuable to academic scientists and environmental managers. In addition to assessment reports and other products to be derived from the data, NOAA will make the system technology available to other Federal agencies and will make the data available to scientists and state and local officials through appropriate distribution channels.

Ocean observations are required for understanding, analyzing and predicting coastal ocean processes, environmental quality, and coastal hazards. The present NOAA coastal observation network consists of 3 tiers of capability:

1. Automated Platforms. Stationary, frequently reporting platforms consisting of 49 Coastal Marine Automation Network (C- MAN) stations, 45 data buoys, and 200 water level monitoring stations.

2. Ships of Opportunity. Ocean-going vessels, some equipped with Shipboard Environmental Data Acquisition Systems (SEAS), recruited under the international Voluntary Observing Ship scheme of the World Meteorological Organization.

3. Mariner Reports. MAREP's from small domestic vessels such as fishing boats and tugs, similar to general aviation Pilot Reports (PIREP's), collected in 25 coastal areas.

All participants in NOAA's programs will be polled to determine their anticipated future requirements for in-situ observations, including location, type and quality of data needed, frequency of observation, and need for real-time access. Through a workshop or other mechanism, the needs of other Federal agencies and of state and local agencies will be determined, as will the current level of technology available within the academic and private sectors. With this information, the future configuration of the coastal ocean observation network will be established.

This mix of data sources is designed to furnish a cost-effective coastal environmental observing system. These observations are complemented by coastal weather radars which are being upgraded under the tri-agency NEXRAD program. However, the observing network is widely distributed along the 12,000 mile U.S. coastline, supplying data on conditions affecting over 2 million square miles of adjacent ocean. As a result, there are major data gaps in U.S. coastal areas which limit our understanding and prediction of the air-ocean environment. These gaps are in danger of being widened by the loss of 15 of the buoys which operate under reimbursable projects with the Minerals Management Service, Corps of Engineers, NASA, and the Alaska Oil and Gas Association. The loss of these systems upon project completion will seriously reduce ocean monitoring and resultant research and services.

In addition, the present platforms and vessels return a limited data set consisting primarily of winds, sea surface temperature, air pressure, waves, and water levels which deal only marginally with environmental quality and fisheries productivity issues. These limitations in network and data type also restrict our ability to develop, validate, and calibrate future space-based sensors.

The technology exists to begin to remedy these shortcomings in the coastal observation capability and thereby provide the in-situ data required for effective prediction and assessment related to important coastal ocean issues.

OBJECTIVES:

The objectives of the FY 91 and outyear effort are to improve the coordination of the existing observation capability and to enhance that capability with new sensing and communication technology. Major tasks for FY 91 will be:

- o modify and augment existing data transmission capability so that data streams from existing platforms are directed to a central location and processed to meet the needs of the NOAA Coastal Ocean Program (NCOP).
- o begin upgrade/redeployment of existing platforms and of VOS/SEAS capability
- o initiate the test and evaluation of a marine optical buoy system (apparent optical properties), and develop a prototype integrated Chemical-Biological- Optical Sensing System (C-BOSS) for future deployment on buoys and coastal fixed platforms
- o deploy RADS units in critical locations
- o determine the optimum distribution of new platforms and sensors to meet anticipated long-term requirements of the NCOP
- o fill key coastal and offshore data gaps with C-MAN and buoy systems
- o recruit volunteer mariners and private coastal radio stations and provide data relay terminals and communications to expand and automate the cooperative MAREP observing program
- o develop a NEXRAD coastal wind research project (NEXWIND) to investigate the use of Doppler radar technology in detecting and mapping coastal wind patterns.

In future years, new platforms will be developed to provide meteorological, physical and chemical-biological-optical data to support identified Coastal Ocean Program (COP) requirements. Upgrades of existing platforms will continue. New data transmission and data quality control capabilities will become operational so that data can be delivered efficiently to data product and data assessment centers.

Approach:

Ultimately, all components of the coastal ocean observation network will transmit data via satellite. This capability will be added to existing platforms not now having it. As part of the upgrade of NOAA's communication network, all coastal observation data will

be directed to a central location. A catalog of available data types and the data itself will be available from this location to all NCOP users. However, long-term data archival will continue to be a responsibility of appropriate existing national data centers.

Existing NOAA ocean buoys will be upgraded with new sensors and redeployed in critical coastal areas. The buoys will be equipped with meteorological sensors, temperature sensors at the sea surface and through the mixed layer, beam transmisometers, fluorometers and dissolved oxygen sensors. Similar current generation meteorological, optical and oxygen sensors will be added to up to 10 NGWLMS installations. Low cost drifting buoys will also be deployed as required. Selection of the appropriate buoy locations and NGWLMS installations will be made in conjunction with other NCOP participants.

Additional Shipboard Environmental Data Acquisition Units (SEAS) and the necessary expendable probes will be acquired and deployed on Volunteer Observing Ships (VOS) that transit coastal areas of the U.S. The data from the VOS will permit improved in situ marine weather data availability and confident interpolation of water mass structure and currents between locations of moored platforms, thus enhancing the validity of NCOP prediction and assessment efforts.

Even with increased NOAA ocean data, resources to solve coastal ocean problems are limited. NOAA and the public must work together through citizen cooperation in voluntary data gathering. Expand localized MAREP programs to approximately 100 coastal areas and supply low-cost terminals and communications for data collection and relay. Besides supplementing NOAA data, MAREP can succeed in sensitizing the public to the benefits of self-help involvement in improving the coastal ocean environment.

Using current technology, remote acoustic Doppler sensors (RADS) will be implemented at new locations such as crucial port entrances to provide real-time current information for shipping and to provide high frequency current observations for circulation modeling and assessment.

NOAA will begin installation of 115 NEXRAD sites in FY 90 to replace the nation's over-30 year old weather radar network. Forty-three NEXRAD sites will have coastal ocean and Great Lakes coverage out to approximately 125 miles. Although these radars will track localized severe storms with greater precision, more scientific investigation is needed on the extent to which the Doppler signal can detect detailed maritime wind conditions which affect vessel handling, safety, and wind driven nearshore currents.

The monitoring of bio-optical parameters and their variability as proposed by the ocean color satellite mission, requires the establishment and maintenance of a parallel in situ measurements capability in order to maintain the integrity of that data set. The CZCS sensor degradation and the problems encountered in parameterizing that degradation without in-water optical measurements supports this requirement. As a result of research and development conducted in part by NOAA, and by other agencies, many new sensors for chemical, biological and optical properties of the ocean are available. Many of them have direct application to identified COP needs. A prototype integrated Chemical-Biological-Optical Sensing System (C- BOSS) will be built based on this emerging technology. This buoy system will incorporate other prototype marine optical measurement systems (i.e., MOS) currently under development designed for long- term buoy deployment with a satellite data telemetry capability.

The success of these and other efforts of similar nature will be a major contribution towards satisfying COP requirements. One or more prototype C-BOSS units will be field tested and evaluated on an existing NOAA platform. In addition, the ability to transmit, quality-control and evaluate this new type of in-situ data will be developed. The most promising candidate bio-chemical sensors, (i.e., Fiber optical chemical sensors) would then be selected and integrated into the system followed by further testing and evaluation.

An Operational Management Information System (MIS)

For the past decade, there has been considerable effort to collect, transmit, and quality control ocean data. This effort has driven the development of data collection systems (such as SEAS, water level gages, and buoys), data transmission systems (such as TIROS-ARGOS and GOES-DCS), and data quality control efforts (such as QUIPS). All these elements are designed to deliver improved data to the primary forecast centers. What is lacking is an integrated system to deliver this information to platform managers, and eventually to the NESDIS archive centers. The first step in developing such an integrated system was the development of a prototype ocean platform inventory in 1988 by the NOS Office of Ocean Services.

This FY 1991 effort will create an operational Management Information System (MIS) as a tool for platform managers to monitor system performance and for Coastal Ocean planners to design optimum observing network(s). Specific tasks to be accomplished in FY91 include:

- development of a dial-in and on-line interrogation capability by platform managers to the MIS;

- development of software to permit remote platform managers to update the inventory (maintenance schedule and activities, new system deployment, etc.);

- development of software to automatically download and maintain a record of quality assurance statistics and platform location/track from the databases of the NOAA Ocean Products Center and Center for Ocean Analysis and Prediction.

Improved platform performance accountability and the capability to design/integrate Coastal Ocean observing networks requires an accessible database specifically designed to include an inventory and quality assurance statistics of Federal/state/local observing platforms. This initiative builds upon the proven successes of the Federal Platform Inventory, resident in the NOS Office of Ocean Services, and the Quality Improvement Performance System (QUIPS), resident at OPC and COAP, and to be located at the National Oceanographic Data Center (NODC).

Statistical information (performance and location/track) will be extracted at the end of each month. The MIS will maintain this statistical information with that of the Federal/state/local Platform Inventory. Managers will have the ability to perform an evaluation of both hardware systems and the institutional arrangements currently in place for collecting oceanographic data. The MIS will also have a feedback loop for data received in the delayed mode by the NODC from data collection activities.

This system will serve as an effective tool to support the management of Coastal Ocean observing systems. It will allow platform managers to obtain data during the interval between ocean data collection and data archiving by NESDIS; a capability which has historically been unavailable. The MIS will also be a powerful tool to aid in designing an integrated Federal/state/local observing capability within the Nation's Coastal Ocean.

SPACED BASED OBSERVATIONS: NOAA CoastWatch

NOAA CoastWatch provides a rapid information acquisition and delivery infrastructure for a comprehensive understanding of the coastal environment. The program has two major applications: coastal water and land. Water applications generally utilize near real-time observing and dissemination methodologies for responding to dynamic specific environmental concerns. Land applications are on longer time scales and are focused on land cover/habitat mapping.

A prototype regional (Southeast U.S.) CoastWatch effort presently provides retrospective and near real-time environmental information to the NMFS Beaufort Laboratory. This first water application was initiated in August 1988 as Southeast CoastWatch in response to a toxic red tide the previous fall. Since that time an experimental weekly hardcopy CoastWatch Bulletin has been produced and distributed by NESDIS for a number of southeast and middle Atlantic governmental users.

In early 1989, to provide Southeast CoastWatch users with more timely information, the initial system was enhanced with the implementation of telecommunicated AVHRR data and a PC image display system at the Beaufort Laboratory. This PC-based interactive system currently allows the Laboratory to integrate and analyze a number of important environmental data sets, such as: digital satellite data, conventional oceanographic observations, and atmospheric numerical model output. The provision of digital image data and wind field estimates is coordinated through NOAA activities in Washington, DC. An ocean feature analysis chart is provided directly to Beaufort from the NWS National Hurricane Center (NHC), based on data from the GOES satellites and integrated with ocean thermal structure charts produced by NOAA's Ocean Products Center (OPC). Figure 1 illustrates the flow of data within this first NOAA CoastWatch site.

INSERT FIGURE 1 COASTWATCH DATA FLOW

A second prototype effort is the Pilot Chesapeake Bay CoastWatch. Began in early 1989, the pilot effort will continue through the summer of 1989 as a cooperative effort between NOAA and the multi-state/Federal agency Chesapeake Bay Program. The primary objective of the project is to improve spatial and temporal resolution of spring algal blooms in the Bay by use of a developmental NASA water color instrument being flown over the Bay in a Virginia Institute of Marine Sciences (VIMS) light aircraft. Additionally, the Chesapeake Bay prototype includes the initiation of a tidal habitat mapping effort to compare land remote sensing imagery from 1978 and imagery from 1988. For the first time basin wide habitat changes can be evaluated, including marine, wetland, submerged aquatic vegetation, and open water areas.

WATER APPLICATIONS OF NOAA COASTWATCH

NOAA-wide capabilities are utilized for coastal water applications of CoastWatch involving unusual environmental events such as noxious algal blooms and anoxia/hypoxia. Two prototype CoastWatch areas are currently being developed, one covering the central North Carolina coast, and another covering the Chesapeake Bay. During FY 89 and 90 functional requirements analysis, research, product development, sample product production, image display software development, information integration, and prototype demonstrations will be conducted. During FY90, products for these regions will be operationally implemented, including automated products, archive/access system development, and high-speed communication of products and data. Activities are also underway, or are planned for the following NOAA CoastWatch regions (Figure xxx):

- maintain the Southeast U.S. effort (through the NMFS Laboratory in Beaufort, NC);

- expand the Chesapeake Bay project in cooperation with the EPA Chesapeake Bay Program.

- develop future CoastWatch sites for:
  -- the Gulf Coast,
  -- the West Coast,
  -- the Great Lakes,
  -- the Northeast

- consider additional (outyear) CoastWatch sites for
  -- Alaska
  -- Hawaii

INSERT Figure aaa. CoastWatch Regions

Systematic research, development, testing and evaluation procedures will be established for NOAA CoastWatch products and services. Figure bbb illustrates this process. Research and development for the next CoastWatch region will probably begin before the previous one is fully operational. Feedback from the end-user NMFS offices and the regulatory agencies is a key element in the success of CoastWatch. Time must be allowed for sample product production and prototype demonstrations so that users can gain enough experience with the data and products to provide accurate requirements. Feedback will be sought at every step of the construction process to support

modifications to the product suite. An analogy for this "assembly line" is not the robotic assembly of production automobiles but rather the crafting of custom musical instruments, requiring continuous testing and fine tuning. As early CoastWatch regions are selected the generic developments produced during implementation will facilitate startup of the next. Each geographical area is recognized as having differing (unique) needs as to specific information requirements, but the fundamental necessity for a geographical display workstation to integrate multiple planes of parameters will remain the same. Principal differences will be the types of local data available and the frequency of the necessary remotely sensed parameters.

INSERT Figure bbb. CoastWatch Assembly Line.

Central data distribution hubs will be the NOAA Ocean Products Center on the East Coast and the NOAA Center for Ocean Analysis & Prediction (COAP, Monterey, CA) on the West Coast. These two NOAA Centers are key components to the NOAA Ocean Communications Network (NOCN), being designed, developed, and implemented in support of the NOAA Coastal Ocean Program. The OPC provides the necessary interface to the NOAA Central Computer Facility (NCCF), the NMFS regional communications network(s) for the eastern U.S. and Gulf Coast, as well as OAR's Marine Laboratories for the Atlantic and Great Lakes. The COAP provides similar access to NMFS and OAR for the West Coast, Alaska, and Hawaii.

Ocean Color

An ocean color instrument is planned for launch in the early 1990s to provide direct-readout observations of ocean color at approximately 1 km resolution and global observations at 4.5 km resolution. It is proposed in FY 91 to begin development of the direct read out capability by providing a data acquisition capability for U.S. coastal regions. This data acquisition system will have broad application throughout the Coastal Ocean Program, including CoastWatch.

Using a combination of visible and near-IR data acquired from the ocean color instrument and in-situ data from a network of optical buoy systems, apparent optical properties, phytoplankton biomass, and total suspended matter, will be derived. These parameters, when appropriately analyzed, can be useful to CoastWatch as indicators of:

(1) fronts, eddies, coastal currents, and other mesoscale oceanographic features
(2) ocean dumping activities
(3) oil spill locations

(4) the presence of red tide
(5) optimum ship routes
(6) hazards to oil drilling operations
(7) productivity
(8) water quality (optical)

Data will be gathered by direct readout stations on both U.S. coasts, processed locally and centrally into products, and made available to CoastWatch workstations. Two options are currently being pursued. In the first option (Figure ccc) data would be received at three NOAA sites, one at the NOAA Command and Data Acquisition (CDA) station in Fairbanks, Alaska, a second at the Center for Ocean Analysis and Prediction (COAP) in Monterey, California, and a third at the NOAA CDA at Wallops, Virginia. In the second option (Figure ddd), NASA would establish three ground stations, one at the University of Miami, one at the Scripps Institution of Oceanography, and one with Canada in Halifax. NOAA would provide some of the operating expenses for these stations as well as establishing two stations of its own, one at the Fairbanks CDA and a second in Hawaii. For both options, NOAA will furnish the data communications system using the NOAA Ocean Communications Network (NOCN) and portions of the TIROS-N DOMSAT communications system. Raw data and locally processed products will be transmitted to Suitland, Maryland for further central processing and forwarding to the CoastWatch network. NODC will develop and maintain a digital archive and on-line access system for ocean color data and derived products utilizing optical disk technology.

INSERT Figure ccc. NOAA CoastWatch - Color - NOAA Option

INSERT Figure ddd. NOAA CoastWatch - Color - NASA/NOAA Option

It is anticipated that ocean color products will be available within six hours of readout from the satellite. The development of products, prototype operations, image workstation display development, operational implementation of products and communication will follow the procedures set up for CoastWatch AVHRR products.

One of the key aspects of the CoastWatch ocean color systems is the availability of data from a Marine Optical Buoy System. Consistently accurate conversion of ocean color raw data into biological parameters requires the near real-time availability of optical measurements from an in situ system. Development will be completed for the prototype of a buoy system capable of measuring the required optical properties of the ocean and telemetering them via the GOES Data Collection System to the NESDIS central processing facility. The buoys will be untended; however, periodic servicing is required to maintain the accuracy of the optical measurement system.

Arctic CoastWatch

The FY 91 launch of the European Remote Sensing (ERS-1) satellite will make routine Synthetic Aperture Radar (SAR) data available for the first time since SEASAT in 1978. One of the most important applications of SAR data is the monitoring of sea ice. With the SAR's 30m resolution, ice-edge, lead, concentration, and iceberg locations will be much more accurate than can be obtained with the 1.1km AVHRR. The SAR can also view ice through clouds and allow discrimination between first year and multi year ice. The ERS-1 SAR will be followed by a Japanese SAR in 1992 and a Canadian SAR in approximately 1994. Data from these three satellites will be read out and processed at a new Alaska SAR Facility (ASF) being built by NASA at the University of Alaska in Fairbanks. In addition, Canada will produce analyses from data received from its Gatineau ground station, with coverage including the Great Lakes. Because of the great utility of these data for ice analyses, the NOAA - Navy Joint Ice Center proposes to conduct an operational demonstration of the utility of SAR data from these various sources to U.S. ice analysis and forecasting activities.

Specific applications include:

- Provide SAR data and analyses to the JIC for improving operational ice products, for directing ship operations, for calculation of ice motion vectors, and to guide oceanographic data gathering activities along the ice edge for the Arctic and Great Lakes,

- Study the role of the Bering and Chuckchi Sea ice in controlling Arctic ecosystems (see Chapter II),

NOAA has agreed to share with the Navy the cost of augmenting the NASA ASF to allow near real time access by NOAA to SAR data for ice analyses in Alaskan and Arctic waters. Hardware will be installed at the ASF to capture, compress, and store high resolution (30m) and low (240m) resolution SAR data.

Communications will be established between the ASF and the NOAA Fairbanks Command and Data Acquisition (CDA) station. The existing NOAA TIROS-N DOMSAT link will be used to forward the data to the Joint Ice Center in Suitland, MD. A image workstation will be installed at the JIC to analyze the SAR data and generate products for NOAA/Navy and other applications demonstrations.

In addition, the JIC and its Canadian counterpart will share the cost of installing and maintaining a communications link to exchange ice data and products derived from data sources that the Center is not capable of receiving. This will allow the JIC to access analyses and products derived from space-borne SAR data not received by the Fairbanks ground station (e.g., Great Lakes coverage), as well as aircraft-borne SAR and SLAR flights conducted by Canada (e.g., Great Lakes and eastern U.S. seaboard). This access requires equipment and software to connect work stations to the current JIC interactive display equipment (DIFAS), as well as outyear software and training support.

West Coast CoastWatch

Work on developing a west coast CoastWatch site is described above in Chapter II. Satellite remote sensing data will be emphasized, along with in situ data, in research efforts and in environmental information disseminated to agency users. Near real-time NOAA satellite AVHRR temperature data and ocean color data, will be employed in research and in monitoring and generation of information for users. Archived AVHRR, Coastal Zone Color Scanner (CZCS) ocean color, and scatterometer (SASS) ocean data will be utilized in research activities.

Among the initial efforts to be undertaken by the West Coast NOAA CoastWatch will be to install a PC-based system with software for interactive processing and analysis of satellite data. A GOES tap will be installed from the appropriate NWS office to provide near real-time AVHRR data collected from satellite overpasses along the west coast and a suite of oceanographic and meteorological products.

LAND APPLICATIONS OF NOAA COASTWATCH

Land use, Habitat Change and Fish

Quantifying changes in land use and vegetation cover in the coastal zone is described in Chapter II. The program will monitor land use and vegetational coverage in the coastal zone of the US in order to provide information supportive of research needed to determine the impacts of wetland and estuarine degradation on the abundance and distribution of fish (see Figure 5).

The activity will emphasize the use of remotely sensed data from the Landsat Multispectral Scanner (MSS) and Thematic Mapper (TM) or the SPOT (HRV) instrument as well as supplemental aerial photography. Data from wetland and estuarine ecologists, and from biologists will be used. Where available aerial photography is best for simple

vegetation inventories of small test sites. However, for repetitive observations of vegetative changes and biomass of areas larger than 10,000 hectares (24,700 acres), use of Landsat MSS or Thematic Mapper (TM) is better suited for rapid analyses with considerable cost savings. This initiative directly supports NOAA legislative responsibilities in estuarine and marine science, monitoring and management contained in the Fish and Wildlife Coordination Act, the Coastal Zone Management Act, and the Magnuson Fisheries Conservation and Management Act.

INSERT Figure 5. Land Applications - Land Use, Habitat Change and Fish.

Although several other land cover mapping programs for the coastal zone are underway in other federal agencies, time scales for their completion and frequency of repeat cycles for change detection make them inappropriate for use by NOAA for effective habitat management on a broad regional, or national scale. For purposes of comparison these programs are briefly described. The National Wetlands Inventory (NWI) is a major national effort by the U.S. Fish and Wildlife Service (FWS) to map coastal and interior wetlands by type cover. Resolution ranges from 0.5 to several acres depending on location. To produce their NWI maps, the FWS makes use of high altitude photography. Interpretation of the photography is subjective and depends on individuals with considerable experience and natural faculties for pattern recognition. Much of the information is not digitized, making analysis of the data difficult. Because the aerial photography is spread out over a number of years, even within a single estuary, trend analysis is awkward due to potential biases caused by gains and losses of adjacent wetland areas. Under the Emergency Wetlands Resources Act of 1986 (Public Law 99-645) the U.S. Fish and Wildlife Service is to produce by September 30, 1988, NWI maps (not including change analyses) for the entire coastal zone of the Unites States. Additionally, the FWS is to produce by September 30, 1988, and at ten-year intervals thereafter, reports to update and improve the information contained in the 1982 report ("Status and Trends of Wetlands and Deepwater Habitat in the U.S., 1950's to 1970's". This report, however, does not contain change analysis maps showing where and what kind of changes have taken place over time. Such change analysis maps would be valuable to managers and researchers who need specific information on location and kind of change in order to make decisions regarding research and management actions.

The Land Use Data Analysis (LUDA) Program of the U.S. Geological Survey is an effort to map all land use for the entire U.S. The program makes use of aerial photography. The data are mapped only to a 10 acre resolution. Again the data base for the U.S. is not yet complete and subsequent surveys can not be repeated on a frequent basis.

County Soil Survey Reports (maps and text) are produced by the U.S. Soil Conservation Service. The reports generally cover all non-federal lands and report on soil type for the top 5 feet of soil. The data are collected on foot with a hand auger. Samples are taken approximately every 5 to 10 acres. The scale on the maps produced ranges from 1:15,840 to 1:250,000. Additionally the SCS is conducting a wetlands mapping project on the nation's farmlands for the swampbuster provision (Food and Security Act). An overlay of wetland coverage is being placed on its soil survey maps. The data are recorded by farm number at the field level and fed to state and national computers. With the computerized soils/wetland map, the SCS will work with the landowner to develop a conservation plan.

Additionally, most coastal states inventory their wetlands. However, wetlands are defined differently from state to state making regional and national analyses impossible. The state surveys, while detailed, generally have been accomplished on foot or in some cases with aerial photography or more rarely with MSS. Only in Florida, Louisiana and Mississippi is there extensive use of TM. Consequently, individual states have taken from 3 to 10 years to complete a survey. In certain states change is taking place faster than they are able to survey it. In all cases, however, these other programs have the potential to provide valuable collateral information to assist in verification of the digital satellite data. Finally, through the various elements of NOAA, field surveys for verification, and ecological research for establishing linkages between land, habitat and fish can be accomplished.

IV BUDGET SUMMARY

(Request in $ M)

Program	FY 1990	Increase	Total Request
Toxics	2.0	7.10	9.10
Nutrients	2.4	6.20	8.60
Physical Impacts		3.75	3.75
Estuaries	4.0	4.16	8.16
Coastal Ecosystems		8.36	8.36
Marine Debris		1.50	1.50
Information Del.	2.0	1.93	3.93
Common Obs.	2.0	9.60	11.60
TOTAL	12.4	42.6	55.00
(Planning ceiling	12.4	3.0	15.40)