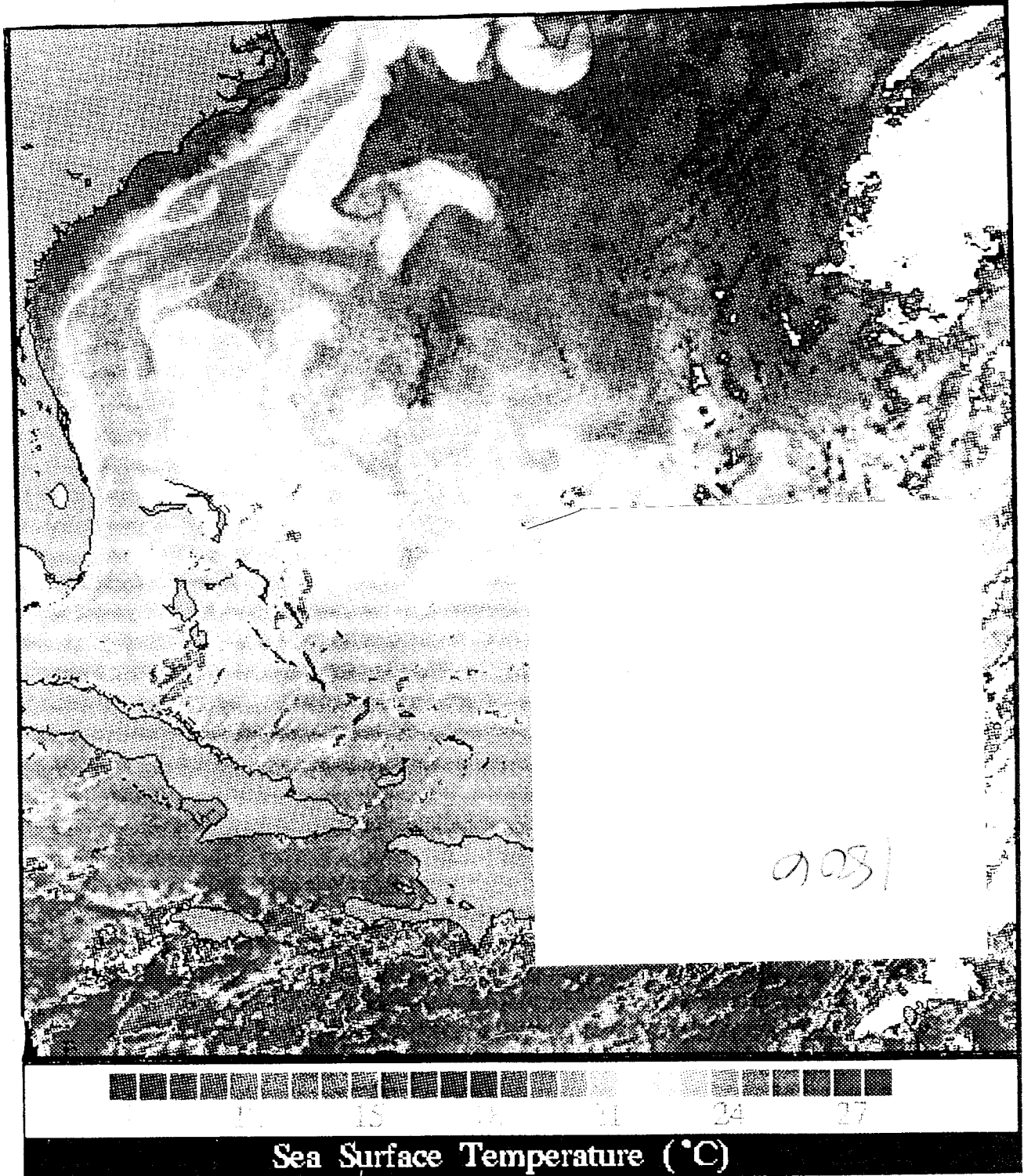


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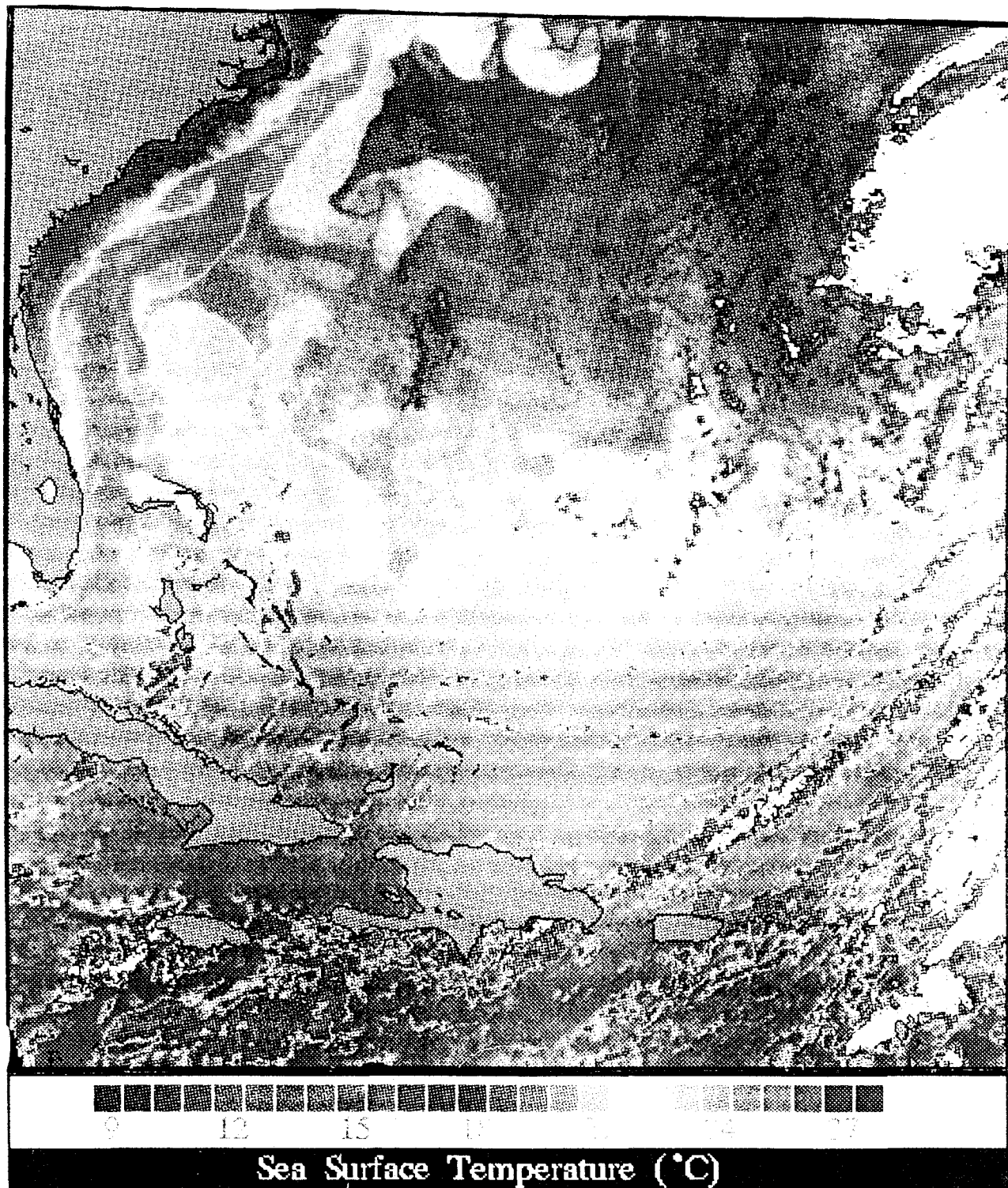
SOUTH ATLANTIC AND CARIBBEAN

REGIONAL MARINE RESEARCH PLAN



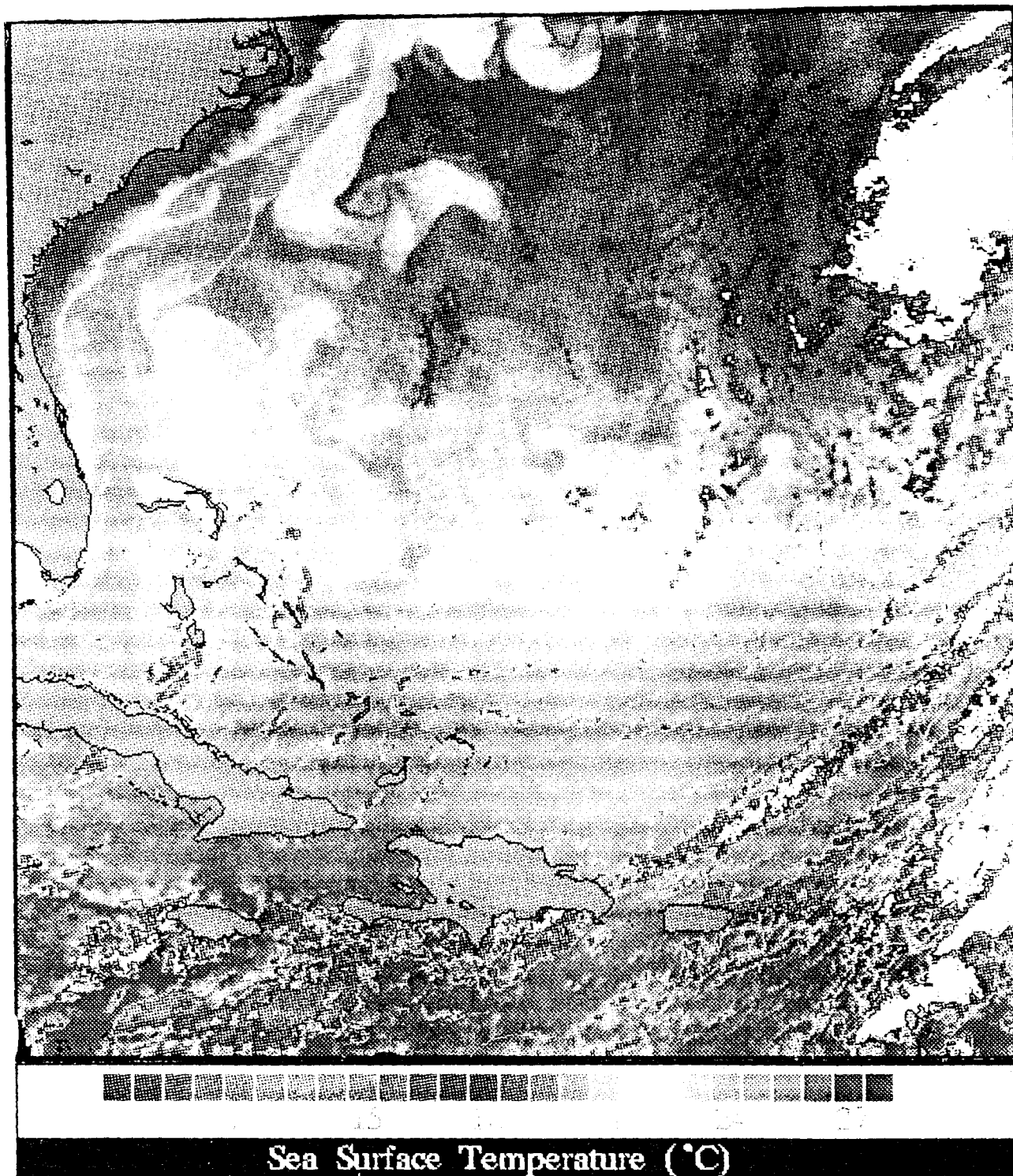
SOUTH ATLANTIC AND CARIBBEAN

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December 1994

III.

PROGRAM GOAL AND OBJECTIVES

Coastal ecosystem processes generally function on regional scales that fall between federal and state or local interests. Ocean currents, frontal systems, diversity and extent of wildlife, habitats, and marine and terrestrial basins often cross state boundaries but are not of a national scale. In order to understand and effectively manage coastal ecosystems it is necessary to study environmental conditions, processes, functions, and responses to perturbations on regional scales.

For years standard scientific method and standard funding mechanisms have supported detailed studies of individual disciplines and individual processes. Studies were generally conducted in response to issue-specific or site-specific concerns or in an attempt to characterize a particular process or locale. State funding is generally allocated for remediating local problems. Federal funding is generally allocated based on national priorities which may not reflect regional issues or concerns. The Regional Marine Research Program offers an opportunity for a new and unique method of addressing the generation, synthesis, and application of scientific research and the resultant environmental understanding from an ecosystem perspective on a regional scale.

The Regional Marine Research Program was designed to support regional, interdisciplinary, and applied research in an effort to address problems of coastal water quality and ecosystem health. The Regional Marine Research Program can look beyond purely local concerns and demands for "quick fixes" and work to establish a foundation or a framework of cooperation and understanding that will serve both the research science and resource management communities for a long period of time. In so doing, the Regional Marine Research Program can also serve a vital role in providing for the long-term coordination of coastal research scientists and resource managers.

The overall goal of the national Regional Marine Research Program is:

"to -- (1) set priorities for regional marine and coastal research in support of efforts to safeguard the water quality and ecosystem health of each region; and (2) carry out such research through grants and improved coordination."

Criteria defining "regional research" were adopted. "Regional research" must:

- have regional or large-scale impact or applicability as opposed to research with primarily local impact or applicability;
- contribute to solving more than one issue of regional concern. Under this criterion, research, the results of which are applicable to several issues, would be of higher priority than that pertinent to only one issue. This criterion would, therefore, discriminate against narrow, site-specific research and against monitoring unless it is research-driven and regionally significant;
- be conducted in order to make scientific progress in dealing with other high priority research themes or questions to be pursued. This criterion will favor research that is interdisciplinary, large-scale, or multi-system oriented or will foster further research or management activities that are interdisciplinary, large-scale, or multi-system oriented;
- be unlikely to receive adequate support from currently available funding sources for mission and/or programmatic and/or budgetary reasons. This criterion will allow a new or expanded focus on high quality research which would otherwise remain in an area largely devoid of organized support; and
- build upon and not duplicate similar research by other researchers which could be applied to this region. This criterion favors research which is directly and uniquely applicable to the region. At the same time, it encourages scientists within the region to keep abreast of all current research that could be applied to issues of regional concern.
- incorporate/acknowledge the human dimension as an integral part of the system and as an integral part of all funded research,
- help to create a regional research program that will help coordinate research and researchers from throughout the region, where possible coordinate activities with other Regional Marine Research Programs (especially the adjacent ones, the Mid-Atlantic region and the Gulf of Mexico region),

- and catalyze other pertinent research and coordination efforts, and
- ensure that all products are useful and are appropriately distributed to federal, regional, state, and local researchers and resource managers.

The Board of each Region is responsible for developing a Regional Marine Research Plan which establishes a process for identifying and prioritizing research needed to safeguard the marine and coastal waters of the region. Every Regional Marine Research Plan must, therefore, describe:

- the environmental health of the region,
- existing research efforts in the region,
- remaining research needs (prioritized) for the next 10 years with a focus on the next 3-5 years,
- a strategy for coordinating existing programs and efforts, and
- a timeline for implementing the recommended research and coordination.

To ensure development of the highest quality Research Plan and successful long-term implementation of the Research Plan, several mechanisms are required:

- provision of a forum for identifying and coordinating research on regional water quality and ecosystem health,
- collection of input for review and comment on the Plan from affected users and interests in the region,
- establishment of a solicitation and peer review system to ensure that the highest quality research projects will be conducted to carry out the comprehensive Plan, and
- development of a comprehensive mechanism for updating the research Plan and making findings available to affected users and interests in the region.

In Section 405(b) of the original legislation, examples of types of research that would qualify for funding are presented:

"Projects eligible for funding under this section shall include research, investigations, studies, surveys, or demonstrations with respect to:

- (A) baseline assessment of marine environmental quality, including chemical, physical, and biological indicators of environmental quality;
- (B) effects or potential effects of contaminants, including nutrients, toxic chemicals, and heavy metals, on the environment including marine and aquatic organisms;
- (C) effects of modification of habitats, including coastal wetlands, seagrass beds and reefs, on the environment, including marine organisms;
- (D) assessment of impacts of pollutant sources and pollutant discharges into the coastal environment;
- (E) transport, dispersion, transformation, and fate and effect of contaminants in the marine environment;
- (F) marine and estuarine habitat assessment and restoration;
- (G) methods and techniques for modelling environmental quality conditions and trends;
- (H) methods and techniques for sampling of water, sediment, marine and aquatic organisms, and demonstration of such methods and techniques;
- (I) the effects on human health and the environment of contaminants or combinations of contaminants at various levels, whether natural or anthropogenic, that are found in the marine environment;
- (J) environmental assessment of potential effects of major coastal and offshore development projects on the region;
- (K) assessment of effects of climate change on marine resources in the region; and
- (L) analysis and interpretation of research data for the benefit of State and local environmental protection and resource management agencies in the region."

The Regional Marine Research Program will, in this way:

- create opportunities for regional research (research that crosses boundaries of geography and scientific disciplines) that often falls between agencies' jurisdictions, researchers' realms of expertise, and traditional funding opportunities;
- allow for the efficient collection, analysis, and exchange of scientific data; and
- allow for the effective and efficient coordination of existing research and management programs.

IV.

REGIONAL PLAN DEVELOPMENT PROCESS

As a cooperative planning endeavor, the South Atlantic and Caribbean Regional Marine Research Program has drawn on the support and participation of over 250 individuals representing over 50 different agencies, organizations, and institutions (see Appendix 1). Development of this Research Plan followed a step-wise process of information collection, information synthesis, Research Plan development, and Research Plan revision, and involved all interested parties to the maximum extent possible.

The South Atlantic and Caribbean Regional Marine Research Program Board first met in August, 1992. The Board directed the Director to gather information regarding the environmental status of the region and the status of research efforts in the region. To that end, the Director developed and sent to all Board members a questionnaire to elicit background information. The Director also conducted a series of preliminary information gathering meetings with over 175 research scientists and resource managers from throughout the region. Based on the responses to the questionnaire and on the preliminary information-gathering meetings, a first draft of the South Atlantic and Caribbean Regional Marine Research Plan was developed.

The first draft of the Research Plan served as the foundation for the regional interdisciplinary workshop (20 participants) held in February, 1993. At the workshop, the expertise of the Board members was augmented with several "outside experts". At the workshop, programmatic goals and themes, research criteria, Research Plan organization, priority research topics, and a general research strategy were discussed and agreed upon. The Director used the results of the workshop to develop the second draft of the Research Plan.

The second draft of the Research Plan was mailed to the Board members and 15 outside experts for their review and comment. Based on their comments, a third draft was developed.

The third draft of the Research Plan was circulated to over 130 federal, state, and local resource managers and interest groups for their consideration. Eight local workshops were held throughout the region to provide an opportunity for those resource managers and interest groups to give direct personal input regarding the content of the Research Plan. Since there was remarkable consensus, all concerns voiced at the workshops were addressed in revisions and a fourth draft of the Research Plan was developed.

The fourth draft of the Research Plan was sent to the members of the Board for their review and was unanimously approved. Once the fourth draft of the Research Plan was approved by the Board, it was submitted to the Administrators of NOAA and EPA for approval. The Administrators of NOAA and EPA have established a Regional Marine Research Executive Committee to coordinate program administration and Research Plan review.

Based on Executive Committee comments, several revisions were made and a fifth draft of the Research Plan was developed. A listing of more specific research needs was developed based on responses of 30 experts to a questionnaire. Greater detail was added to the program inventory sections. The list of Participants was added. The fifth draft was approved by the Board and resubmitted to NOAA and EPA.

Once the Research Plan has been approved by NOAA and EPA, ecosystem-oriented workshops will be convened to gather small groups of scientific and management experts from a variety of disciplines to develop and refine specific research needs. The Director will then assist in the final development of a Request for Proposals. The RFP will solicit interdisciplinary research proposals that support the Research Plan's priorities and criteria. All proposals will be reviewed by an *ad hoc* peer review committee of knowledgeable scientists from inside and outside the region. The committee will be established by the Board and NOAA's Office of Oceanic Research. Comments from the *ad hoc* committee will be sent to the Board for their consideration. The Board will send its recommendations to NOAA. NOAA will then make the final determination regarding the funding of project proposals.

V. DEFINITION OF THE SOUTH ATLANTIC AND CARIBBEAN REGION

The South Atlantic and Caribbean Region, as defined in the legislation, includes the waters from Cape Fear, North Carolina to Cape Canaveral, Florida (i.e., most of the South Atlantic Bight) and the territorial waters around Puerto Rico and the U.S. Virgin Islands (i.e., the north-central Caribbean). The South Atlantic and Caribbean Regional Marine Research Program includes, therefore, the cooperation of the states of North Carolina, South Carolina, Georgia, and Florida, the commonwealth of Puerto Rico, and the territories of the U.S. Virgin Islands (Figure 2).

The legislative boundaries do not, however, accurately reflect hydrologic or biological boundaries and do not specifically identify the landward or seaward extent of the region.

To ensure that the program reflects true physical and biological parameters of the region, the Board of the South Atlantic and Caribbean Regional Marine Research Program passed a resolution (below) to address all waters of the South Atlantic Bight and southeastern Florida and the Florida Keys. They agreed, therefore, to address through joint management with the Mid-Atlantic Regional Marine Research Program, the region between Cape Fear, N.C. and Cape Hatteras, N.C., and through joint management with the Gulf of Mexico Regional Marine Research Program, the region containing the Florida Keys.

The Gulf of Mexico Regional Marine Research Program and the Mid-Atlantic Regional Marine Research Program will assume primary responsibility for these regions of "joint concern". The South Atlantic and Caribbean Regional Marine Research Program will address these areas of joint concern as necessary in a manner consistent with and supportive of the adjacent Regional Marine Research Programs.

Figure 2. South Atlantic and Caribbean Regional Marine Research Program Area

**Resolution Regarding "Joint Waters" in the South Atlantic and Caribbean Region
Adopted by the South Atlantic and Caribbean Regional Marine Research Program Board
August 7, 1992**

Whereas, the Florida Keys are ecologically linked with both the Caribbean Sea and the Gulf of Mexico and so are logically the object of attention, input, and planning by both the South Atlantic and Caribbean Regional Marine Research Program and the Gulf of Mexico Regional Marine Research Program Boards, and;

Whereas, the region between Cape Fear and Cape Hatteras is similarly linked to both the South Atlantic and Caribbean Region and the Mid-Atlantic Region and so is logically a concern of both the South Atlantic and Caribbean Regional Marine Research Program and the Mid-Atlantic Regional Marine Research Program Boards; therefore

The South Atlantic and Caribbean Regional Marine Research Program Board resolves to approach its tasks under Title IV of the South Carolina Fish Hatchery Act (1990) with respect to each of these two regions of biological and physical process overlap, to overlap with the Gulf of Mexico and Mid-Atlantic Regional Marine Research Programs, as appropriate.

The seaward boundary of the "continental portion" of the Region has been defined as the western wall of the Gulf Stream or the edge of the Continental Shelf break, whichever is further away from shore. The seaward boundary of the "island portion" of the Region has been defined as the edge of the continental shelf or the edge of the island plateau.

The landward boundary of the program area has been defined as the highest part of the watershed (with all its associated characteristics and process) that has a direct influence upon the water quality and ecosystem health of the coastal ocean.

VI. DESCRIPTION OF THE SOUTH ATLANTIC AND CARIBBEAN REGION

INTRODUCTION

Two Sub-Regions: The Caribbean and The South Atlantic Bight

Because of the diversity of the habitats represented in the South Atlantic and Caribbean Region, two "sub-regions" have been identified, the:

- (1) "Caribbean Sub-Region" (the U.S. Caribbean, the Florida Keys, and southeastern Florida) characterized by the dominance of tropical species in a biogenic environment, and
- (2) "South Atlantic Bight Sub-Region" characterized by more temperate species in a non-biogenic environment.

There is, of course, no distinct dividing line between the two regions -- the two are intrinsically linked and share many commonalities. But, for the purposes of applied research, because of the different geographical, geological, hydrological, climatological, and biological regimes represented in each, the two sub-regions are discussed individually in this chapter.

Dominant Domains and Habitats

This chapter is further divided according to five major themes, all of which are inherently complex, and intrinsically and complexly interrelated:

- (1) the terrestrial domain,
- (2) the character of coastal development and land use,
- (3) the marine geological domain,
- (4) the marine hydrological domain, and
- (5) marine habitats.

The natural geology, land cover, and hydrology of terrestrial environments adjacent to the ocean have a great affect upon the resulting character of the receiving coastal waters, sediments, and associated habitats. Watersheds, the basic definitional unit of terrestrial ecosystems, integrate issues of terrestrial hydrology, geology, and biology.

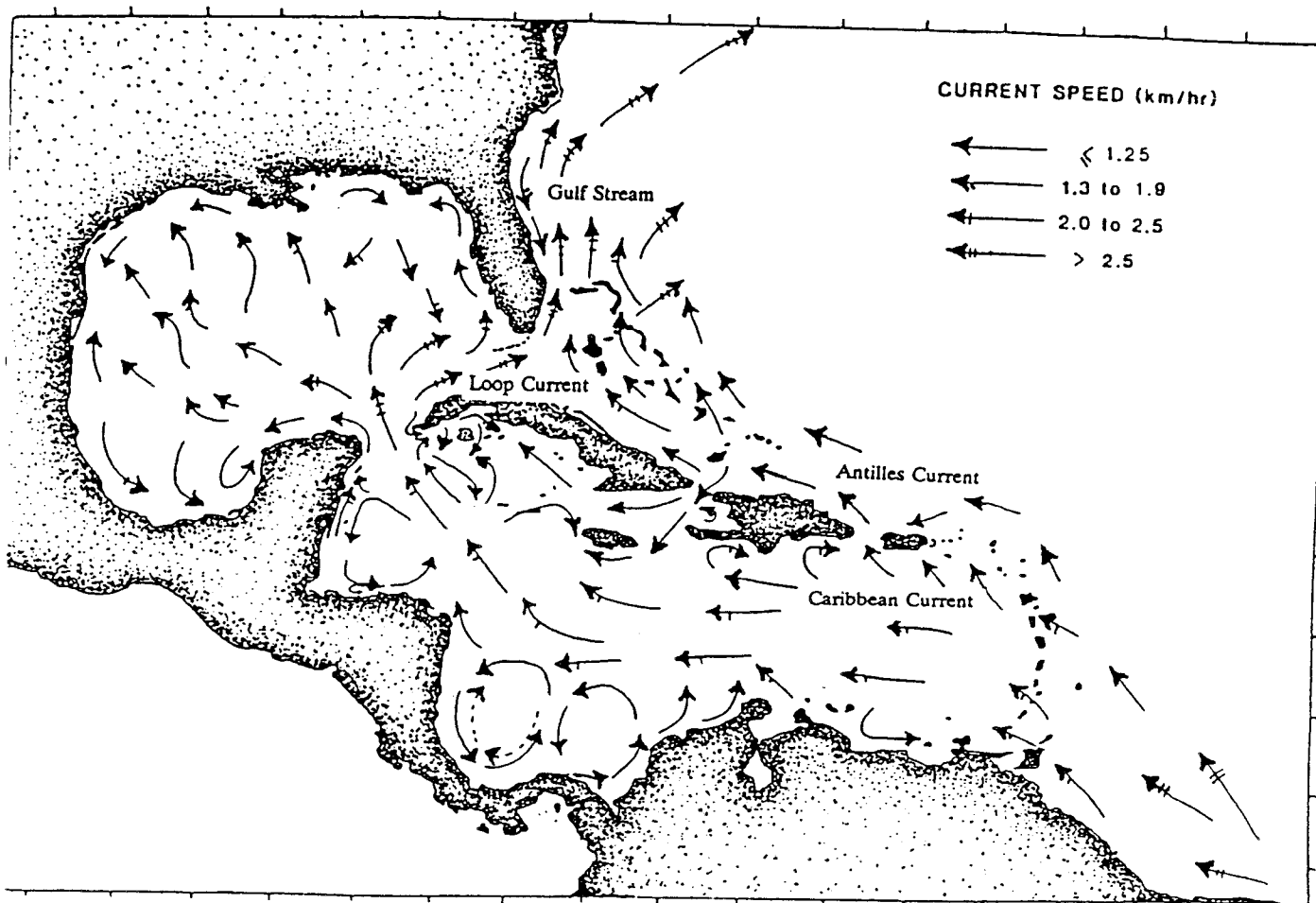
The character of land cover and human land use practices, especially those close to the coast, have significant effects on the water quality and ecosystem health of the adjacent near-coastal oceans. Land covered in old and established forests, for example, will interact differently with the near-coastal ocean than will fully cultivated agricultural fields or heavily developed urban areas.

The geology of the near-coastal oceans themselves, like the geology of adjacent land masses, has a profound affect on the character and functioning of near-coastal water quality and habitats. Character and quality of sediments and rocks (e.g., are they consolidated or dynamic, carbonate or siliceous, contaminated or free of toxicants) to a great extent determine (and are determined by) the types of biota that exist and so determine the levels and characteristics of near-coastal productivity.

The hydrology of the coastal region is, of course, of central concern to a program addressing coastal water quality and ecosystem health (Figure 3). Hydrology changes in timeframes of minutes, days, weeks, months, and years in response to episodic events, seasons, and regional and global trends.

The marine habitats found within the region are both the products of and key factors shaping local terrestrial, geological, and hydrological regimes. Coral, for example, proliferates because of the tropical qualities of the sub-region and, in turn, determines many of the sub-region's geological and biological qualities. Primary and secondary production are, in part, controlled by the habitat's physical factors and are, in part, the determinants of the habitat's form and function.

Figure 3.
Surface Ocean Current Patterns in the South Atlantic and Caribbean Region



THE CARIBBEAN SUB-REGION

Introduction

The waters of the Caribbean Sub-Region include the coastal waters surrounding the U.S. Virgin Islands, Puerto Rico (Figure 4), and the Florida Keys, and the near-coastal waters off the southeast coast of Florida north to St. Lucie Inlet (Figure 5). While the waters of the U.S. Caribbean islands, the Florida Keys, and Southeastern Florida exhibit some local differences, they exhibit considerable similarities and are intrinsically linked -- hydrologically and biologically.

The territory of the U.S. Virgin Islands includes roughly 63 islands in total, the largest of which are St. Thomas (83 square kilometers or 32 square miles), St. John (52 square kilometers or 20 square miles), and St. Croix (207 square kilometers or 80 square miles).

The commonwealth of Puerto Rico includes many islands, the largest of which is Puerto Rico. To the south lie numerous cays covered with sand, coral, and mangroves. To the west lie Mona, Monito, and Desecheo Islands. To the northeast lies the chain of islands called La Cordillera. To the southeast lies Vieques Island.

All of these Caribbean islands, with the exception of St. Croix, are part of a volcanic chain of islands formed by the subduction of one tectonic plate beneath another. There, tremendously diverse habitat (rocky shores, sandy beaches, mangroves, seagrasses, algal plains, and coral reefs) and the consistent light and temperature regimes characteristic of the tropics are conducive to high species diversity.

The waters of the Florida Keys and southeastern Florida are intrinsically linked with the waters of the Gulf of Mexico and the waters of the Caribbean to the west, south, and east and to the waters of the South Atlantic Bight to the north. These waters represent a transition from insular to continental regimes and from tropical to temperate regimes. This zone, therefore, contains one of the richest floral and faunal complexes.

The Natural Terrestrial Character of the Caribbean Sub-Region

The land masses in the U.S. Caribbean islands differ significantly from those in the Florida portion of the Caribbean Sub-Region.

St. John, St. Thomas, and Puerto Rico are all quite steep and mountainous, but unlike St. John and St. Thomas, Puerto Rico has a fairly broad coastal plain around its entire perimeter. The bedrock of the islands is mostly of volcanic origin, thrust up by tectonic activity. Puerto Rico's highest point is 1065 meters (3494 feet). Cliffs of volcanic bedrock are often exposed at the shoreline. In the Caribbean, small, steep, and rugged watersheds are common (slopes on St. John average 30 degrees). St. Croix, the result of the upthrust of the ocean floor, has a little more level ground suitable for agriculture and urban and residential development, but it also has rugged hills.

Rainfall typically comes as intense cloudbursts and often results in flooding. Consistently warm temperatures and steady winds cause high rates of evaporation and so, in coastal areas during periods of low precipitation, hyper-salinity often results.

Few if any perennial streams exist on the U.S. Virgin Islands. There, large volumes of water (and significant volumes of sediment and other materials) are carried out of the rugged watersheds, through intermittent streams and "guts" to the coastal waters during and immediately following significant rainfall events. In Puerto Rico several major perennial river systems exist along with numerous intermittent streams.

Figure 4.
The U.S. Caribbean

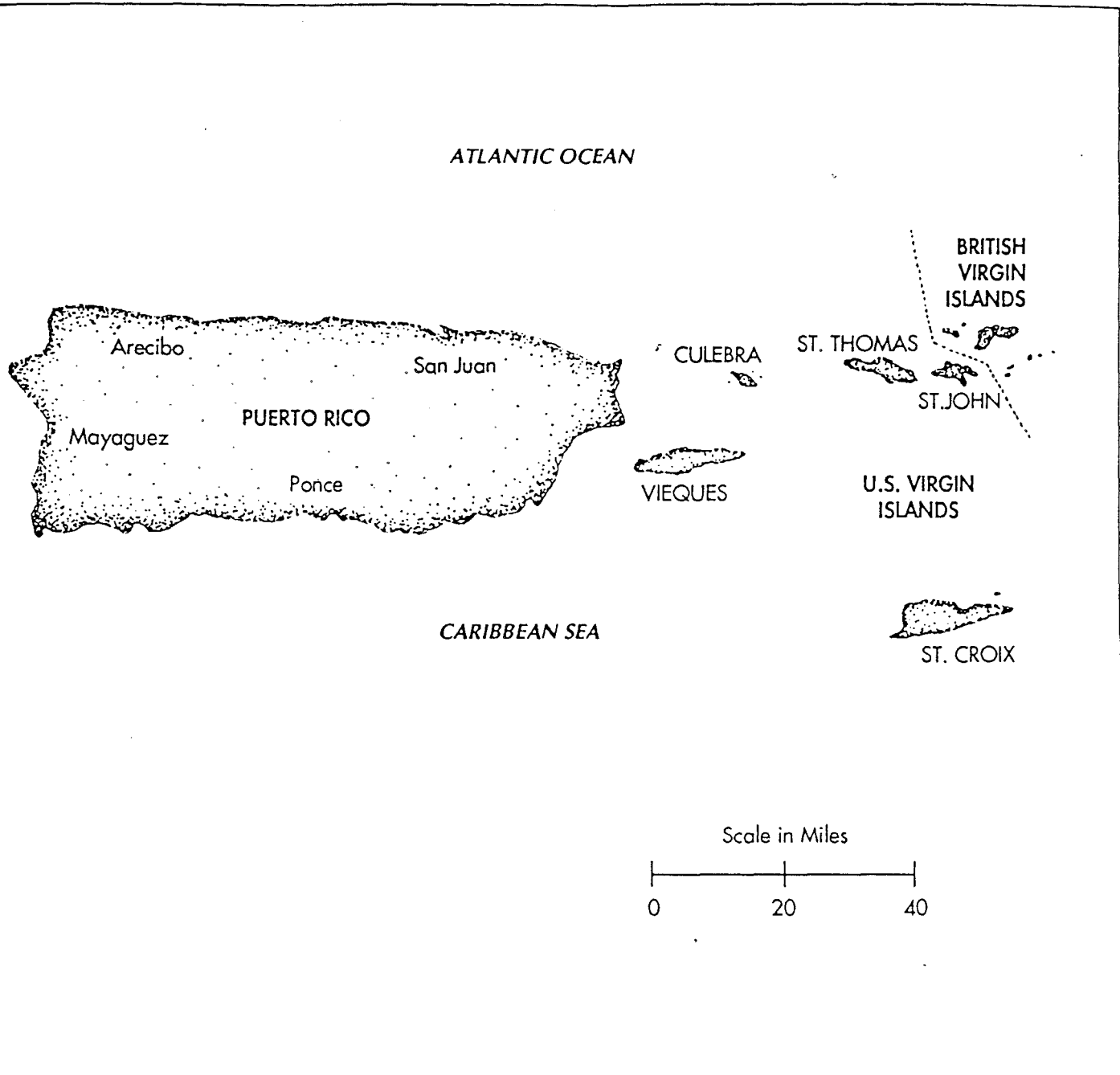
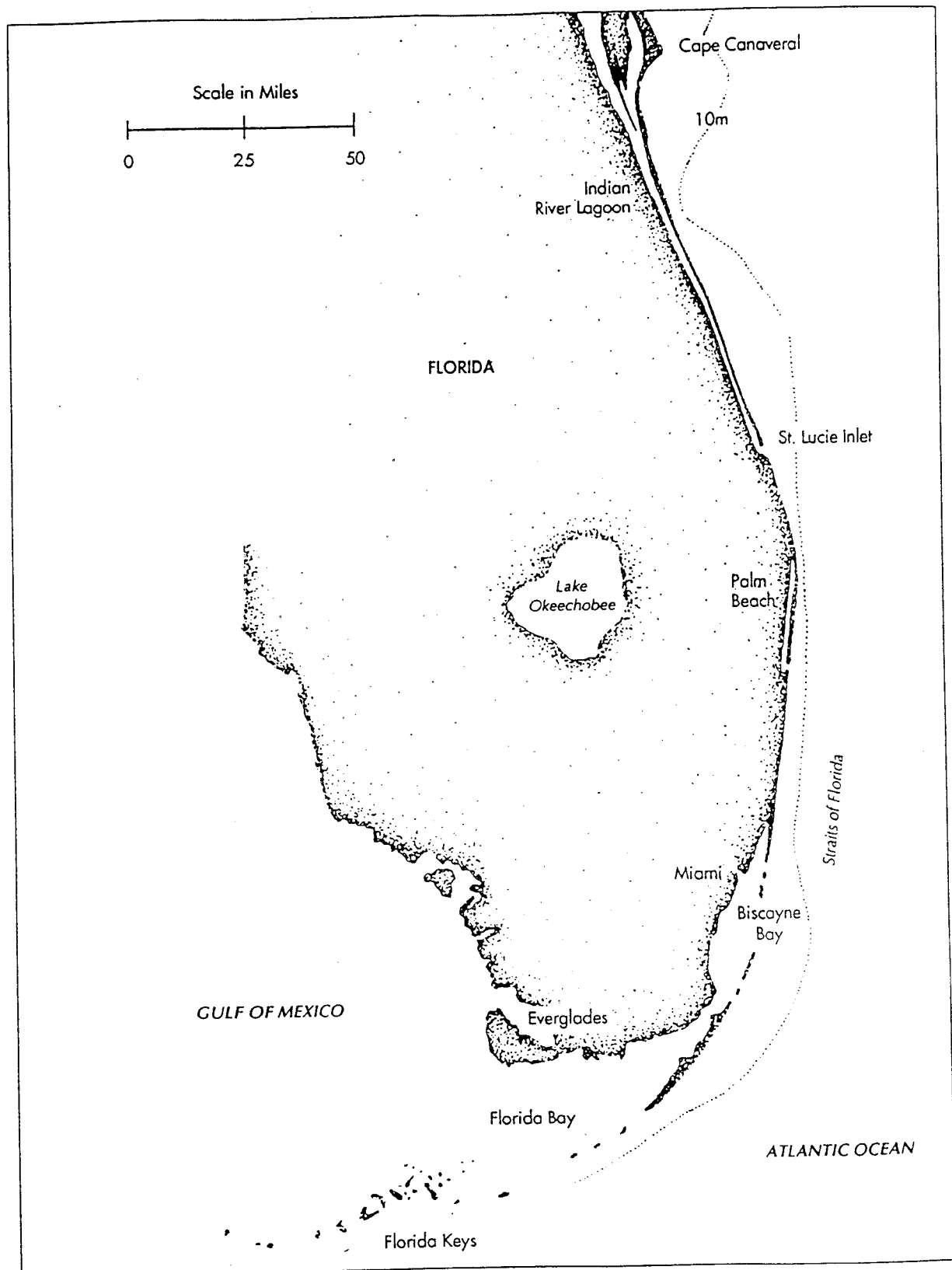


Figure 5.
The Florida Keys and Southeastern Florida



Vegetation on the Caribbean islands varies tremendously with the different precipitation regimes, from lush and dense rain forest assemblages (where rain fall can exceed 500 centimeters or 200 inches per year) to sparse desert-like assemblages (where rains of just 50 centimeters or 20 inches per year are common.) Dense or sparse, however, secondary scrub vegetation covers much of the land area, the original deciduous dry and semi-evergreen moist forests having been cleared for timber and agriculture long ago; few small pockets of the once dense and expansive virgin timber remain. The U.S. Virgin Islands and Puerto Rico are in the general path of tropical storms that travel from the southeast to the northwest, most often between June and December. Hurricanes play a large role in Caribbean ecosystem form and function.

In contrast to the tropical/warm-temperate character of the aquatic domain, the character of terrestrial flora and fauna in southeastern and southern Florida is predominantly warm-temperate.

The land of southeastern Florida is very low-lying, relatively flat, and sandy or marshy. Low-energy beaches dominate the northern portion of the coast of southeastern Florida; higher energy beaches dominate the southern portion, as is made evident by the lack of mangroves on seaward shores. Southeastern Florida is protected from the Atlantic Ocean by the Bahama Bank and Greater Antilles. All significant terrestrial water sources and drainage systems (including the Everglades, Lake Okeechobee, and the Indian River Lagoon) have been manipulated and modified by man. Extensive water storage areas, canals, locks, and floodgates dictate flow regimes. Large volumes of water may be stored or quite suddenly released, regardless of season or natural patterns of precipitation or drainage. Southeastern Florida has one of the highest average annual rainfalls for coastal areas in the southeastern United States, receiving roughly 125 centimeters (50 inches) per year.

The Florida Keys, elevated remnants of a relic Pleistocene coral reef tract, curve southwest-northeast and semi-enclose the large, shallow, island-dotted Florida Bay. Most of the Keys rise to only 0.6-1.0 meters (2-3.5 feet) above mean high sea level. The highest Key, Key Largo rises to only 5 meters (17 feet). There are no perennial streams on the Florida Keys. The Florida Reef Tract lies offshore to the south and east of the Keys. The best-developed portions of the Florida Reef Tract are in the northeastern and southwestern ends of the tract; the central portion is strongly affected by the inimical Florida Bay waters and reef development is poorer in that region. Beyond the reefs, the Straits of Florida separate the Keys from the north shore of Cuba.

Characteristics of Coastal Development and Land Use in the Caribbean Sub-Region

Development in the U.S. Virgin Islands varies quite a bit, but all of the larger islands have pockets of relatively dense development, generally, associated with the growing residential areas, the burgeoning tourist market, and a few large industries.

56% of St. John is National Park land, so it is relatively undisturbed, but development in inholdings and outside the park boundaries continues, particularly in Cruz Bay. St. John is home to approximately 3,400 people.

St. Thomas (pop. 55,000) is the most heavily developed of the U.S. Virgin Islands. It has large areas of relatively dense residential and commercial development and an active deep water port (Charlotte Amalie). Of the U.S. Virgin Islands, St. Thomas is the most affected by tourism.

St. Croix, the second most heavily developed island (pop. 50,000), has two major urban developments (Christiansted and Fredriksted) and the western hemisphere's largest oil refinery (Hess). St. Croix also has some expanses of tropical dry forest and open space remaining.

Puerto Rico (with over 4 million people) is relatively densely developed along much of the coast. There are a few areas of very dense coastal development (e.g., San Juan, Arecibo, Mayaguez, and Ponce). In these areas of denser development, urban and suburban residential development is often mixed with commercial and industrial development. Large-scale industries of pharmaceutical manufacturing and oil refining exist on Puerto Rico.

Now, second growth forests, limited agriculture, and increasing residential and industrial development characterize these "jewels of the Caribbean."

The coastal lands of the Florida Keys and southeastern Florida are, in general, heavily and increasingly developed. Southeastern Florida has the highest coastal population density within the southeastern United States -- the state's population density increased from 180 people per square mile in 1980 to 239.6 people per square mile in 1990, an increase of 33%. Florida (southeastern Florida in particular) has the highest growth rate in the U.S. and much of that growth has occurred within the coastal zone. Florida is now home to nearly 13 million people (see Figure 7). The Florida Keys are also, for the most part, quite heavily developed, although in the Keys development is almost exclusively residential. From Miami, FL to Stuart, FL, dense residential development is mixed with active commercial and industrial development. Centers of development in this "continuous megalopolis" area include Miami, Fort Lauderdale, Palm Beach, and West Palm Beach.

Inland of the dense coastal developments agriculture, marsh, and woodlands dominate the human landscape. Large-scale water management projects have altered vast expanses of coastal habitat. Large areas have also, however, been protected from development, such as in the Everglades National Park and numerous other parks and sanctuaries.

The Marine Geology of the Caribbean Sub-Region

All of the islands in the U.S. Caribbean, with the exception of St Croix and 4 cays, lie on the Puerto Rico Bank, a submerged plateau defined by the 183 m (600 ft) depth contour. All of the sediments of the Bank itself are of volcanic origin. Most are igneous sediments that have been thrust up by tectonic activity. Some are theorized to be direct deposits from more recent volcanic activity. Deep water surrounds the Bank. The Puerto Rico Trench, lying to the north, is over 8,000 meters (26,500 feet) deep. The Muertos Trench, to the south, is over 5,000 meters (16,500 feet) deep. Less than one mile from the western shore of Puerto Rico in the Mona Passage (the channel that separates Puerto Rico from the Dominican Republic), depths of over 1,000 meters (3,300 feet) are reached.

In more recent times, coral reef growth and evolution have dominated surficial sediment character and sedimentary processes -- vast supplies of carbonate sediments (relatively insoluble in warm water) have been created and deposited, covering much of the shelf. Much of the shelf surface is covered with carbonate nodules. In areas that have a lot of fluvial activity, volcanic sediments may dominate surficial habitats, but in areas that do not have much fluvial activity, the deposition of the "carbonate platform" dominates and covers the volcanic material.

Most of the islands in the U.S. Caribbean have rocky shorelines (volcanic in nature) with protected sandy beaches. The sands are usually calcium carbonate from fragments of coral, molluscs, and calcareous algae. In some places, "beach rock" has formed as calcium carbonate from the seawater percolated through the sediments and "cemented" the grains together. Linear "beach rock" outcroppings are apparent on many beaches. Exposed windward beaches may suffer significant rates of erosion unless fringing reefs provide protection and a source of carbonate sand.

Offshore, between the seagrass beds and the coral reefs and in deeper waters, sandy bottoms and algal plains dominate. These areas may be sparsely or densely vegetated with a canopy of up to 1 meter of red and brown algae. Algal plains are not areas of active sand transport.

Under the waters of the Florida Keys and southeastern Florida lies the Floridian Plateau, a portion of the Continental Shelf. To the south of the Florida Keys the narrow Shelf drops off quickly into the Straits of Florida where depths of over 1,000 meters (3,300 feet) occur. Off the southeastern shore of Florida, to the south of Jupiter Inlet (just north of Palm Beach), the Shelf is essentially lacking; water depths quickly approach 900 meters (3,000 feet). While these waters are "protected" by the Bahama Bank and the Greater Antilles that lie off shore, treacherous seas can develop as a result of interacting currents and winds. Off the southeastern shore of Florida to the north of Jupiter Inlet, the more gently sloping Shelf begins to broaden.

The surface of the Continental Shelf around the Florida Keys and southeastern Florida is composed of chemically and biologically produced autochthonous carbonate sediments -- limestones and oolites. The carbonate sediments significantly affect the biogeochemical processing of terrestrial inputs. Significant reef structures occur across the Shelf.

Florida reported an average annual rate of erosion of 9 cm (0.3 ft) per year (NOAA, 1986), but in many areas, especially along the east coast in areas near inlets, erosion rates are much higher and threaten coastal development.

The Marine Hydrology of the Caribbean Sub-Region

Hydrologic patterns link the waters of the U.S. Caribbean with the Florida Keys and southeastern Florida.

The marine waters of the U.S. Caribbean are primarily influenced by the waters of the westward flowing North Equatorial Current. The North Equatorial Current splits at the Lesser Antilles. The Caribbean Current flows into the Caribbean Basin at roughly 0.5 meters (1.7 feet) per second. The Antilles Current flows to the west along the northern edge of the Bahamas Bank and so links the waters of the Caribbean to those of southeastern Florida. Several rivers exert intermittent but important influence on the waters of the Caribbean Basin including the Amazon, the Orinoco, the Magdalena, and the Columbian. The plume from the Orinoco River that flows up the Lesser Antilles and along the Greater Antilles, for example, can carry with it high concentrations of suspended particles, unique chemical properties, and biota. The plume, therefore, can be responsible for events of high turbidity and algal blooms that usually occur in October.

Near shore waters range from 0 to 20 meters in depth and outer shelf waters range from 20 to 30 meters in depth, the depth of the shelf break.

The North Equatorial Current is the predominant hydrological driving force in the Caribbean region. It flows from east to west along the northern boundary of the Caribbean plateau.

The Trade Winds ("Easterlies") blow quite consistently from the east (ESE-ENE) at 10-15 knots, but can vary in magnitude as the relative strengths of the Bermuda High (to the north) and the Equatorial Trough (to the south) vary with the seasons. Waves and swells are mainly driven by the Trade Winds. Waves are usually 3-5 feet high and the customary easterly swells are usually 4-6 feet high.

Coastal surface water temperatures remain fairly constant throughout the year and average between 26 and 30°C. Salinity of coastal waters is purely oceanic and so is usually around 36 parts per thousand, but in enclosed or semi-enclosed embayments, salinity may vary widely depending on fluvial and evaporational influences.

It is believed that no up-welling occurs in the waters of the U.S. Caribbean (except perhaps during storm events) and, since the waters are relatively stratified, they are severely nutrient-limited. In tropical waters nitrogen is the principal limiting nutrient.

The waters of southeastern Florida and the Florida Keys are dominated by the narrow Straits of Florida which carry the surficial Florida Current waters to within a few kilometers of the shore. The waters of southeastern Florida and the Florida Keys are intrinsically linked with the waters of the Gulf of Mexico by the Loop Current and with the waters of the Caribbean by the Yucatan, Caribbean, and Antilles Currents. The Loop Current flows out of the Gulf of Mexico around the tip of the Florida Peninsula, and off to the north-north-east. The Yucatan Current flows along the eastern coast of the Yucatan Peninsula and joins with the Loop Current off the western end of Cuba. The Caribbean Current flows from the Caribbean Basin towards the southern tip of Florida. The Antilles Current flows along the northern edge of the Bahama Bank, coming close to shore near Cape Canaveral. At the confluence of the Florida Current and the Antilles Current, the Gulf Stream flows to the north-north-east, linking southeastern Florida with the South Atlantic Bight.

Wind-driven currents are very important driving forces in these waters. Annual coastal up-wellings all along southeastern Florida and major freshwater releases through the multitude of canals and locks also greatly influence coastal water quality. The most important physical processes, in terms of resultant water quality, however, may be episodic events such as hurricanes, tropical storms, and frontal events associated with the Florida, Loop, or Antilles Currents (USEPA, 1992).

Near-coastal sea surface temperatures peak in July off Key West at roughly 32°C (87°F) and are generally lowest in January or February at roughly 20°C (71°F).

The Marine Habitats of the Caribbean Sub-Region

Because of the hydrologic and meteorologic linkages between the waters of the U.S. Caribbean, the Florida Keys, and southeastern Florida, many biological connections and similarities exist.

The U.S. waters of the Caribbean are relatively nutrient poor and so have low rates of primary and secondary productivity, but these waters display some of the greatest diversity of any part of the South Atlantic region. High and diverse concentrations of biota are found where habitat is abundant. Coral reefs, seagrass beds, and mangrove ecosystems are the most productive of the habitat types found in the Caribbean, but other areas such as soft-bottom lagoons, algal hard grounds, mud flats, salt ponds, sandy beaches, and rocky shores are also important in overall productivity. These diverse habitats allow for eclectic floral and faunal populations.

In the waters of the Florida Keys and southeastern Florida, tropical/sub-tropical marine habitats dominate.

Offshore, **algal plains** are common. These are algae-dominated sandy bottoms, often covered with carbonate nodules. They occur primarily in deep water (> 15 meters or 50 feet) and account for roughly 70% of the area of the insular shelf of the U.S. Virgin Islands. Algal plains support a variety of organisms including algae, sponges, gorgonians, solitary corals, molluscs, fish, and worms. Algal plains may serve as critical juvenile habitat for commercially important (and diminishing) species such as Queen triggerfish and lobsters.

Coral reefs and other coral communities are one of the most important ecological (and economic) coastal resources in the Caribbean Sub-Region. They act as barriers to storm waves, provide habitat for a wide variety of marine organisms including most of the economically important species of fish and shellfish, are the primary source for carbonate sand, and serve as the basis for much of the tourism. Coral communities are made by the build up of calcium carbonate produced by living animals, coral polyps, in symbiosis with a dinoflagellate, *zooxanthellae*. During summer and early fall, most of the coral building organisms are at or near the upper temperature limit for survival and so are living under natural conditions of stress. Further increase in local or global temperature could prove devastating.

Studies of 2 fringing reef sites near St. John indicated the total fish biomass is comprised of roughly 60% carnivores, 24% herbivores, and 16% omnivores. Stock assessments are, however, especially difficult in the tropics because of the large number of species (there are 300 species of common reef fish alone!) and the complex interrelationships of the coral reefs, seagrass beds, and mangrove ecosystems which the fish and shellfish inhabit. The high species diversity of the tropics has been related to the high habitat complexity of the area (Randall, 1967).

Reef habitats associated with the Florida Keys and southeastern Florida are composed of and support hermatypic corals, algal gardens, sponges, soft corals, and sabellariid worm reef growth. In this region there is a transition of dominant coral types; tropical stony coral reefs dominate to the south of the St. Lucie Inlet and algal/rock reefs dominate to the north of the St. Lucie Inlet. To the south of the Keys lies the Florida Reef Tract. Most of the living reef is on the reef's seaward edge.

Seagrass beds are highly productive ecosystems. They are quite extensive in the Caribbean Sub-

Region -- some of the largest seagrass beds in the world lie beyond the shore on both sides of the Keys. Seagrass beds often occur in close association with shallow-water coral reefs. Turtle grass (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*), and shoal grass (*Halodule wrightii*) are the three most abundant species. Seagrasses are true flowering plants that spread through the growth of roots and rhizomes. Seagrasses act to trap and stabilize sediments, reduce shoreline erosion, and buffer coral reefs; they provide food for fish, sea turtles (heavy grazers), conch, and urchins; they provide shelter and habitat for many adult species and numerous juvenile species who rely on the seagrass beds as nursery areas; and they provide attachment surfaces for calcareous algae.

Mangrove habitats are very productive coastal systems that support a wide variety of organisms. The mangrove food web is based largely on the release of nutrients from the decomposition of mangrove leaves, and in part on the trapping of terrestrial material. Red mangroves (*Rhizophora mangle*), with their distinctive aerial prop roots, grow along the shoreline, often in mono-specific stands. The roots of the red mangroves help to trap sediments (and pollutants) associated with terrestrial runoff and help to buffer the shore from storm waves. Red mangrove forests support a diverse community of sponges, tunicates, algae, larvae, and corals, as well as juvenile and adult fish and shellfish. Black mangroves (*Aveicennia germinans*) and white mangroves (*Laguncularia racemosa*) grow landward of the red mangroves. They also act as important sediment traps. Exposed and sheltered mangrove shorelines are common throughout the U.S. Caribbean and dominate the natural fringing vegetation of the Florida Keys and southeastern Florida.

Throughout the U.S. Caribbean, both **rocky shores** and **sandy beaches** are common. While many of these beaches are high-energy and extremely dynamic, buffering by reefs and seagrasses allows some salt-tolerant plants to colonize the beach periphery. Birds, sea turtles, crabs, clams, worms, and urchins use the intertidal areas. In southeastern Florida, sandy beaches dominate.

Estuaries occur where tidal waters mix with fresh riverine waters. There are two major estuaries in southeastern Florida: Florida Bay and Biscayne Bay. Florida Bay lies to the north of the Florida Keys. It is one of the most important and productive ecosystems of South Florida, where sub-tropical/warm-temperate species of fish, seagrass, shrimp, and molluscs abound (RSMAS/FAU, 1992). Florida Bay is a transitional estuary between the Gulf of Mexico and the Atlantic, and between the Everglades and the Florida Keys Reef Tract. Biscayne Bay, to the north and east of Miami, is a tropical polyhaline-marine estuary largely open to the Florida Straits, lacking many of the true estuarine warm-temperate species. Both estuaries commonly demonstrate hyper-salinity during drier seasons and major salinity drops during heavy summer-fall rains or large freshwater releases from inland drainages.

Salt ponds, common in the U.S. Virgin Islands, are formed when mangroves or fringing coral reefs grow or storm debris is deposited, effectively isolating a portion of a bay. The resulting "pond" undergoes significant fluctuations of salinity with changes in relative evaporation and runoff. The biota associated with salt ponds, are, therefore very specialized, and usually somewhat limited. Salt ponds are extremely important in trapping terrestrial sediments before they reach the coastal waters.

THE SOUTH ATLANTIC BIGHT SUB-REGION

Introduction

The South Atlantic Bight (SAB) is a relatively distinct hydrographic and bio-geographic region, but its boundaries are somewhat vague (Figure 6). The northern and southern geographic boundaries of the SAB are sometimes disputed. The SAB is generally considered to encompass the continental shelf waters from roughly Cape Canaveral or West Palm Beach, Florida to Cape Hatteras, North Carolina. For the purposes of this Research Plan, Stuart, Florida (between West Palm Beach and Cape Canaveral) shall represent the southern boundary of the SAB. Stuart (and St. Lucie Inlet at the mouth of the Indian River Lagoon) represents a relatively distinct boundary between temperate and tropical waters and species -- it is the southern extent of a transition zone from tropical waters to warm-temperate waters.

The width of the SAB is also somewhat unclear. Some contend that the SAB extends seaward to the western wall of the Gulf Stream, a seasonally variable but extremely influential boundary. Others contend that the SAB extends seaward to the edge of the continental shelf break, a relatively stable boundary. For the purposes of this Plan, the broadest definition of the extent of the seaward SAB applies.

The SAB, then, is characterized by the dominance of the northerly flowing Gulf Stream, shallow continental shelf waters, and complex terrestrial interactions. Dominance of the warm Gulf Stream influences results in reduced seasonal variation. Shallow shelf waters, terrestrial influence, and Gulf Stream influences result in high productivity.

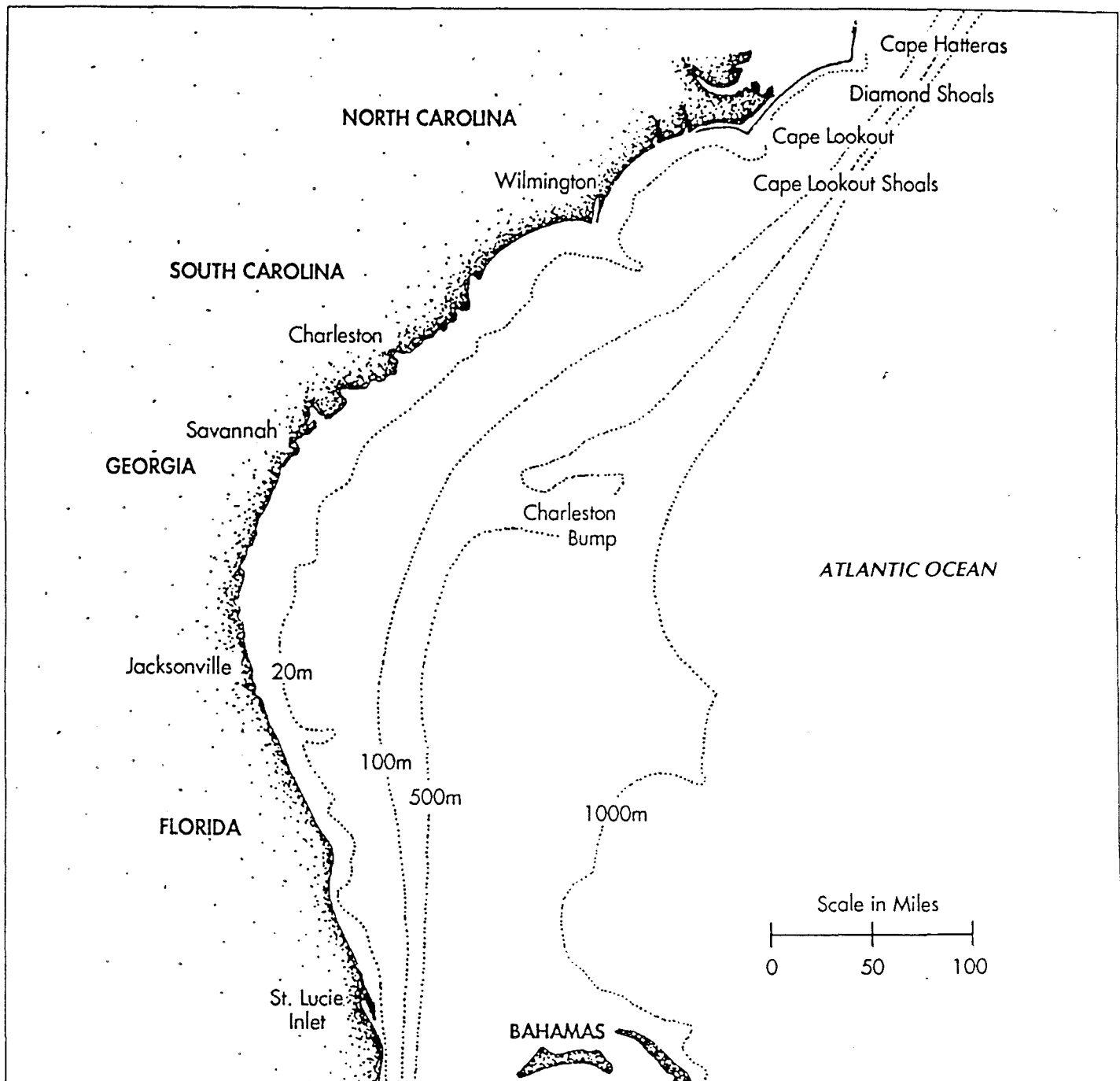
The Terrestrial Character of the South Atlantic Bight

The coastal plain lands adjacent to the SAB are relatively flat and marshy. They are, by and large, dominated by scrub-shrub forested wetland and marshy wetland vegetation. As a result of changing coastlines and dynamic coastal processes, mud, sand, clay, and organic rich soils are interbedded; the quality of the surficial layer at any one place depends on the latest events to affect that area.

Throughout the SAB, the barrier islands -- well-developed and linear in the north and south, more fragmented or even non-existent in the central portion -- are a prominent geological feature, an important type of habitat and a critical factor in determining fluxes of water, sediment, and biota in the near-coastal oceans.

In the southern portion of the SAB (from the St. Lucie Inlet to Jacksonville), extensive linear barrier islands are common, creating long, smooth, sandy beaches that run for miles, protecting very narrow lagoonal systems. High energy beaches dominate. Sandy ground and sparse scrub-dune vegetation dominate. The southern portion of the SAB, like the northern portion, is very narrow -- the Gulf Stream (and shelf break) is only 5 kilometers (3 miles) off the coast of West Palm Beach and only 50 kilometers (30 miles) off the shore of Cape Canaveral.

Figure 6.
The South Atlantic Bight



In the central portion of the SAB (from Jacksonville to Cape Romain) the continental shelf is very broad; the shelf break (and Gulf Stream) is roughly 120 kilometers (72 miles) off the coast of Georgia and South Carolina. Here several large rivers (Cape Fear, Cooper, Santee, Savannah, Altamaha, and St. John's) drain directly into and so exert significant influences on the near-coastal environment. In some areas, complex shorelines and dendritic patterns of tributaries are exposed to the Atlantic Ocean, while in other areas expanses of estuarine marsh are protected by sand-based and bedrock barrier islands. Further out on the broad shelf the Gulf Stream is the dominant hydrological influence.

In the northern portion of the SAB (from Cape Romain to Cape Hatteras), flat and marshy coastal plains are drained by 3 coastal rivers (Roanoke, Tar-Pamlico, and Neuse) and numerous smaller meandering streams into estuarine lagoons, creating a crenelated interior coastline. In the north, the estuaries are very broad, protected and insulated from the open ocean by the prominent chain of barrier islands, known as the Outer Banks with their numerous shoals and cusped bays. In the south, the estuaries are much narrower and are protected by more fragmented barrier islands. The estuarine lagoons themselves are lined with vast expanses of brackish water marshes. The Gulf Stream (and shelf break) lies only 30 kilometers (18 miles) off of Cape Hatteras.

Characteristics of Coastal Development and Land Use in the South Atlantic Bight

The coast of Florida from Stuart to Jacksonville is relatively heavily developed for residential and resort living, industry, and commerce. The population and pace of development in this area are both growing rapidly. Florida's population is increasing by 800 people every day; the majority of that increase is taking place in the coastal area. The major centers of development in this area include Jacksonville, St. Augustine, and Daytona Beach.

The coastal lands adjacent to the central and northern portions of the SAB are, in general, more sparsely developed than the Florida coast, but pockets of denser development do exist. The majority of the coastal plain is forested, in agriculture, or essentially undeveloped scrub-shrub or marsh land. The barrier islands and beaches in this area are, in places, quite heavily developed for residential and resort living (e.g., golf resorts), but do not generally harbor heavy industry or commerce. Several major urban centers, industrial operations, and active ports exist within the central portion of the SAB -- paper mills exist throughout the area; a large phosphate mine is located in Aurora, NC; active ports and industrial facilities are located in Morehead City, NC; Wilmington, NC; Charleston, SC; Savannah, GA; Brunswick, GA; King's Bay, GA; and Jacksonville, FL.

North Carolina has approximately 6.6 million residents, South Carolina approximately 3.5 million, Georgia approximately 6.5 million, and all of Florida approximately 13 million. The average rate of population increase in each of these states has been well above the national average for the past three decades (see Figure 7).

The Marine Geology of the South Atlantic Bight

The SAB sea floor is a relatively smooth, gently sloping plain covered in a thin sheet of well-sorted sand roughly 5 meters thick. The sands are fine and mixed with some muds and some organic material near-shore. Organic rich muds are particularly common in the protected estuarine areas in the deeper basins, river mouths, and channels. Outside the estuarine areas, much less organic matter is found in the sediments. Farther out on the shelf, coarser sands are mixed with broken shells and rock outcroppings (Menzel, 1993). In general, the SAB is characterized by net deposition and significant subsidence, but there is significant local variation -- Onslow Bay, for example, is sediment starved and erosional.

Particulate matter is carried in suspension or entrainment in river water to the coastal waters. Most sediment is transported along shore, and some is transported landward from further out on the shelf. Little is known, however, about the sources and reservoirs, fluxes, and sinks and fates of sediment in

this region. Barrier islands in the north and the south dictate much of the patterns of near shore sediment transport. Terrigenous particles may react to salinity or current gradients and flocculate and be deposited, or may remain in suspension or become re-entrained. Terrigenous sediment may, therefore, be deposited in the fringing marshes, or may cross the river-marsh boundary and be carried farther out into the coastal system or to or beyond the shelf break.

Coastal erosion -- caused by subsidence, sea level increase, or coastal management practices -- is a very location-dependent problem. In areas affected by severe storms or areas associated with inlets, for example, erosion rates may be many times the annual average rate for the entire coast. In northeastern Florida rates of erosion vary from 1 to 20 feet per year, but the average is closer to 1 foot per year. An average annual rate of erosion has not been calculated for the state of Georgia, but coastal erosion is considered to be a serious problem for coastal developments. Sixty percent of the coast is in a "severe state of erosion" and rates of erosion in some locations (primarily locations associated with natural inlet activity) are as high as 40 feet per year. The average annual rate of coastal erosion for South Carolina is 15 centimeters (0.5 feet) per year (NOAA, 1986) and areas of major erosional problems exist (e.g., at Folly Beach, Capers Island, and Kiawah Island). North Carolina has reported an average rate of coastal erosion on the Outer Banks of 1.4 meters (4.7 feet) per year.

Further offshore, as one heads out towards the shelf break, a progression of benthic habitats can be found, the character of which depends on the morphology, thickness, and uniformity of the geologic base. The upper flat hardbottom may resemble stairs, as a result of fractures that erode from underneath, leaving prominent overhangs. A more uniform morphology will result in a solid wall or escarpment. A softer cap layer can result in erosional knobs being left behind. Often, a rubble slope can be found at the base of walls or under overhangs. The progression often continues to a middle flat hard bottom and a lower flat hard bottom.

The Marine Hydrology of the South Atlantic Bight

The Gulf Stream is one of the major defining forces of the SAB. The warm Gulf Stream travels north-northeast along the southeastern shore of the U.S. at roughly 8 kilometers (5 miles) per hour. The southern extent of the Gulf Stream is marked by the confluence of the Antilles Current that flows westward along the northern edge of the Bahamas Bank, and the Florida Current that flow northeast through the Straits of Florida.

The SAB is composed of three distinct hydrographic zones: the inner shelf zone (0-20 meters or 0-70 feet in depth), the mid-shelf zone (21-40 meters or 71-130 feet in depth), and the outer shelf zone (41-75 meters or 131-250 feet in depth) (COBIA, 1992).

The inner shelf is dominated by tidal currents, river inflow, local and short-term winds (that can cause up- or down-welling), and interaction with the coastal estuaries (Menzel, 1993). The inner shelf is one integral component of the Coastal Boundary Zone. The Coastal Boundary Zone includes freshwater rivers, tidal rivers, mud flats, estuaries, fringe marshes, salt marshes, barrier islands and inlets, and the inner shelf. Many small- and medium-sized rivers empty into this zone between Jacksonville, FL and Cape Fear, NC. Maximum flows usually occur between February and April; minimum flows generally occur between September and November. Because of the large riverine influence, turbidity is usually high, salinity is relatively low, stratification is common, and a fairly distinct frontal zone is usually established (Atkinson et al., 1985). Southerly flow generally predominates in the Coastal Boundary Zone. The Coastal Boundary Zone can be a zone of transport and a zone of impedance -- it acts as a conduit for or barrier to the transport of materials between the ocean and the coastal systems. Currents and stratification establish hydrologic barriers to cross-zone transport. Wind-, tide-, and river-generated flow, up-welling, and down-welling patterns assist in the seaward transport of continental shelf water and materials and the landward transport of oceanic water and materials. Net transport of materials across the SAB may be seaward or landward. Most of the particulate matter delivered via the rivers or transported from offshore, however, is eventually deposited in estuarine and near-shore environments. Tidal fluctuation is greatest in the central portion of the SAB. The average tidal range off Cape Hatteras, NC and Cape Canaveral, FL is only

about 1.2 meters (4 feet) , but off the coast of Georgia, it is roughly 2.4 meters (8 feet). Near-coastal sea surface temperatures peak in July at roughly 23°C (73°F) off Cape Hatteras and are generally lowest in January or February at roughly 7°C (45°F).

Kinetics of the middle shelf can be dominated by either local wind-induced pressure gradients, astronomical tidal pressure gradients, or the Gulf Stream. Current variability is, therefore, quite great. The middle shelf often becomes stratified in spring and summer. In fall and winter the waters of the middle shelf are usually vertically mixed (COBIA, 1992).

The character and dynamics of the waters of the outer shelf are primarily controlled by the Gulf Stream and, to a lesser extent, the wind. Seasonal changes in the position of the Gulf Stream axis affect the outer shelf zone on a seasonal basis. Sporadic northward propagating meanders, frontal anti-cyclonic filaments, and cyclonic frontal eddies affect the outer shelf zone over a shorter time scale.

Three distinct masses of water are represented in the SAB: "Georgia Bight Waters", "Carolinian Coastal Waters", and "Virginian Coastal Waters". These masses (that move around within the SAB as relatively distinct units) are defined by unique temperature and salinity characteristics and can be readily recognized (Pietrafesa, pers. comm.).

Up-wellings from the Gulf Stream are the most significant source of nutrients for the middle and outer shelf. Common locations for up-welling events have been identified, mostly associated with Gulf Stream-shelf interactions. Up-wellings are most common: (a) where the shelf break induces up-wellings; (b) in the "lee" of (to the north of) the major shoals; and (c) in the cyclonic Charleston Trough, northwest of the Charleston Bump (Pietrafesa, pers. comm.). The up-welled waters are generally resident for roughly one or two weeks.

Sea level is rising in the SAB. The principal stimulus of sea level rise is, likely, a global volumetric increase as the result of global warming. Sea level, however, appears to be rising faster in the SAB (3.4 millimeters or 0.14 inches per year on average since the 1920s) than in other places around the globe (1 millimeter or 0.04 inches per year). The increased rate of sea level rise in the southeast is likely due to a combination of factors including atmospheric pressure fields, wind patterns, ocean currents, river runoff, crustal movement, and compaction of underlying sediments (Menzel, 1993).

The Marine Habitats of the South Atlantic Bight

Between Stuart, Florida and Cape Canaveral, Florida, exists a zone of transition from tropical Caribbean and temperate Carolinian faunal provinces. In this zone is the Indian River Lagoon, an estuarine system with the highest floral and faunal richness of any mainland U.S. estuary -- it is home to roughly 400 species of fish.

The coastal region from Cape Canaveral to the Florida-Georgia border is dominated by barrier islands. Behind the long, linear **barrier islands** lie narrow estuaries; on the seaward side of the barrier islands long sandy beaches are sporadically interrupted by mangrove swamps and pine-oak forests.

The coastal region from the Florida-Georgia state line to Cape Romain is dominated by more segmented barrier islands with salt marshes and oak-hickory-pine complexes.

In the coastal region from Cape Romain (SC) to Cape Fear (NC) the "Grand Strand" dominates the shoreline -- no barrier islands protect the shore.

From Cape Fear (NC) to Cape Lookout (NC) barrier islands lie just off shore and protect very narrow estuaries.

In the most northerly portion of the SAB, the coastal region from Cape Lookout (NC) to Cape Hatteras, broad estuarine lagoons lie behind narrow, linear barrier islands and salt marshes and oak-beech-bald cypress complexes dominate.

The SAB sustains relatively constant high primary production in the **inner shelf waters** due to the shallow waters, riverine and marsh inputs, and the regular hydraulic and biological recycling of nutrients. The estuaries, the salt marshes, and the mangrove habitats, with their associated seagrass beds and fringing marshes, and the near-coastal waters of the SAB are especially rich and productive areas.

Estuarine and near-coastal waters are, in general, nitrogen limited. Given the correct conditions of temperature, salinity, and species composition, up-wellings of nutrients derived from the Gulf Stream circulation or terrestrially or atmospherically derived inputs of nutrients can foster intense blooms of phytoplankton at anytime of the year (Menzel, 1993).

The estuaries serve as nursery grounds for the larvae and juveniles of many fish and shellfish and as primary habitat for adults of all types of coastal species. The SAB serves as the spawning grounds for many fish (estuarine, anadromous, coastal, reef, pelagic, and oceanic pelagic species) and invertebrates, including many commercially and recreationally important species. Many of these species spawn offshore; the larvae are then transported by the currents into the estuaries where they grow and develop. The National Marine Fisheries Service states that in North Carolina roughly 90% of the commercial fishery landings and 50% of the recreational fishery landings are composed of estuarine-dependent species (NOAA, 1986). Similar figures have been cited for other states within the SAB.

The **seagrass beds** and emergent **salt marsh** and **mangrove** habitats that fringe the shoreline serve as critical habitat to a wide variety of birds, mammals, fish, and invertebrates. These habitats act as the interface between terrestrial and aquatic environments and as such serve as critical filters for terrestrial runoff. Seagrasses and other benthic macrophytes contribute greatly to production in the SAB (Menzel, 1993).

Unvegetated portions of the bottom are also very active habitats -- vast stocks of benthic fish and shellfish flourish in the estuaries and near shore waters.

Marine mammals and turtles are common in the **open waters** of the coastal region in addition to large populations of pelagic fish.

Offshore, corals, sponges, and diverse assemblages of other biota are associated with the exposed **"hardbottom"** habitats found throughout the SAB. Biota are scattered sparsely on the broad expanses of flat and usually sandy bottom near these hardbottoms, but are clustered densely on the rubble slopes and escarpments. Large populations of reef fishes support commercial and recreational fisheries.

VII. REGIONAL ENVIRONMENTAL TRENDS AND CONCERNS

INTRODUCTION

On a very large-scale (i.e., considering the entire South Atlantic and Caribbean Region) and compared to other regions around the nation, the near-coastal oceans of the South Atlantic and Caribbean are, in general, healthy -- water quality, sediment quality, and biological health of the near-coastal oceans taken as a whole are fairly good. But there are many large areas in which water quality and habitat form and function are changing. Not all changes in water quality and habitat form and function are bad -- some changes can cause productivity of a desirable species to increase. Not all environmental changes are human induced -- hurricanes, natural global temperature changes, and variable solar radiation, for example, can have severe, widespread, and long-lasting effects on natural habitats.

Natural Processes

Natural forces and processes described in the previous chapter help define the character of the near-coastal oceans of the South Atlantic region. Some of the natural forces and processes are relatively consistent (e.g., seasonal temperature changes); some are relatively sporadic (e.g., storms and hurricanes). Some are considered to be relatively benign or even positive (e.g., the Gulf Stream); some are considered to be terribly damaging (e.g., hurricanes that can have widespread and devastating effects on habitats and communities, or red tides). All are quite variable and all interact with one another. The resulting character of the natural system is, therefore, naturally extremely dynamic.

Trends in natural coastal processes, processes unaffected by humans and human activities, are generally very slow, non-threatening to human welfare, and inherently unmanageable. Natural long-term global climate changes, for example, are of little concern compared to the possible dramatic threats of rapid, human-induced climate changes, and are essentially unable to be altered.

Human Activities

The real forces or processes of concern are those which cause destruction of the environment and over which we have control -- those which we can hope to manage -- detrimental human activities.

Humans are affecting coastal environments in many ways. Some human activities cause rapid and essentially irreversible changes that are having grave, widespread, and expanding effects on coastal water quality and ecosystem health (e.g., dredging an embayment to create a harbor or filling wetlands to construct housing for development). Some human activities cause low-grade environmental alterations (e.g., careful farming). Some human activities can be relatively benign and have little or no measurable environmental effect (e.g. rowing).

Some areas have suffered extensive and dramatic alteration and damage to natural habitats and communities. Some areas are in a slow state of decline as pressures from human activities (and natural processes) mount. Some habitats suffer a reduced capacity to recover from stresses because of altered inputs, dynamics, and processes, and so are more susceptible to future stresses. Many areas are threatened by stresses but no obvious signs of degradation are yet apparent.

Many of these disturbing changes are new phenomena and many of the changes are quickening. Most of the changes, damage, and imminent threats are associated with areas of dense or inappropriate development and land use practices and poor hydrologic flushing. As population pressures continue to increase and as the variety and intensity of resource utilization continues to increase in the coastal zone, an ever wider extent and variety of areas will be stressed and threatened.

We humans, as components of the coastal ecosystem, will have some effects on the system around us.

All species utilize resources, produce wastes, and in other ways alter their surroundings. Human activities, however, unlike the activities of most other species are of a scale and an intensity that demand careful consideration and management. And unlike the activities of most other species and natural events, human activities can be managed.

Since the South Atlantic and Caribbean Region has broad areas of relatively healthy coastal habitat, there is much to protect. This knowledge, while pleasing, should spur on greater action to study, understand, and protect the coastal ecosystem. Steps must be taken to protect the areas that are healthy, stem new trends towards ecosystem degradation, and correct the causes and results of existing degradation.

CAUSES OF ENVIRONMENTAL CONCERNS

The largest problem facing the health of near-coastal ecosystems and overall water quality is the tremendous increase of the permanent and seasonal coastal population (Figure 7). Many areas within the South Atlantic region are experiencing or are about to experience growth pressures similar to the rapid and extensive growth pressures experienced in the Mid-Atlantic region over the past 10 to 20 years. Recent trends of population growth and development are expected to continue throughout the southeast and Caribbean for the near future.

The U.S. Virgin Islands are experiencing an increasing permanent population and a rapidly expanding tourist population. Puerto Rico's rapid population growth is occurring almost exclusively in the coastal periphery of the island. Florida's tremendous population growth is concentrated in the coastal zone. Georgia is experiencing slow but continued development in its coastal areas. South Carolina's coastal zone is experiencing rapid development and population increases. The coast of North Carolina has one of the fastest growing regions in the state.

Associated with the population increase are increases in coastal development, the demand for water supply and wastewater disposal, and the demand for other coastal resources. Illustrative of the growth of population and development in the southeastern U.S. is the fact that in the past few years half of all dredge and fill permits issued by the U.S. Army Corps of Engineers for the nation as a whole were awarded in the southeast.

More specifically, the greatest human threats to water quality and the overall health of near-coastal ecosystems are the activities associated with:

- coastal developments;
- point sources and nonpoint sources of pollution;
- water management;
- extractive uses of coastal resources and the coastal environment; and
- non-consumptive uses of coastal resources and the coastal environment.

The primary driving forces behind these practices (and, thereby, behind the environmental changes) are of a sociological, political, and economic nature. Individual activities, by and large, are a reflection of social, political, and economic values. Individual activities, in turn, have environmental ramifications. Environmental health in the near-coastal oceans is often affected by human activities that take place on land or on the water. Environmental health may, in turn, affect sociological, economic, and political realms. As environmental health (and possibly human health) become endangered or degraded and as resource bases become eroded or destroyed, the very foundation of society is threatened (see Figure 8). Following is a discussion of each of the categories of activities listed above, their specific effects on environmental factors and processes, and their general effects on environmental health (Figure 9).

Figure 7.
Population by State, Territory, or Commonwealth
(Information from U.S. Bureau of the Census: Summary Reports)

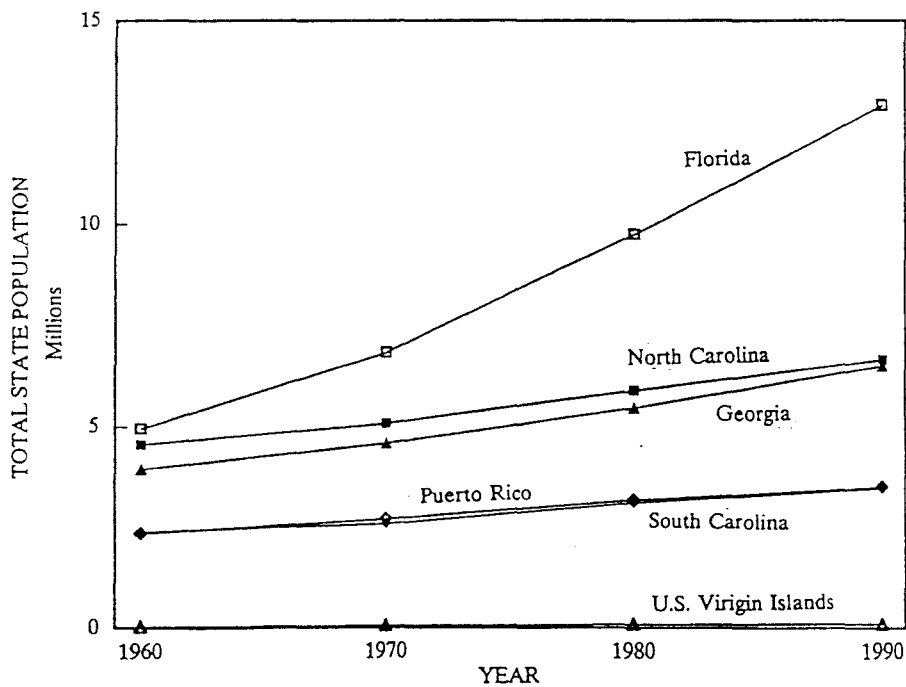
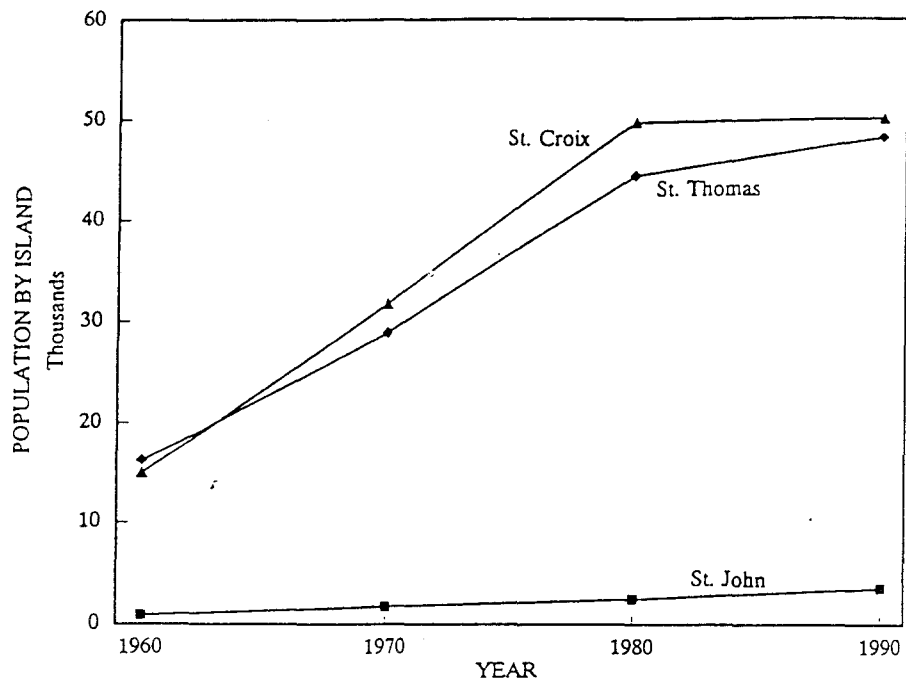


Figure 8.

Human Interaction with the Near Coastal Environment

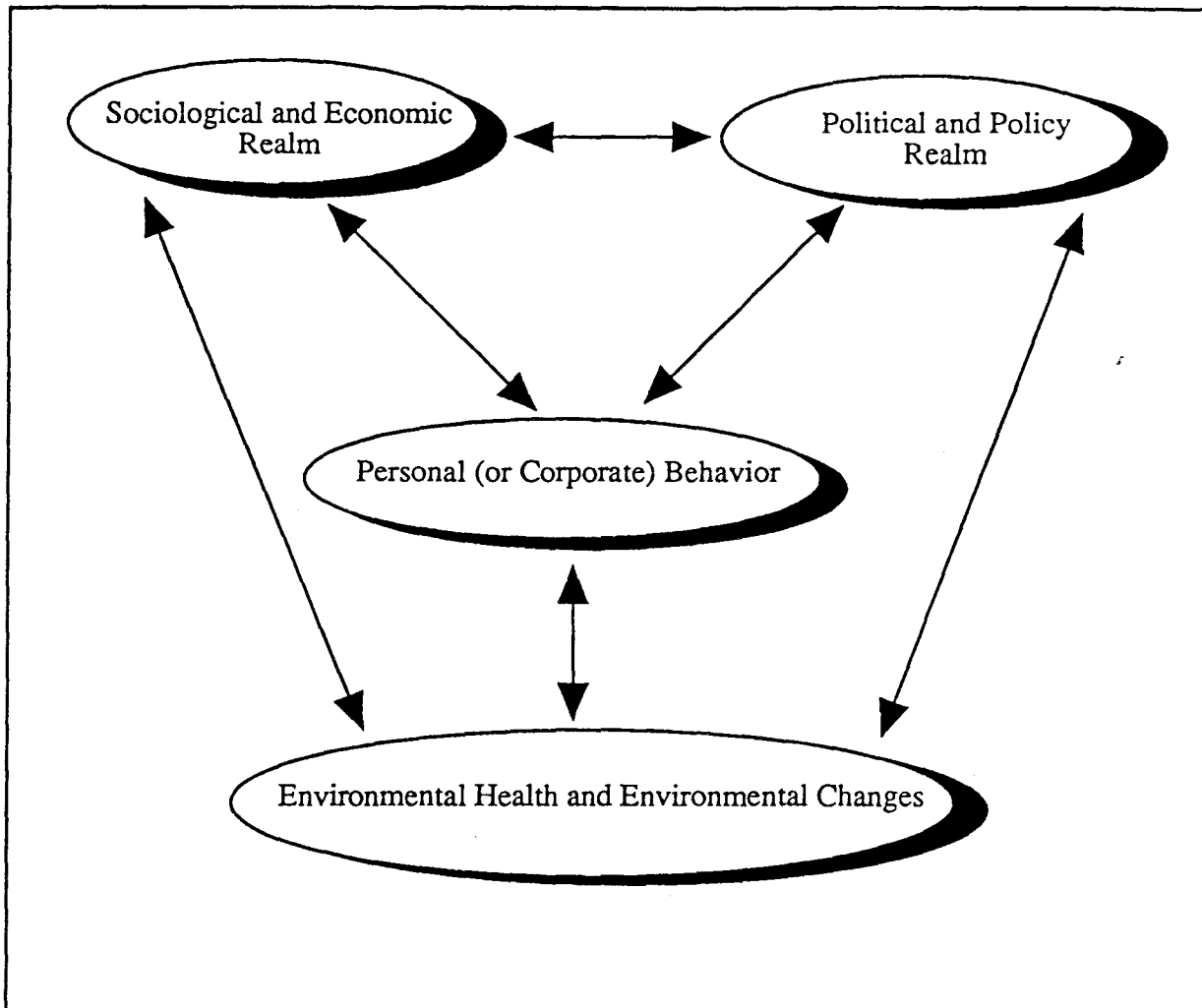


Figure 9. Effects of Human Activities on Different Aspects of Habitat Health

KEY: WD = Effects on coastal Water Dynamics 0 = detectable negative effect
 WQ = Effects on Coastal Water Quality L = (low) small negative effect
 SD = Effects on coastal Sediment Dynamics M = (medium) significant negative effect
 SQ = Effects on coastal Sediment Quality H = (high) serious negative impact
 BIO = Effects on coastal BIOlogical integrity * = far-reaching (vs. solely local) effects

POTENTIALLY DAMAGING HUMAN ACTIVITIES		WD	WQ	SD	SQ	BIO
Coastal Developments	Structures (buildings, parking lots)	0	0	0	0	H
	Marinas, Ports, Channels (the structures)	H	0	M	0	M
	Shoreline Hardening (bulkheads, jetties)	M	0	M*	0	M
Point and Nonpoint Sources	Municipal Wastewater Treatment Plants	L	H*	0	M*	H*
	Industrial Wastewater	L	H*	0	M*	H*
	Industrial Thermal Discharge	L	H	0	M	L
	Applied Contaminants (silv, agric, resid)	0	H*	0	M*	H*
	Land Disturbance (ag, silv, construction)	0	H*	H*	M*	H*
	Impervious Surfaces (urban, residential)	L	H*	L	M*	H*
	Dredge Disposal, Beach Renourishment	L	H*	H*	H*	H*
	Septic, Landfills (groundwater contamination)	0	M	0	M	M
	Port/Marina/Boat/Mariculture (operation)	0	H	0	H	H
	Atmospheric Sources (cars, smokestacks)	0	H*	0	M*	M*
Water Management	Dams	H*	M	H*	H*	H*
	Artificial Drainage, Channels	H*	H*	L*	L	H*
	Channelization	H*	M	M	L	M
	Groundwater Withdrawal	M	M	L	L	L
Extractive Uses	Mining (sand, gravel, phosphate, etc.)	L	M	L	M	M
	Drilling (oil, gas)	0	L	0	L	L
	Fishing	0	L	0	L	H
	Collection of Live and Dead Organisms	0	0	0	0	M
Uses, Non-consumptive	Tourism (sightseeing, diving, etc.)	0	H*	0	H	M
	Boating (recreational and commercial)	0	H	M	H	H

These practices, unfortunately, are essentially irreversible and are often cumulative in their effects. Water management projects initiated in the 1930s still exist and exhibit effects on modern-day hydrologic regimes. Coastal developments established decades ago still occupy lands that were once valuable wetlands. The biological alterations caused by long-term accumulations of sediments or toxicants continue to be exhibited as clogged coastal waterways or diminished biological diversity. The result, as these practices continue, is a cumulative and quickening pace of ecological alteration and disturbance.

SPECIFIC EFFECTS OF HUMAN ACTIVITIES ON COASTAL HABITATS

Coastal Development

The term "coastal developments" refers to coastal structures such as houses, resorts, offices, industries, ports, marinas, channels, groins, jetties and other facilities in and around the coastal zone. Land disturbing activities and polluting characteristics associated with the construction, maintenance, and use of such structures are discussed in "Effects of Point and Nonpoint Sources of Pollution".

Coastal developments can have direct and immediate effects such as the destruction of coastal habitat (e.g., marshes and mangroves). Coastal developments can also have secondary and long-term effects on coastal water quality and ecosystem health -- coastal developments often represent significant deviations from natural hydrological, sedimentological, and biological processes; coastal developments also represent sources of problems categorized below, such as large areas of impervious surfaces, increased density of people, increased amounts of wastes.

Coastal development is continuing to increase throughout the entire South Atlantic and Caribbean region. Tourism and recreation, primary and secondary residential development, and commercial and industrial development are all growing in every state, commonwealth, and territory within the region.

Hydrodynamics: Ports, harbors, marinas, and channels that represent significant deviations from natural harbors and channels reflect significantly altered hydrodynamics. Altered local hydrodynamics can also result from structures such as groins, jetties, and bulkheads that are designed to alter patterns of sediment transport and deposition. Structures that are built to modify (or maintain) ocean inlets may alter the natural hydrodynamic balance. Inlets are formed as outlets, to allow storm overwash and stormwater to drain to the ocean. If structures (such as jetties) are put in place that restrict the outlet, a new outlet may be formed.

Sediment Dynamics: Ports, harbors, marinas, and channels can also represent significant deviations from natural patterns of sediment dynamics. Sediment traps such as groins and jetties can starve downstream environments of sediment. Jetties can also stop sediments that would have been transported into the coastal lagoon from entering, thereby impeding adjacent barrier islands from transgressing shoreward. The constriction of flow within a jetty channel may also cause accelerated flow, erosion, and scour near the seaward end and deposition near the landward end; jetty disintegration and channel clogging may result. Erosion "barriers" such as bulkheads can actually increase local rates of erosion and so alter sediment dynamics.

Sediment Quality: Sediment characteristics (grain size and morphology) may be altered if sediment sources are eliminated by, for example, a jetty or a groin.

Habitat Health and Species Survival: The existence of buildings and other structures and facilities in the coastal zone represents a change, land that is no longer in its original form and, therefore, habitat that is no longer able to function as it once did. Ports, harbors, marinas, and channels are often dredged, thereby drastically altering the natural benthic habitat. Bulkheads may increase the rate of erosion directly in front of the bulkhead itself, thereby eroding valuable benthic habitat. If habitat alteration or loss is sufficiently extensive, entire populations of species may be lost. Coastal wetlands (mangroves and marshes) are one of the types of habitat most vulnerable to coastal development.

The accidental or purposeful introduction of exotic coastal species is often associated with coastal development and commerce. Highly competitive exotic species can devastate the natural balance of native species and drastically alter native habitats or ecosystems.

Point and Nonpoint Sources of Pollution

Point sources of pollution include all direct and readily identifiable discharges of wastes and wastewater, such as: municipal wastewater treatment outfalls, commercial and industrial discharges (paper mills, pharmaceutical industries, oil refineries, textile industries, etc.), desalination plants, and power generation plants.

Nonpoint sources of pollution include all indirect or hard-to-identify scattered and diffuse sources of pollution, such as agricultural fields and golf courses to which fertilizers or pesticides have been applied or parking lots, roadways, and bridges on to which oil has leaked or disturbed land from which eroded sediment flows.

Land-based nonpoint sources usually supply pollutants to streams and coastal waters when rainwater washes over them and carries the pollutants to the receiving waters. Some areas are land-based nonpoint sources of pollution because of the direct application of a potential pollutant or the result of the disturbance of the soil (e.g., agricultural, residential, or silvicultural land to which fertilizers or pesticides are applied or which are tilled or cleared). Some areas are land-based nonpoint sources because impervious surfaces block or impede the percolation and filtration of contaminated waters (e.g., roadways, parking lots, and urban areas). Some land-based nonpoint sources affect groundwater and coastal waters through the direct leaching of contaminants (e.g., landfills and septic systems).

Water-based nonpoint sources (such as individual boats, marinas, ports, and dredge disposal sites) may accidentally leak contaminants (such as fuels or toxic paints) or may pump or "dump" contaminants directly into coastal waters (such as wastewater from marine toilets, nutrient-enriched waters from mariculture operations, contaminated dredge spoils, or contaminated bilge water). Boats that are equipped with heads (toilets) often discharge the untreated sewage directly into coastal waters. Some nonpoint sources generate pollutants that are dispersed by the winds and are deposited as dry particles or when rain "flushes" the particles from the sky. It is estimated that atmospheric deposition may contribute up to 20-30% of the biologically available nitrogen to northern estuaries. The Sahara Desert "dust", carried in the wind, is believed to be a significant source of nutrients for the waters of the Caribbean between June and September (Hillis, pers. comm.).

Pollutants from point and nonpoint sources are, in general, carried downstream (or downdrift) to receiving waters. In some cases, however, pollutants are sequestered in one area and in some cases pollutants may be transported "upstream". Many pollutants are associated with solid particles and settle out in the sediments. In coastal systems, where salinity gradients lead to density currents, pollutants may be transported upstream.

With improving technology and more stringent regulations, most point sources of pollution have decreased their potentially adverse effects, but as the volume of wastes increases, the total point source pollution continues to increase. Since nonpoint sources of pollution have only received regulatory and popular attention more recently and since the problem of the control of nonpoint source pollution is inherently less tractable, the problem continues to grow.

Hydrodynamics: Vast impervious areas built near the coast may change local drainage sufficiently to alter the dynamics of coastal waters. Altered hydrodynamics occurs near the beach face in response to major beach renourishment projects.

Water Quality: Both point and nonpoint sources can contribute significantly to problems of eutrophication, turbidity, bacterial and viral contamination, toxic contamination, excessive fresh water, and litter.

Eutrophication (over-enrichment with nutrients) and its associated effects such as algal blooms are exacerbated by effluent from wastewater treatment plants, runoff from agricultural lands, and a number of other nonpoint sources. Eutrophication is a major concern throughout the South Atlantic and Caribbean Region, but is of special concern in areas of poor circulation close to coastal development. Tropical coastal waters are, in general, more sensitive to eutrophication than their temperate counterparts. In productive temperate environments, large loads of nutrients, sediment, and organic material create a high demand for oxygen, and conditions of hypoxia or anoxia can result. In cooler oxygen starved environments, if nitrification (ammonium, NH_3^- transformed to nitrate, NO_3^-) has already occurred, denitrification will occur, transforming biologically available nitrate to relatively inert nitrogen gas (N_2), thereby mitigating the effects of the nutrient loading. In warmer tropical waters, however, this process of denitrification is less effective, and so tropical waters are more sensitive to nutrient loading and more prone to eutrophication.

Often associated with eutrophying effluents are organic-rich effluents from sewage, industrial discharges, and the like. Organic-rich discharges increase the bio-geo-chemical oxygen demand, thereby lowering levels of dissolved oxygen in the receiving waters. Increased turbidity can result from agricultural and silvicultural operations, the land-clearing and soil disturbance associated with construction processes, beach renourishment programs, dredging operations, and boat traffic. Excessive suspended sediments can significantly degrade water clarity and transparency and, by limiting light penetration, reduce primary productivity.

Pathogenic contamination of coastal waters is a human health concern. Municipal wastewater treatment plant effluent, septic system leachate, marina-associated wastes, agricultural land runoff, and urban stormwater runoff are often contaminated with pathogens, some of which may pose real health threats to people. Fecal coliform bacteria are used as indicators of human-transmitted pathogens in all states, commonwealths, and territories within the South Atlantic and Caribbean Region. The presence of fecal coliform bacteria indicates a potential risk associated with the consumption of fish or shellfish or with direct water contact (swimming). Federal and state standards have been established and are used to determine safe levels of seafood consumption and body contact. Fecal coliform bacteria, however, are not perfect indicators of human health risk since fecal coliform are not unique to human wastes and since the resilience of fecal coliform to water purifying treatments is different from that of other human pathogens. In temperate waters the indicator is believed, by some, to be a somewhat flawed indicator of true health risk; in tropical waters, where the temperate standards are currently applied, there is even less confidence in its ability to predict true health risk.

Toxicants are usually introduced to coastal systems from the wastes of industrial processes, commercial discharges, and the discharges of municipal wastewater treatment plants. Some toxicants are introduced from nonpoint sources. Pesticide-laden runoff from agricultural land or contaminated groundwater that recharges estuarine or coastal waters, for example, may have serious and far-reaching effects. Some toxicants have quite short lifetimes in the water column and degrade or settle out into the sediments. Others can remain available and toxic in the water column, often associated with sediment particles, for long periods of time. Contaminants can be re-introduced to coastal waters as a result of dredging that remobilizes sediments that once successfully sequestered the contaminants. This is especially problematic in the immediate vicinity of boat yards and marinas where copper and other anti-fouling paints end up in the water.

In excessive volumes, freshwater can be a contaminant in marine systems, significantly altering natural salinity regimes. Excessive freshwater is generally introduced as a result of water management projects (see "Water Management" below), but can also result from mining operations and so qualify as industrial discharge. Salt water can also be a contaminant. The heated and hyper-saline water that is discharged by desalination plants, for example, can alter natural salinity regimes and degrade near-coastal habitats.

Litter comes from a wide variety of nonpoint sources such as ships, beach-goers, landfills, accidental spills, etc. Litter may affect the biochemical oxygen demand and so may affect the level of dissolved oxygen in the water; litter may alter the chemical property of the water; or litter may be a relatively inert contaminant in and of itself.

Sediment Dynamics: Patterns of sediment transport and deposition can be altered by the addition of large loads of sediment from nonpoint sources such as agricultural lands, freshly harvested or prepared silvicultural lands, land-disturbing construction sites, beach renourishment projects and dredging operations. These not only create sources of loosely consolidated sediment, but also alter natural topographic features that once dictated sediment dynamics. Patterns of sediment delivery and deposition may also be affected as the result of large areas of impervious surfaces impairing natural filtration and sediment entrapment.

Sediment Quality: Sediment characteristics (grain size and morphology) may be altered if new sources of sediment are introduced from, for example, a construction site or a beach renourishment project (that uses off-shore sediments).

Contaminants of all sorts (nutrients, toxicants, bacterial and viral contamination, and litter) from all point and nonpoint sources can become sequestered in the sediments, causing them to be "toxic" or otherwise rendering the benthic habitat degraded. The highest concentration of contaminants are generally found in the sediments of poorly circulating bodies of water near areas of development or in the immediate vicinity of a industrial or military port, boat yard, or marina.

Nutrients are often associated with sediment particles, and so become sequestered in the floors of estuarine basins and the near-coastal oceans. Chlorinated hydrocarbons (such as DDT, aldrin, lindane, dieldrin, endrin, biphenyls, and PCBs) and heavy metals (such as mercury, lead, copper, arsenic, nickel, cobalt, zinc, chromium, and cadmium) collect in the sediments, are quite persistent, and can be highly toxic to infauna and filter feeders. Litter in the sediments may also be a real problem, especially in areas close to old or current solid waste dump sites and ports. Sequestered and once "inert" contaminants can be resuspended or released by biological or mechanical activities (such as dredging).

Habitat Health and Species Survival: Point and nonpoint sources of pollution often result in the degradation or total loss of original habitat function. Sediments, nutrients, toxicants, bacterial and viral contamination, litter, and thermal contamination can impair the health and survival of individual organisms and can have long-term and widespread ramifications for the health of the habitat. Coastal wetlands, beaches, and benthic habitats are some of the most vulnerable types of habitat.

One of the most common causes of coastal habitat degradation associated with human activities (i.e., one of the most serious threats to coastal habitats) is an increase in the levels of turbidity and sedimentation. Large loads of sediment (and turbidity) are most commonly associated with construction sites, agricultural lands, and silvicultural lands, but elevated turbidity may also result from dredging operations, beach renourishment projects, and boat traffic. Sediments (suspended or deposited) can have sub-lethal and lethal effects on coastal biota. High turbidity reduces the amount of light available for photosynthesis, thereby affecting all types of aquatic plant life --excessive turbidity can cause the degradation and ultimately the death of corals, submerged aquatic vegetation, and aquatic fauna. It is felt that nearly all of Puerto Rico's near-shore reefs have died due to high sediment loads and high turbidity (Boulon, pers. comm). Sediments may also settle directly on to marine organisms themselves, causing effective suffocation or complete burial. Beach renourishment projects can also directly destroy beach habitats (including important sea turtle nesting habitat), at least temporarily. Dredging operations in formerly productive benthic habitats can be extremely destructive of the benthic biota.

A wide variety of near-coastal habitats have been adversely affected by excessive loads of nutrients (eutrophication) and the biogeochemical demands associated with organic wastes. Marshes, reefs, mangroves, lagoons, and estuaries throughout the South Atlantic Region show signs of eutrophication and degradation. Excess nutrients in lower estuaries, near-coastal waters, and sediments can foster algal blooms, the proliferation of undesirable species, hypoxia, or anoxia. Excessive loads of nutrients and organic wastes are most commonly introduced to the coastal system by wastewater treatment plants, industrial wastes, agricultural lands, and residential lands and by atmospheric sources of nutrients such as NO_x emissions from cars and smokestacks.

Organochlorines and heavy metals are usually the product of industrial processes or applied as pesticides in agricultural practices. They are, therefore, found in industrial effluent, power plant effluent, municipal wastewater, ports and marinas, and nonpoint source runoff. Organochlorines and heavy metals are often associated with organic particles. They can become biologically available and very toxic to micro-organisms, fish, shellfish, and humans -- their presence in lethal or sub-lethal concentrations will likely affect individual health, community composition, and human health. Most fauna do not have the enzymes necessary to digest these compounds and so they become concentrated in the food chain, thereby presenting greater threats to higher level consumers (including humans). Outbreaks of disease in coastal biota have been associated with higher levels of pollutants.

Oil spills, primarily associated with tanker traffic and port areas near oil refineries, are a serious problem throughout most of the Caribbean and in parts of the South Atlantic Bight. The most noticeable aspects of oil spill damage are the tar and residues left on beaches and rocky shorelines, but the damage goes far beyond those. Spilled oil can damage shallow water habitats (and the detergents sometimes used as dispersants may be even more damaging than the oil itself). Corals, especially those in shallow water reefs where direct contact is likely, are particularly sensitive to oil smothering and poisoning. Mangrove ecosystems are also particularly susceptible to oil spills because the pneumatophores and the prop roots can become coated with oil, effectively cutting off the requisite supply of oxygen to the plant and suffocating it. Toxic residues left behind in sediments may cause long-term die-offs, deformities, or partial defoliation in a variety of habitats. Many areas are subject to chronic impacts of very small oil discharges from, for example, the pumping of boat bilges.

The effects of bacteria and viruses (from human sources such as municipal wastewater and septic system leachate and from natural sources) on indigenous populations of flora and fauna are poorly understood, but it has been suggested, for example, that a viral or bacterial infection was responsible for the widespread death of *Diadema antillarum* Phillippi (long spined sea urchin) in the Caribbean in 1983 and 1984 (Lessios et al., 1984 and Bauer and Agerter, 1987).

Marine debris and litter can have serious adverse effects on fish, birds, turtles, mammals, and benthic communities. Plastics are particularly problematic because they are so persistent in the environment, but all litter is problematic. Marine debris and litter can trap or entangle larger marine animals, causing their movement to be impaired or stopped altogether. Air breathing animals may, in this way, be drowned. Some animals ingest litter and so choke or have their digestive tracts filled with indigestible material and thereby starve or become septic from intestinal blockage. Large pieces of debris can smother benthic habitats.

Thermal contamination (generally associated with power plants) may result in direct community changes by changing dominant temperature regimes. Thermal contamination also affects the solubility of gasses. As temperature increases, the solubility of gasses decreases. Yet as temperature increases, respiration increases. So as the amount of oxygen held in solution declines, the demand for that dissolved oxygen increases. Hypoxia, or anoxia (and organism death or community changes) may well result. Because tropical species rarely encounter substantial temperature changes, they are more sensitive to changes in temperature than temperate species and so are more sensitive to thermal contamination. Thermal contamination generally affects a very limited area since mixing rapidly dilutes the thermal discharge.

Water Management

The term "water management" refers to the operation of dams, artificial drainage channels and navigation channels (with their locks, tide gates, and water diversions), channelized streams, and practices of groundwater withdrawal. Water management projects may be initiated for any of a variety of reasons, including: flood control, water conservation, power generation, pest control, drinking water supply, navigation, or recreation. The result of water management projects is an alteration in a system's natural drainage patterns and so an alteration in the natural rate or pattern of the flow of water (and associated constituents).

As development pressures mount, water management projects continue, altering more and more of the natural hydrologic regime of the coastal zone. The long-lasting effects of water management projects result in mounting and cumulative effects.

Hydrodynamics: Hydrodynamics are clearly affected by projects that block, enhance, or otherwise alter the natural rate, volume, or character of water flow. Dams change riverine systems to lacustrine ones. Artificial drainage channels may cause there to be huge releases of freshwater in areas where there were previously very few small and slow releases. Channelization causes stormwater runoff to peak much sooner and more dramatically than in natural watersheds and stream beds. Large-scale groundwater withdrawals (for drinking or industrial processing) in the coastal zone can starve estuaries from their customary supply of freshwater, thereby changing salinity regimes, density currents, and the transport of materials and biota.

Water Quality: With water management structures altering rates and/or volumes of flow, patterns of salinity, temperature, and sedimentation, and other chemical characteristics of the managed waters or the receiving coastal waters may be significantly altered. Dams that create deep lakes, for example, cause colder water to be released down the stream channel. Artificial drainage channels in coastal areas can cause large volumes of freshwater to be introduced to normally brackish or marine coastal environments. Channelized stream beds tend to carry more sediment in suspension because a higher average water velocity is maintained.

Sediment Dynamics and Sediment Quality: Water management structures alter the flow of fresh and saline waters which in turn alters existing patterns of sediment transport and sediment deposition. Water retention structures that cause flow to be slowed and so allow sediment to settle out are one of the primary agents causing change in sediment dynamics in the near-coastal zone. Such structures (e.g., dams) effectively trap most of the sediment carried in suspension or entrainment and so "starve" the receiving waters and associated environments of the replenishing sediment. Since retention structures tend to selectively trap the larger-grained sediment, the "land-building" sands are kept from replenishing the coastal environment and the characters of benthic habitats are radically changed (wetlands are particularly sensitive to sediment deprivation and so to rising sea level). Artificial channels and channelization cause accelerated erosion, scour, and sediment transport.

The diversion of the Santee River (in South Carolina), for example, took the water that had fed the Santee delta and all its associated habitats, fed it into the Cooper River, in hopes of increasing the flow and the scour, and so decreasing the need for dredging. The sediment load of the Santee, however, was so great that sediment deposition and the need for dredging increased. So the Santee was "rediverted" back to its original pathway. The lasting disruption of coastal habitats has not yet been assessed, but is considered to be quite high (as were the economic costs of the engineering work).

Habitat Health and Species Survival: Some water management can affect habitat health and species survival more directly by reducing the amount of viable habitat. Dams, for example, can destroy miles of stream habitat by changing once fluvial environments to lacustrine ones. Channels dug through wet land to dry it out can alter or even destroy once productive wetland habitat and the channelization of natural streams alters benthic and aquatic habitats. Dams can block access to and species movement between still viable habitats. Other water management structures can alter flow regimes, salinity regimes, or sediment regimes to such an extent that the original function of even distant habitats can be lost. Dams, for example, can starve coastal receiving waters of freshwater input, rendering them more saline. Artificial drainage systems can result in an increase in and sometimes a sudden and voluminous release of fresh water to normally brackish or saline waters.

Extractive Uses

"Extractive uses" of the near-coastal ocean resources refers to activities that temporarily or permanently deplete a natural resource. Examples of extractive activities include: (1) mining for sand, gravel, peat, and other minerals, (2) drilling for oil, (3) timber harvest, (4) commercial and recreational fishing, and (5) the collection of natural resources such as fish and "live rock" for large

and small aquarium displays. Extractive practices can, if poorly managed, have severe detrimental effects on the resource being exploited and on other adjacent or associated resources.

Effects of extractive practices are usually very localized, but in the effected areas constitute real and growing threats to local water quality and ecosystem health.

Hydrodynamics: While large-scale hydrodynamics are not likely to be changed by extractive practices, local hydrodynamics may be altered by large-scale mining operations that significantly alter the local topography.

Water Quality: Water quality may be significantly affected by drilling, mining, or fishing operations that either disturb the bottom or introduce contaminants into the water column. Mining and trawling, for example, can greatly increase local levels of turbidity. Offshore drilling causes some petroleum or natural gas products to be leaked into the marine environment (see the Point and Nonpoint Sources of Pollution Section above for more detail).

Sediment Dynamics: Some mining operations may affect local sediment dynamics; rates of erosion and sedimentation may be significantly altered as the result of disturbing sediments and altering local topography.

Sediment Quality: Mining may cause the nature of the surficial sediments to be radically altered through direct removal or through contamination with mining slag. Some practices such as oil drilling, may, if an accidental spill or leak occurs, cause contamination of local sediments.

Habitat Health and Species Survival: Near-coastal habitats (such as sea turtle nesting habitat) and populations may be directly and immediately damaged or destroyed by activities such as careless mining or fishing practices. Habitat damage could occur as the result of mining in productive benthic habitats or drilling (and leaking or spilling) in sensitive coastal or marine habitats.

Overfishing and the destruction of huge volumes of "bycatch" are widely believed to be responsible for the slow but steady decimation of many populations of finfish and shellfish. Many pelagic temperate species, most shallow water reef fish, lobster, and conch are being harvested near or over the limit of sustainability. Although the situation has been greatly improved by the widespread application of turtle excluder devices (TEDs) and regulations regarding fishing practices, the "bycatch" of marine mammals and marine turtles in fishing nets is still a problem. Trawling over sensitive or productive bottom habitats such as seagrass beds can have severe effects on the populations that rely on the seagrass habitat. The setting of fish traps on sensitive reefs can be a very destructive practice. The collection of corals and aquarium fish has also had fairly devastating effects on some coral reef populations. Poaching of officially protected species, such as the hawksbill, leatherback, and green sea turtles and black coral, continues in some areas. Changes in community structure of fish on reef systems alters the natural "balance" of species and ecological functions. The loss of herbivorous fish, for example, results in a decline in grazing which may cause an increase in algal growth and consequent decrease in the settlement of coral larvae or coral reefs.

Non-Consumptive Uses

"Non-consumptive uses" of the near-coastal ocean resources refers to human activities that do not deplete (temporarily or permanently) a given coastal resource but that, nevertheless, rely on and in some way utilize the coastal resource. Examples of non-consumptive activities include: (1) tourism (sight-seeing, etc.) and (2) recreational boating, and (3) commercial coastal ocean transport.

Non-consumptive uses, like all other uses of coastal resources can, if carelessly practiced or poorly managed, have severe detrimental effects on the resource and on other adjacent or associated resources. Because of the complex and inter-related nature of human activities and their effects on the coastal environment, many of the effects of non-consumptive activities have been discussed in previous sections of this chapter ("Coastal Development" and "Point and Nonpoint Sources of Pollution"). A brief discussion of the effects of tourism and boating follows. For more detailed

information about the specific effects of each process on water, sediments, and biota, refer to the previous sections of this chapter.

Non-consumptive practices are increasing rapidly throughout most of the South Atlantic and Caribbean region. Tourism and recreational boating are growing particularly rapidly in this tropical and warm-temperate region. Islands in the Caribbean and Florida are experiencing the most rapid growth, but throughout the region pressures on coastal resources are mounting and are likely to continue to do so.

Water Quality: Water quality is affected by tourism. With increasing tourism, increasing demands are made for coastal development, coastal resource consumption and utilization, and waste disposal. Water quality is also significantly affected by boat traffic. Leaks and "small" spills of oil, gasoline, and diesel fuel represent a significant volume of such contaminants entering the near-coastal ocean system. Wake-induced resuspension of sediments and the resulting increases in turbidity is significant, especially in shallow waters. The discharge of sewage from recreational boats contributes to the nutrient over-enrichment of coastal waters.

Sediment Dynamics and Sediment Quality: The demands for waste disposal that tourism brings affects sediment quality. Boat wakes can cause severe local erosion and significant sediment resuspension, thereby altering local sediment regimes. The operation of harbors and marinas has long been associated with the discharge and accumulation of toxicants associated with bottom paints, human wastes, and petroleum products. Accidental spills or leaks of potential toxicants associated with ocean commerce can have severe and devastating effects on sediment quality. Damage to seagrass beds as the result of bad boat anchoring techniques results in an overall decrease in the stability of bottom sediments and so can result in an increase in turbidity.

Habitat Health and Species Survival: Tourism can indirectly damage local habitats and biotic assemblages by increasing the demand for coastal development. "Eco-tourism" practices, such as the viewing of nesting sea turtles, may also have detrimental effects on biological processes. Cruise ships and boats, private recreational boats, and commercial boats all contribute to the problem. Sensitive near-coastal habitats, such as beds of submerged aquatic vegetation and reef communities, be damaged by careless anchoring practices, boat groundings, and destructive ground tackle; they may also be damaged by boating practices that generate excessive turbidity or cause erosion. Sensitive coastal habitats are also be harmed by careless divers and snorkelers.

The introduction of exotic species via ballast water of commercial ships can have widespread and damaging results on assemblages of native species.

THE MAJOR CONCERNS -- ENVIRONMENTAL CHANGES

Introduction

Although the South Atlantic and Caribbean Region is vast and diverse, much of the region appears to be demonstrating similar environmental changes and problems. The greatest problems of environmental alteration and degradation seem to be manifest in areas of dense or inappropriate development and land use and limited hydrologic circulation.

Of greatest concern are human activities that have caused simultaneous increases in stresses and the loss of ability for individuals, species, habitat, and ecosystems to recover from such stresses. Sub-lethal effects of contamination, disease, or habitat alteration are very difficult to detect or measure, but they may be severe. The loss of the ability of individual organisms, species, or entire habitats and ecosystems to recover from stress or damage may be a problem throughout the region. Since the thresholds beyond which recovery will not occur are not known, however, scientists have been unable to determine which ecosystems are in danger of continued decline or loss despite continued management efforts.

The most significant and problematic effects on the water quality and ecosystem health of the near-coastal oceans of the human activities described in the pages above are listed below (not in order of priority):

- loss or degradation of habitat (especially reefs, wetlands, and estuaries) and biodiversity,
- eutrophication (and associated responses such as increased blooms of nuisance and toxic algae),
- contamination of resources with other toxicants (and associated declines of environmental health and threats to human health), and
- declining fisheries

Loss of Habitat and Biodiversity

Decline of Reef Habitats: In the South Atlantic and Caribbean Region, particularly in the more tropical portions, the alarming decline of coral and other live-bottom habitats is of great concern. Coral health around the globe appears to be in a state of long-term and worsening decline. There appears to be a declining amount of coral cover, a declining number of individuals, a general decline in species diversity, a declining number of large communities (in shallow and deep water), declining recruitment, net erosion, and increasing incidence of "bleaching" and disease (Porter, 1992).

Increases in turbidity and sedimentation constitute the greatest threats to coral reefs. High turbidity diminishes the ability of the *zooxanthellae* to photosynthesize, so the corals become malnourished and may eventually die. Sediment that settles on the coral impairs its ability to capture food. Nutrient enrichment causes an increase in algal growth which also acts to decrease light penetration and photosynthesis, thereby diminishing coral growth. Dense growth of algae can also overgrow and "smother" corals.

Coral diseases also seem to be on the increase, occurring in previously unaffected areas and spreading in affected areas. "White band disease" primarily affects *Acropora palmata*, the dominant shallow water coral in the Caribbean, and *Acropora cervicornis*. The disease is characterized by a white strip, roughly 1 centimeter wide where the live coral tissue has been removed from the carbonate skeleton. The band begins at the base of a branch and migrates outward to the growing tip, weakening the coral colony (and so increasing its susceptibility to storm damage) and altering the structural complexity of the reef. No causative agent has been identified with certainty for white band disease, but it has been postulated that colonial bacterium may be responsible.

"Black band disease" affects the rounder corals including *Monastrea annularis*, *Monastrea cavernosa*, *Diploria strigosa*, and *Diploria labyrinthiformis*. It is caused by a blue-green alga (*Phormidium corallyticum*) that becomes established in the coral tissue and disrupts the normal functioning of the coral polyp. It is not known, however, whether or not anthropogenic eutrophication is promoting the outbreak of this disease.

Coral "bleaching" is a phenomenon wherein corals actually expel the normally resident symbiotic *zooxanthellae*. Bleaching results in a loss of the acidic buffering and carbon dioxide (CO₂) removal and oxygen (O₂) production capability of the *zooxanthellae*. Therefore, there is a loss of the input of nutritive material and removal of metabolic by-products by the algae and a resultant slowing of skeletal production. Growth and weight are, thereby, reduced. Some corals can recover from bleaching but sterility may persist for a year after the bleaching. Bleaching has been known to cause coral death. The 1987 episode of coral bleaching was the worst on record in Florida and the U.S. Virgin Islands. The phenomenon is believed to be related to changes (increases) in temperature and, possibly, changes in salinity and turbidity.

Hardbottoms and live bottoms in the South Atlantic Bight and Caribbean sub-regions have been damaged by anchoring practices. The bi-fishing has depleted many of the highest-level predators, causing an overall ecological imbalance to result. There is also concern that freshwater that seeps from the outcroppings associated with hardbottoms may be contaminated with excessive nutrients or toxicants and so may further disrupt the flora and fauna of hardbottom habitats.

Declining Health of Estuaries and Associated Wetlands (Mangroves, Salt Marshes, and

Seagrasses): Estuarine systems characterize much of the coast of the South Atlantic Bight. Associated wetlands and aquatic vegetation (inland and coastal) play vital roles as filters of terrestrial runoff, buffering the receiving waters, and as habitat for terrestrial and aquatic fauna. The decline of aquatic vegetation and wetlands in the South Atlantic and Caribbean Region is of great concern because of their intrinsic ecological value, their historic areal extent, and the alarming rate of their decline.

Ten "southeastern" states account for 50% of the total (fresh and marine) wetlands in the nation. Florida, Georgia, South Carolina, and North Carolina account for 57% of the wetland acreage in those 10 southeastern states. In those 10 states, estuarine wetlands account for 10% of the total wetland acreage (Hefner and Brown, 1985).

The 10 southeastern account for 50% of wetland coverage but account for 84% of the total wetlands loss in the nation between the mid-1950s and the mid-1970s. Marshes in the temperate regions and mangroves in the subtropics and tropics have been severely affected, recently mostly as a result of unplanned dredging and filling associated with residential, commercial, industrial, and agricultural development. According to the U.S. Fish and Wildlife Service, between 1955 and 1975, 14% of all wetlands in the Southeast were lost (NOAA, 1986). Two-thirds of all estuarine wetland loss was attributed to conversion to deep-water habitat and one-third of all loss was attributed to urban development (Hefner and Brown, 1985). As much as 50% of the original extent of mangrove habitat in the U.S. Virgin Islands, for example, has already been lost (NOAA, 1986). In the recent past improved regulation and ecological awareness have greatly slowed the rate of coastal wetland loss, but loss and degradation still occur.

The decline of submerged aquatic vegetation is of general concern throughout the South Atlantic region. Some loss has clearly been the result of dredging and coastal development, but some loss seems to be the result of less direct factors. It is known that turbidity reduces the amount of light available for photosynthesis and so causes reduced growth. There is also evidence in the U.S. Virgin Islands' turtlegrass beds of the vegetative "wasting" disease propagated by *Labyrinthula*. Florida has experienced the loss of vast areas of seagrasses to disease. Many scientists believe that changing sediment loads and changing salinity regimes are responsible for the decline. Some scientists believe that concentrations of nitrate could be directly toxic to certain species of seagrass.

Decline of Barrier Island Habitats: Barrier islands throughout the South Atlantic and Caribbean Region have been subject to very heavy development pressures. The erection of houses, commercial buildings, and associated infrastructure has directly destroyed much of the sensitive dune, marsh, and forest communities. The introduction of exotic species and the destruction of native species and habitats have had significant effects on the character, diversity, and overall health of affected barrier island ecosystems. Alteration of hydrogeologic processes has also taken its toll on barrier island ecosystem health. Shoreline hardening has precluded the natural landward advance of marine and brackish water environments in response to rising sea level and has starved many environments of needed sediment. Dredging and beach renourishment practices have altered natural patterns of erosion and deposition, destroying some environments by sediment removal and others by deposit and siltation. Groundwater pumping has adversely affected the health of some maritime forest communities. The result is a more depauperate barrier island community, one becoming ever more fragile and threatened.

Decline of Fisheries Habitats: There is particular concern over the loss of fish and shellfish habitat. Mangroves, seagrass beds, reefs, and other vital nursery areas and adult habitat have been lost throughout the region as a result of coastal development and water management projects. Reef fisheries throughout the region are in states of decline. Large-scale water management projects in Florida have altered vast expanses of coastal habitat. Populations of fish in the region have been adversely affected by the construction of dams that block access to historical spawning grounds. Loss of harvestable shellfish grounds to pollution and disease has greatly affected landings of shellfish.

Introduction of Exotic Species: In some areas, the introduction of exotic species has caused dramatic changes in species assemblages and in habitat form and function. In the U.S. Virgin Islands, for example, the mongoose, a very successful predator introduced from the Old World, has had a

devastating affect on endemic ground nesting bird populations and on the eggs of threatened and endangered species of sea turtles.

Decline of Marine Mammals and Sea Turtles: Several problems have plagued the marine mammal and sea turtle populations of the South Atlantic and Caribbean Region recently.

In 1987, all along the Atlantic coast dolphins died in record numbers. The precise cause of the deaths is still unknown. Toxic dinoflagellates have been implicated in some deaths, and it has been speculated that nutrient enrichment of near-coastal waters played a role in the blooms. Viruses and other pathogens have been implicated in other deaths.

High incidence of drowned sea turtles along the southeast coast of the U.S. have been correlated with periods of bottom trawling. Use of turtle excluder devices (TEDs) has greatly reduced the impact of this fishery on populations of sea turtles.

It is clear that plastic debris poses a real threat to mammals and sea turtles alike, by entangling them, blocking their digestive systems, or filling their bellies, thereby causing them to starve.

Poaching of turtles and turtle eggs and illegal harvest are still problems in some areas.

Foraging and nesting habitat for sea turtles are being lost at disturbing rates, in large part due to increasing tourism and associated development and activities. Green turtles rely on seagrasses for food, hawksbills depend on reefs for their primary food resource (sponges) and refuge, and loggerheads rely on sandy bottoms for crabs. All species of sea turtles rely on coastal areas for nesting; most rely on sandy beaches, but hawksbills utilize beach forests and rocky shorelines.

Eutrophication

Eutrophication is the excessive addition of nutrients and organic material to an aquatic system. Eutrophication is of general concern throughout the South Atlantic and Caribbean Region, especially in developed areas, estuarine areas, and other coastal areas associated with limited circulation. Throughout the region, eutrophication has been associated with large-scale algal blooms, significant changes in phytoplankton species assemblages, increases in the biochemical oxygen demand, events of anoxia, and ultimately, fish and benthos kills. Excessive algal growth on mangrove roots can so severely decrease or eliminate the spaces between the roots that their ability to serve as nursery habitat for juvenile fish can be eliminated. As a result of prolonged eutrophication, then, entire ecosystems may be altered.

Declining Fisheries

Declining Landings: Declining fisheries landings are of concern throughout the South Atlantic and Caribbean Region. Numerous reasons for declining harvests have been suggested, including the sheer volume of commercial and recreational harvests, the phenomenon of bycatch, and declining habitat availability and quality. Most of the species commercially exploited within the South Atlantic and Caribbean Region are presently fully utilized or over-fished (NOAA, 1986). Reef fisheries have been particularly hard hit by over-fishing and habitat decline.

Increasing incidence of Diseases: Localized increases in the incidence of diseased organisms has also been of great concern, especially in the temperate portions of the South Atlantic and Caribbean Region, where, for example, widespread outbreaks of ulcerative mycosis, dermocystidium, and other fish and shellfish diseases have been recently documented.

Fish diseases have become epidemic in some areas in the South Atlantic and Caribbean Region. In North Carolina (and parts of Florida), for example, outbreaks of ulcerative mycosis in finfish, shell disease in blue crabs, and dermocystidium and MSX in oysters have been sporadically epidemic. While specific causes of these diseases remain unknown, some scientists believe that outbreaks of

disease may be associated with conditions of environmental stress and elevated concentrations of pollutants.

Threats to Human Health: Also of concern is the health and edibility of fish and shellfish that are landed. Concerns about the contamination of individual fish and shellfish with heavy metals, other toxicants, or human pathogens have been raised throughout the region. Concerns about human pathogens are particularly great in the estuaries of the northern portion of the Region and in the Caribbean where vibrio, fecal coliform, cholera, histamines, yeast carboxylation, and ciguatera have all been identified in fish and shellfish tissue.

Ciguatera fish poisoning is a widespread human health problem in the Caribbean and in the expanding Caribbean fish export markets. Over half of the fish landed and half of the commercially important species in the Caribbean are at risk of carrying the ciguatera toxins. The fish are apparently unaffected, but consumers may suffer a host of gastrointestinal problems and various neurological symptoms. An estimated 20,000 - 30,000 cases of ciguatera poisoning are reported annually in Puerto Rico and the U.S. Virgin Islands (Tosteson, 1992). Cooking, smoking, drying, salting, and freezing do not destroy the toxins responsible for ciguatera fish poisoning, and at the present time, no antidote is known for Caribbean strains of ciguatera.

Contamination of Sediment and Tissues

Other environmental contaminants or hazards of general concern throughout the South Atlantic and Caribbean Region include terrestrial sediment, pathogens, heavy metals, polychlorinated hydrocarbons and organochlorines, petroleum products, biotoxins, thermal contamination, and marine debris. Increases in turbidity (decreases in transparency) and increases in sedimentation are proving to be damaging to a number of habitat types, including submerged aquatic vegetation and coral. Pathogens that pose threats to human health (but not necessarily to marine life) are a serious concern throughout the South Atlantic and Caribbean Region; they are often but not always (e.g., vibrios) associated with human wastes and so are most problematic in areas of dense development and poor circulation. Heavy metals accumulated in the tissues of fish or shellfish may pose a health threat to human consumers. Polychlorinated hydrocarbons, organochlorides, petroleum, and biotoxins are problematic in both the water column and in the sediments; significant quantities of any of these can cause extensive species death and even, in the case of oil, habitat destruction. Marine debris is likewise a threat to individuals and entire local habitats. Both point and nonpoint sources of contamination have been implicated in these problems of contamination. Depending on the location point or nonpoint sources of pollution may dominate.

CONCLUSION

Some human activities have direct effects on water quality and ecosystem health; some human activities have indirect or secondary effects; some human activities place stress on the environment or act in concert with other factors to create cumulative effects but have no direct or singular detectable effects. Direct effects are readily seen, secondary effects are more difficult to detect, and stress and cumulative effects are extremely difficult to discern. Nevertheless, it is these secondary and cumulative effects that are likely to be most important and long-lasting.

In most coastal ecosystems, we understand neither how individual stressors act nor how multiple stressors may interact with one another to alter or damage a system. We are also, in general, unaware of "how much is too much", that is, how many incremental changes a given system can endure before it is altered beyond recovery or functionality.

VIII. REGIONAL RESEARCH NEEDS

INTRODUCTION

This chapter describes, in a hierarchical manner, the research needs of the South Atlantic and Caribbean Region. During the preliminary information gathering meetings, a vast array of research needs was gathered from the scientific research and resource management communities representing essentially every scientific and management discipline and every possible combination of disciplines. They range from the very general ("existing data should be analyzed") to the very specific ("determine how many sea turtles utilize this particular beach for nesting activities"). A careful process was followed to focus in on the highest priority research needs for the region.

This chapter follows the course of decisions made by the Board, step-by-step focusing in on more specific research needs. The section entitled "Prioritizing Research Needs -- Goals and Criteria" begins to narrow down the field of possible research needs by identifying the goals and criteria of the South Atlantic and Caribbean Regional Marine Research Program. The section entitled "Priority Research Themes -- Humans and Ecosystems" focuses in on the desire to address ecosystem form and function from a uniquely human perspective and takes the reader through the decision process that narrowed the field of seven "habitats of concern" to a field of two "highest priority habitats of concern". This section identifies the general research topics to be tackled over the next 10 years of the program. The section entitled "Priority Research Needs" delves into the specific research needs that should be addressed in the first 3-5 years of the program.

PRIORITIZING RESEARCH NEEDS -- GOALS AND CRITERIA

Introduction

To develop the research priorities for the South Atlantic and Caribbean Regional Marine Research Program (and ultimately to develop a Request for Proposals and to select research projects), a specific program goal and a set of selection criteria is needed. The guidance in the original legislation, decisions by administrators of the program at the national level, input from local area managers and scientists, and considerations of the Board members must all be incorporated.

Goal of the Regional Marine Research Program

The Regional Marine Research Program was initiated because of a concern about the degradation of water quality and ecosystem health in the near-coastal ocean. It was recognized, however, that proper management of these resources requires a solid understanding of the systems in place and processes at work. The Regional Marine Research Program was designed, therefore, to support research to fill in critical gaps in our knowledge of the near-coastal ocean system. Research supported by the Regional Marine Research Program should, therefore, fill in such gaps as they are identified and should be applicable to resource management needs.

The goal of the Regional Marine Research Program is:

"to -- (1) set priorities for regional marine and coastal research in support of efforts to safeguard the water quality and ecosystem health of each region; and (2) carry out such research through grants and improved coordination."

Criteria for "Regional Research"

The Regional Marine Research Program identified the following criteria as essential in order for research to receive the support of the program.

"Regional Research" must:

- (1) have regional or large-scale impact or applicability as opposed to research with primarily local impact or applicability;
- (2) contribute to solving more than one issue of regional concern. Under this criterion, research, the results of which are applicable to several issues, would be of higher priority than that pertinent to only one issue. This criterion would, therefore, discriminate against narrow, site-specific research and against monitoring unless it is research-driven and regionally significant;
- (3) be conducted in order to make scientific progress in dealing with other high priority research themes or questions to be pursued. This criterion will favor research that is interdisciplinary, large-scale, or multi-system oriented or will foster further research or management activities that are interdisciplinary, large-scale, or multi-system oriented;
- (4) be unlikely to receive adequate support from currently available funding sources for mission and/or programmatic and/or budgetary reasons. This criterion will allow a new or expanded focus on high quality research which would otherwise remain in an area largely devoid of organized support; and
- (5) build upon and not duplicate similar research by other researchers which could be applied to this region. This criterion favors research which is directly and uniquely applicable to the region. At the same time, it encourages scientists within the region to keep abreast of all current research that could be applied to issues of regional concern.

At the regional interdisciplinary workshop held in February, three new criteria were identified and adopted by the Board. Research supported by the South Atlantic and Caribbean Regional Marine Research Program must:

- (6) incorporate/acknowledge the human dimension as an integral part of the system and as an integral part of all funded research,
- (7) create a regional research program that will help coordinate research and researchers from throughout the region, where possible coordinate activities with other Regional Marine Research Programs (especially the adjacent ones, the Mid-Atlantic region and the Gulf of Mexico region), and catalyze other pertinent research and coordination efforts, and
- (8) ensure that all products are useful and are appropriately distributed to federal, regional, state, and local researchers and resource managers.

Goal of South Atlantic and Caribbean Regional Marine Research Program

To develop a specific program goal and criteria (and thereby to establish basic research priorities) the Board members and 10 outside experts met for two days in February, 1993 at the regional interdisciplinary workshop.

A long list of research needs and general considerations, collected during the initial round of information gathering meetings, was discussed, organized, and focused. Consensus regarding a programmatic goal, priority research criteria, priority research realms, and a general research strategy was eventually achieved.

The goal of the South Atlantic and Caribbean Regional Marine Research Program is to define the links between human activities and environmental response from a habitat perspective and to develop information and understanding for the purposes of improved resource management.

"The goal of the South Atlantic Regional Marine Research Program is to promote regional interdisciplinary research that will help to identify, characterize, and quantify the relationships between human population and human activities associated with coastal development and habitat structure and function."

Reason for the Goal

The intent of the Regional Marine Research Program is to promote understanding of the near-coastal environment and, ultimately, to promote integrated and coastal zone management and sustainable coastal resource utilization. Management reflects a combination of scientific understanding and social, economic, and political forces. Hopefully the Regional Marine Research Program will play a key role in helping to increase our understanding of the near-coastal environment and solve, in the present, the questions and concerns of the future.

For scientific understanding of and effective management of near-coastal resources, it is desirable to have a comprehensive regional "model" of the near-coastal ocean. For this, a common framework of quantified, synthesized, and integrated information is needed. Information must be readily comprehensible and readily applicable. A lot of data currently exist, but come from small, relatively disconnected projects. New understanding and new tools are needed to conduct syntheses and to integrate information from a diversity of disciplines.

Growth of the coastal population within the South Atlantic and Caribbean Region and the associated coastal development are of central concern. The growth of human populations and related developments produce a growth of point and nonpoint sources of pollutants and an increase in activities that lead to the direct and indirect destruction, degradation, alteration, or stressing of natural habitats and associated natural resources.

Customarily, in studies of ecosystem structure and function, the human component has been considered only as an outside perturbation, not as an integral component of the system itself. This frame of mind (i.e., the belated and often very limited consideration of humans and their activities based on the interests of the researchers or the desired or anticipated product) has propagated a dearth of information about and understanding of the human role in environmental systems around them. **To overcome this deficit and to be responsive to current and future scientific and managerial needs, consideration and incorporation of social and economic considerations must occur from the very beginning.**

Determining specific relationships (links) between human activity and ecosystem response and quantifying those relationships is essential for well-founded environmental policy and management decisions. Sociological and economic issues must, along with issues of natural coastal science, be considered and incorporated in the determination of information and research needs and in the development and conduct of each research project. Both factors are integrally involved in determining human activities, use of natural resources, and policy and management decisions.

PRIORITY RESEARCH THEMES -- HUMANS AND ECOSYSTEM HEALTH

Introduction

Priority research themes of greatest concern and to be addressed in the first 3-5 years of the program are the loss of habitat and biodiversity due to increased stress and decreased ability to respond to or recover from additional stress (see chapter VII). Along with this is the interest in the character and magnitude of the role humans and human activities play in alteration of habitats and biodiversity.

In later years in the program other varieties and aspects of habitat loss and decreased biodiversity will be explored and other concerns cited and described in the previous chapter will be addressed.

Human Focus: The South Atlantic and Caribbean Regional Marine Research Program recognizes that human influences on the coastal systems are of central concern (see "Reasoning for the Goal" above). The South Atlantic and Caribbean Regional Marine Research Program will support research that helps to sharpen understanding of human influences on environmental health in the near-coastal oceans.

To better understand (and to more adequately manage) the human influences on the near-coastal system, however, more must be understood about the human activities that influence the near-coastal oceans including:

- the motivational structures and forces (social, economic, educational, or political) that cause people to take certain actions -- these forces are, in many ways, the foundational causes of environmental decline and are often the object of resource management actions;
- the regulatory and management structures that pertain;
- the character, frequency, and intensity of the actions themselves;
- the effects (individual and cumulative) of those actions on habitat structure and function (i.e., the quantified cause and effect relationships);
- the temporal and spatial scales of causes and effects; and
- the possible actions to mitigate the potentially detrimental effects of these human activities.

Ecosystem Focus: The marine system is an inherently complex system that incorporates many physical realms and dynamic processes. This complexity is reflected, for example, in the study of marine biogeochemistry. An analysis of the near-coastal ocean system could, therefore, categorize and present information according to a number of different schemes.

- Geo-political boundaries could be used to determine "parcels" of water to be addressed, leading to categories such as: the coastal waters of the U.S. Virgin Islands, the coastal waters of Puerto Rico, the coastal waters of Florida, the coastal waters of Georgia, the coastal waters of South Carolina, and the coastal waters of North Carolina,
- Qualities of "physical realms" could be the determinants, leading to categories such as: the atmospheric realm, the sedimentological realm, the hydrologic realm, and the biological realm.
- Qualities of "dynamic processes" could be the determinants, leading to categories such as: hydrological and atmospheric dynamics, geological dynamics, chemical dynamics, and biological dynamics.
- Problems or issues of concern could be the determinants, leading to categories such as: excessive turbidity and sedimentation, nutrient over-enrichment, increased shoreline erosion, the introduction of contaminants, physical disturbances, and the introduction of exotic species.
- Qualities of "marine ecosystems" could be the determinants, leading to categories such as: estuaries and coastal lagoons, marshes, mangroves, beaches, reefs, seagrass beds, algal plains, sandy bottoms, outer shelf (pelagic), and outer shelf (benthic).

All of these options, and several others, were considered, but it was agreed that the fifth one, an ecosystem focus, was the one with the most utility for a regional interdisciplinary research program. Ecosystems are systems of interconnected biotic and abiotic components that incorporate all of the interconnected physical qualities, biological components, and dynamic processes that exist within a region in which internal dynamics are the primary driving forces. It should be noted that humans are an integral part of all near-coastal ecosystems, not entities separate from the natural system. Ecosystems are relatively definable units with relatively definable physical boundaries -- processes or elements do not have such boundaries.

An ecosystem focus will allow for an inherently long-term program of research and analysis while

including all of the short-term processes and functions of concern. An ecosystem focus will ensure ecologically large-scale considerations to be taken and conclusions to be reached.

It is recognized that no ecosystem operates independently or as a closed system. All ecosystems are intrinsically tied with other ecosystems and are influenced by (and in turn influence) surrounding ecosystems and external processes.

Because of their relatively discrete, yet integrated nature, ecosystems are an ideal basis from which to begin the study of true system functioning. The ecosystem focus will allow common regional themes of ecosystem structure, function, and alteration to be addressed in complementary manners (e.g., through comprehensive classification schemes). The ecosystem focus will help to improve understanding of large ecosystems -- large ecosystems are the supporting framework for a network of ecosystems (or habitats). Ecosystems are, increasingly, the focus of management efforts.

The South Atlantic and Caribbean Regional Marine Research Program will support research that builds understanding of ecosystem form, function, and dynamics.

The relational framework implied in an ecosystem approach (small systems acting as components of larger systems) should be considered and applied in the development of research projects and the creation of final research products so that ecosystem-level information is gathered in support of understanding large ecosystems that span and together define the sub-regions and Region as a whole. That is, ecosystems are to be considered from a sub-regional perspective and sub-regions are to be considered as components of the overall South Atlantic and Caribbean Region. This will ensure maximal utility of the information gathered. So, not only are intra-ecosystem processes to be considered, but linkages with other ecosystems and regimes are to be considered.

It should be noted that while not discussed as a theme of research priority in this Research Plan, water quality is a central concern and is directly linked to marine ecosystem health. It should be addressed as needed by individual research efforts as a critical integrating factor.

First Iteration: The Ecosystems of Concern

Seven types of ecosystems were identified as "ecosystems of concern" (see the alphabetical list below) in the South Atlantic and Caribbean Region. They were determined to be dominant ecosystem types, were recognized to be of critical ecological and human importance, and considered to be generally threatened or in a state of decline. It should be noted again, however, that these systems are not mutually exclusive.

- Coral Reefs, Hardbottoms, and Associated Benthic Ecosystems
- Estuaries, Embayments, and Salt Ponds (Coastal Lagoons)
- Mangroves
- Salt Marshes
- Sandy Beaches
- Sandy Bottoms
- Seagrass Beds

For each type of "ecosystem of concern", the most potentially damaging human activities have been identified (Figure 10).

Figure 10. Ecosystems of Concern, Types of Degradation, and Causal Human Activities

ECOSYSTEMS OF CONCERN	TYPES OF DEGRADATION	CAUSAL HUMAN ACTIVITIES
Coral Reefs and Hardbottoms	sedimentation, turbidity	construction, silviculture, agriculture, deforestation, dumping fine sediments
	increased reef & fish mortality & disease	wastewater treatment plant effluent (WTPE), residential and agricultural runoff
	physical/mechanical damage	boat anchors, boat groundings, harvest of coral, trawling
Estuaries, Embayments, Salt Ponds	sedimentation, turbidity	construction, deforestation, silviculture, agriculture
	changes in salinity	changing freshwater input, water management
	nutrient and organic enrichment	WTPE, residential and agricultural runoff, industrial discharge
	contamination by toxicants	point and nonpoint sources of pollution
	contamination by pathogens	WTPE, septic systems, urban/residential/agricultural runoff
Mangroves	physical damage	removal/pruning of mangroves for development
	nutrient enrichment	WTPE, residential and agricultural runoff
	contamination by toxicants	hydrocarbon spills
	flooding	water management
	erosion	boat wakes, sea walls, jetties, channelization
	changes in salinity	water management
Salt Marshes	physical damage	removal and fill of wetland vegetation
	contamination by toxicants	point and nonpoint sources of pollution
	sedimentation, turbidity	construction, deforestation, silviculture, agriculture
	changes in salinity	changing freshwater input, water management
	invasion of exotic species	commerce, coastal development, research
Sandy Beaches	change in sediment transport, erosion	jetties, groins, bulkheads, mining
	marine debris	ocean transport, coastal and land use, recreational boating
	nutrient enrichment	outfalls, septic systems, nonpoint source runoff
	contamination by toxicants	outfalls, spills (tar, oil)
Sandy Bottoms	contamination by toxicants	point and nonpoint sources of pollution
	physical damage	mining, dumping fine sediment (dredge material)
Seagrasses	sedimentation, turbidity	construction, deforestation, silviculture, agriculture
	nutrient enrichment	WTPE, septic systems, agricultural runoff
	changes in salinity	changing freshwater input, water management
	physical damage	dredging, trawling, anchor damage, dumping fine sediment (dredge material)
	thermal changes	power plant effluent
	disease	changing freshwater input, nutrient enrichment

Second Iteration: The Priority Ecosystems of Concern

Three types of ecosystem were identified as being priority ecosystems of concern in the South Atlantic and Caribbean Region. Again, in selecting these three ecosystems, consideration was given to their ecological values (extent, form, function, etc.), their human values (economic, sustenance, aesthetic, etc.), and the level of human perturbation. Note that minor alteration of the original seven types of ecosystems occurred. They are listed alphabetical order below:

Barrier Islands

Definition:

- sandy bottoms, sandy beaches, and dune complexes with vegetation and biota

Reason for selection:

- the magnitude of active alteration at the hands of man;
- their economic importance;
- the existence of good and quantified data.

Occurrence:

- Caribbean: limited occurrence in southeastern Florida
- South Atlantic Bight: long, narrow, islands (north and south); shorter, broader islands (central)

Coral Reefs and Other Livebottom Communities

Definition:

- "live bottom ecosystems" including coral reefs and systems, oyster rock, and biologically active hardbottom structures

Reason for selection:

- their recent and rapid decline;
- their relative sensitivity to environmental changes;
- their value as ecosystem;
- their economic value (commercial and recreational); and
- their regional distribution.

Occurrence:

- Caribbean: coral reef ecosystems (fringe and patch), free standing coral ecosystems
- South Atlantic Bight: hardbottom ecosystems

Estuaries, Embayments, and Salt Ponds

Definition:

- marine and terrestrially influenced environments including estuaries, coastal lagoons, salt ponds, and other embayments

Reason for selection:

- the extent of aquatic vegetation (mangroves, saltmarshes, and seagrasses)
- their regional distribution;
- their value as filters of terrestrial runoff and as buffers of human activities;
- their interface position between land and ocean filters,
- their economic importance as fish and shellfish nursery areas;
- their importance as ecosystem for other plants and animals.
- the similarity of natural and anthropogenic stresses the different types suffer;
- the extent of human disturbances; and
- the baseline data base that exists from which studies can be conducted

Occurrence:

- Caribbean: small estuaries at river mouths; salt ponds on Virgin Islands and Puerto Rico
- South Atlantic Bight: narrow, protected (north-central and south); broad, unprotected (south-central); broad, protected (north)

It should be noted that although these ecosystems were identified because of concerns about degradation, consideration will not only be given to research proposals addressing degradation of these ecosystems.

The Third Iteration: The Highest Priority Ecosystems of Concern

For identifying the initial focus of the research to be supported by the South Atlantic and Caribbean Regional Marine Research Program, the two sub-regions discussed in Chapter VI "Description of the South Atlantic and Caribbean Region" were maintained -- the South Atlantic Bight and Caribbean. Four primary reasons for maintaining this distinction exist:

- the physical distinction between the two sub-regions (climatological, geological, geographical, hydrological, geological, and biological);
- the concern about the resulting potential lack of cross-sub-regional applicability of data and information gathered from each of the two sub-regions;
- the difference in management and basic science concerns between the two sub-regions; and
- the difference between the degrees of environmental degradation in the two regions (the Caribbean is experiencing rapid degradation, the SAB is in the position of protecting a relatively healthier assembly of ecosystems and ecosystems).

For each sub-region, one type of ecosystem was identified as being of highest priority:

Caribbean Sub-Region

Initial Focus: Coral Reef Ecosystems

Reason for selection:

- the widespread and rapid decline of coral reefs in the Caribbean;
- the critical ecologic value of coral reefs
- the critical economic value of coral reefs
- the continued lack of understanding about cumulative effects of human activities on coral reef ecosystem health
- the need for information regarding coral reef preservation, recovery, and damage mitigation to support effective land and water quality management

South Atlantic Bight Sub-Region

Initial Focus: Estuaries and Embayments -- focus on Coastal Wetlands and Aquatic Vegetation

Reason for selection:

- the tremendous areal extent of estuarine habitat in the South Atlantic Bight sub-region -- estuaries and coastal wetlands are a defining characteristic of the sub-region.
- the value of marshes and seagrasses as filters, buffers, and critical ecosystem
- the relationship between wetland function and estuarine productivity
- the importance these ecosystems play in issues of human health
- the degree of human perturbation and the apparent extent of the negative effects of human activity on many of these ecosystems -- the connective role they play linking human activities with coastal and oceanic effects
- the opportunity for comparative studies of similar systems and for characterization studies of a range of systems
- the opportunity for effective land and water use management (and resultant water quality and ecosystem health protection) given sufficient information -- the relatively healthy condition of much of the estuarine area.

HIGH-PRIORITY RESEARCH NEEDS

Introduction

To determine priority research needs for the next 3-5 years, an exhaustive list of research needs was developed for Coral Reef Systems and Estuaries and Embayments from discussions held during the preliminary meetings and workshops and from numerous pertinent publications. The exhaustive lists were sent to over thirty experts in a wide variety of scientific fields. The experts were asked to identify and rank the top three research priorities. Responses were compiled and the results are reflected in the lists shown below. Levels of funding made available for research will determine, to some extent, the research needs selected for immediate attention, but it is hoped that those needs listed below as "high-priority" will be addressed in the order presented.

As more funding is made available over the following 5-7 years, remaining high-priority research needs, other ecosystems of concern, and other issues of concern (e.g. barrier island ecosystems and fisheries habitats) will be addressed under the general primary concern of "loss of habitat and biodiversity". With adequate funding, other concerns (e.g., eutrophication and declining fisheries) will be able to be addressed. This program is intended, however, to be an evolving one based on careful review and revision as needed in response to changing understanding and changing levels of funding.

It should be noted that the categories of research needs listed on the following pages are not meant to be comprehensive, mutually independent, or exclusive. They are meant to give an indication of the general realms of the most needed scientific endeavors. Researchers should augment and coordinate, as appropriate, all research and research products. Nor are the categories of research listed intended to be static. It is anticipated that the list of priority research needs will evolve as understanding and scientific and management needs change.

Specific High-Priority Research Needs for Coral Reef Ecosystems

Introduction

The overall goal of this portion of the South Atlantic and Caribbean Regional Marine Research Program is to determine how complete coral reef ecosystems function. Such a determination will require an evaluation of the dynamic functional roles of the multiple components and processes that interact within estuarine ecosystems. Consideration should be given to hydrologic circulation; the role of nutrients, temperature, and salinity; and sociological and economic factors affecting and being affected by natural processes.

A central concern of the South Atlantic and Caribbean Regional Marine Research Program is a determination of the role of human activities in altering natural components and processes. To this end, all research projects funded by the South Atlantic and Caribbean Regional Marine Research Program must address, as appropriate, the character of human activities and their impacts in and on the natural system as well as pertinent sociological and economic responses to ecosystem dynamics.

Studies and analyses may take the form of comparisons along latitudinal gradients or across hydrologically-coupled zones. Temperate reefs, therefore, may be included in comparative studies if appropriate. Examples of comparative studies include:

- Characterization of different types of reefs
- Comparison of the controls on the productivity of the different types of live bottoms (consider, for example, the differing roles of nutrients, effects of sediment, and predation)
- Comparison of the contribution of different reefs to off-shore production
- Development of models of the functions of different reef ecosystems

All studies will require the collection of data. In cases in which new field data is required, some form of monitoring will have to be undertaken and the data then integrated into the analysis. All

monitoring efforts should be conducted in coordination with the on-going monitoring efforts of the National Science Foundation (NSF), National Oceanic and Atmospheric Administration (NOAA), Florida Keys National Marine Sanctuary (FKNMS), National Park Service (NPS), CariComp, IOCaribe, and others.

Specific Research Needs

- I. Determine the mechanisms, causes, and effects of coral decline as manifest by coral disease, low coral recruitment, and decreased growth rates of individual species. Determine, thereby, factors affecting reef recovery and reef succession.

Investigate the sources, ambient levels, transport-cycling-transformation, fate, and effects of:

A. Nutrients and nutrient dynamics. Specific research questions include:

1. Determine the relationship between the volume and character of the nutrient load and reef productivity.
 - a. Consider developing nutrient water quality standards for preserving reef health.
2. Identify relevant sources of nutrients.
 - a. Determine the role of in-ground discharges
3. Identify controls on recycling and near-shore cycling (including benthic cycling) of nutrients.
 - a. Create or refine hydrographic models in coordination with the National Science Foundation (NSF), Department of Energy (DOE), National Oceanic and Atmospheric Administration (NOAA), and others.
4. Determine the effect of eutrophication on micro-organisms and algae.
 - a. Determine the role of micro-organisms and algae on reef health. Consider total population density and community dynamics (i.e., settlement, success, mortality, growth, diversity).
5. Investigate the connection between ciguatera prevalence and nutrients and physical disturbance

B. Macrobiology. Specific research questions include:

1. Determine the role of fish and urchins in reef health
2. Determine the role of fishing on fish-reef interactions
3. Determine the role of nutrients on fish-reef interactions
4. Determine the effect of divers and boats on reef health
5. Determine the effects of changing biodiversity on reef ecosystem function

C. Temperature

D. Sediment

E. Salinity

1. Determine the effect of road and bridge construction (i.e., correlative changes in freshwater flow and marine circulation) on reef health

- II. Determine economic and sociological ramifications of reef decline
 - A. Develop cost estimates and success criteria for reef recovery plans
 - B. Determine losses to fisheries due to reef declines
 - C. Determine losses to tourism due to reef declines
- III. Develop (in coordination with the US Environmental Protection Agency [EPA]) tropical water quality standards and classifications for the maintenance of reef health. Consider standards for:
 - A. salinity
 - B. nutrients
 - C. light attenuation (as affected by turbidity)

Specific High-Priority Research Needs for Estuaries and Embayments

Introduction

The overall goal of this portion of the South Atlantic and Caribbean Regional Marine Research Program is to determine how complete estuarine ecosystems function. Such a determination will require an evaluation of the dynamic functional roles of the multiple components and processes that interact within estuarine ecosystems. Consideration should be given to hydrologic circulation; the role of nutrients, sediments, and organic materials; and sociological and economic factors affecting and being affected by natural processes.

A central concern of the South Atlantic and Caribbean Regional Marine Research Program is a determination of the role of human activities in altering natural components and processes. To this end, all research projects funded by the South Atlantic and Caribbean Regional Marine Research Program must address, as appropriate, the character of human activities and their impacts in and on the natural system as well as pertinent sociological and economic responses to ecosystem dynamics.

Studies and analyses may take the form of comparisons along latitudinal gradients or across hydrologically-coupled zones.

Research Needs

- I. Evaluate complete estuarine systems (including estuaries, embayments, marshes, and mangroves) -- i.e., characterize (and classify, if appropriate) complete estuarine systems or major estuarine habitat types (along latitudinal gradients, if appropriate) based on function and functional status (see footnote 1).

The interdisciplinary, large-scope of this concern will require research efforts that cut across a number of traditional disciplinary boundaries and incorporate and integrate a wide variety of information. The result will likely be research efforts that incorporate items and issues from a number of the following categories.

- A. Determine the functional roles of major estuarine habitat types including:
 - 1. Shallow tidal creeks and rivulets
 - a. Identify major threats to the normal function of creeks and rivulets
 - b. Determine proportion of fisheries dependent on rivulets
 - c. Determine the role of creeks and rivulets in maintaining water quality (in the creeks and rivulets and in the larger estuaries)
 - d. Determine anthropogenic effects on creeks and rivulets

- e. Determine the effect of changing areal extent
- f. Determine the possibilities for restoration of damaged creeks and rivulets
- 2. Live bottoms
 - a. Consider the character and extent of hypoxia, disease, contamination, development, biological diversity, harvesting, areal coverage, and restoration.
- 3. Unvegetated habitats
 - a. Determine the relative contribution of unvegetated habitats to estuarine production and material budgets
- 4. Marshes
- 5. Submerged aquatic vegetation

Consideration should be given to components and processes associated with botany, sedimentology, hydrology, faunal biology.

B. Determine the function and functional roles of major ecological processes and relationships including:

- 1. The flow of energy and trophic pathways
- 2. Primary productivity
- 3. Estuary-continental shelf coupling
- 4. Community (e.g., detrital-based community or specific habitat type) structure, function, succession, and possible methods of restoration
- 5. Constituent dynamics (e.g., nutrients and sediments)

This will require research and analysis of individual system components (see Section C below). Appropriate research will require short sampling intervals over long periods of time.

C. Determine the function and functional role of major estuarine components including:

- 1. Function and dynamics of nutrients (see footnote 2) in coordination with other national and regional programs such as the National Estuary Program, the National Oceanic and Atmospheric Administration, and the Land Margin Ecosystem Research program
 - a. Determine transformations of organics
 - b. Determine cost-benefit of changing loadings associated with alternative treatments
 - c. Determine the role of flocculants in concentrating pollutants
 - d. Determine the dynamics of nutrient dissipation relative to accumulation
 - e. Determine the character and effect of seasonal loadings
 - f. Determine links among: nutrients, algal blooms, low dissolved oxygen, etc. for management application
 - g. Study benthic boundary layer processes
 - h. Determine atmospheric contribution
 - i. Determine nutrient loads to groundwater
 - j. Design desk-top information systems to describe eutrophication status
 - k. Assess degree of sediment nutrient contamination

2. Function and dynamics of sediment, detritus, and particulate matter (see footnote 2)
 - a. Determine interactions among nutrients, sediments, and wind/wave action
 - b. Assess sediment contamination
 - c. Study benthic boundary layer processes
3. Function and dynamics of the flow and freshwater (see footnote 2)
 - a. Create hydrologic circulation models
 - b. Determine flow of groundwater to near-shore waters
 - c. Determine effects of jetties, inlets, stormwater modifications, etc. on productivity and habitat
 - d. Determine the effects of frontal processes on productivity

II. Create numerical ocean circulation models

- A. Create a geographically-referenced, regional ocean circulation model of the South Atlantic Bight
- B. Create a geographically-referenced model of a defined system that links physics, chemistry, biology, and socio-economics in a predictive way

III. Stand-alone socio-economic and policy-oriented research needs

- A. Determine the benefits and value of reduced nonpoint source pollution
- B. Determine the costs and efficacy of mitigating poor water quality
- C. Determine the indirect costs of environmental policies
- D. Develop the technology to evaluate trade-offs between ecological functions and costs of preserving/degrading them

Footnotes

1. It should be noted that in pursuing a number of the categories of research listed above, it would be natural to undertake a study of factors affecting abundance of fish, crustaceans, and other important nektonic invertebrates. Studies, such as those listed below, may be a relevant component of research sponsored by the South Atlantic and Caribbean Regional Marine Research Program, but any efforts in this realm should be carefully planned in coordination with the National Marine Fisheries Service (NMFS), state fisheries agencies, the South Atlantic Bight Recruitment Experiment (SABRE), and Coastal Ocean Boundaries Interactions Assessment (COBIA) to avoid duplication of existing efforts and jurisdictions.
 - A. Compare growth and survival of fish among estuaries in a model including indexes of water quality, abundance of submerged aquatic vegetation, etc.
 - B. Habitat, habitat selection and artificial reefs
 1. determine whether populations are habitat limited
 2. determine whether artificial reefs enhance populations
 3. interactions among stream/estuary/ocean communities
 - C. Adult migration
 1. determine what factors affect adult migration
 - D. Water quality and hydrodynamics -- effects on disease, fitness, etc

- E. Other organisms
 - 1. trophic interactions
 - F. Dissolved oxygen
 - G. Model bio-economic effects of changes in these components/characteristics and resulting changes in stocks
2. A study of the "function and dynamics" of individual components of estuarine systems could involve investigation of any or all of the following:
- bio-geo-chemical cycles
 - constituent budgets
 - transport/flux (pathways) of constituents
 - linkages with other systems or components
 - boundary processes
 - transformations of constituents
 - different functions of constituents within the system
 - anthropogenic activities and their impacts on constituent dynamics

DESIRED CHARACTERISTICS OF RESEARCH AND RESEARCH PRODUCTS

General Research Progression

Introduction: Following is a list describing a generic progression that should be followed for most research endeavors. Tailoring of these steps will be required depending on existing understanding. Within the South Atlantic and Caribbean Region, scientific understanding and specific research needs differ. In one portion of the Region, scientists addressing one issue may be in the very first stages of developing a data collection system, while in another portion of the region scientists may already have an extensive local database and may be involved in modelling exercises or may be applying the model for resource management.

- conceptual model creation,
- data collection, compilation, and analysis,
- system characterization, and
- refined conceptual or quantitative model development.

It should be noted that although the final step of the research progression is "model development", the ultimate goal of the endeavor is refined understanding and improved management of natural/human systems. System characterization and modelling efforts are tools to help achieve better understanding of the systems and help implement the sound management of the resources involved.

Initial Conceptual Model Creation: The "system" of interest (ecosystem, network, or process) must be identified. The system may be a pristine ecosystem (e.g., a pristine tidal creek), a natural ecosystem affected by human activities (e.g., a developed embayment), or a social system that relates only to human activities (e.g., the operation of a port).

Initial conceptual model creation will involve the development of specific hypotheses, the generation of specific questions, and the postulation of specific relationships to be investigated -- from which the research (data collection and analysis) will begin to form. A general framework for the collection of data must be developed so that pertinent data may be collected in the most efficient, integrated, and potentially useful manner. It is essential that this stage of research be conducted with full input from all involved research scientists representing all pertinent disciplines in order for the products of the research to be truly reflective of the interconnected system as whole.

Data Collection, Compilation, and Analysis: Existing and new data regarding the system of interest must be collected, stored, and analyzed in as coordinated a manner as possible.

Identified as a major need throughout the South Atlantic and Caribbean Region is the consideration and analysis of pertinent existing data to determine its utility and applicability to the task at hand. In many areas a situation of being "data-rich but information-poor" exists. A lot of data have been collected but never suitably compiled or analyzed. Time and effort may be well spent in cataloging and analyzing data that already exist. Such an analysis would allow a foundation of knowledge to be laid without the expense of new data collection and analysis. An analysis of existing data can also help to focus the design of new data collection endeavors. Concerted effort should be made to build upon existing databases to allow for long-term trends analyses.

Whether the data are new or old, consideration must be given to the pertinence of the data; standardization of collection, analysis, and storage techniques; flexibility of the data for other uses; compatibility of the data with other related databases; accessibility of the data to resource scientists and managers; and the ultimate utility of the data by managers and other scientists.

Among the categories of data to be collected are:

- information regarding the "anthropogenic landscape" (e.g., rates and character of population growth and levels and character of economic development)
- information regarding human activities of concern (e.g., fisheries harvest and physical destruction),
- information regarding the effects of human activities and natural processes on system form and function, and
- information regarding the identification of critical thresholds.

The responsibility for and resulting structure of data management will vary with every research endeavor. In some cases it may lie in the hands of the investigators alone; in some cases it may be a combined effort with state and federal agencies. In some cases large centralized databases and repositories will prove to be the most useful or appropriate; in other cases smaller databases will prove to be more useful or appropriate.

System" Characterization: This stage of research will involve: the characterization of processes and linkages; the determination of quantitative relationships; the initial assessment of hypotheses validity; the initial assessment of model applicability and adequacy; and the comparison of related activities, processes, and systems.

Once databases have been established and analyzed, the rudiments of the system of interest can be described or characterized -- the first attempts at synthesis can be undertaken. Boundaries can be defined; primary processes can be described and quantified; linkages, fluxes, and driving forces can be determined; spatial and temporal variations can be determined; budgets and cycles can be developed; and trends and thresholds can be identified.

Efforts should be made to develop three-dimensional understanding of fluxes and interactions, along the shore, perpendicular to the shore, and vertically, as well as those between land and sea, and air and sea.

Efforts should be made to characterize populations of, for example, humans, fish and shellfish, sea turtles, birds, and mammals, so that they can be more effectively managed. Information should be gathered on species' location, size, demography, health (disease and response to marine toxins), recruitment, ecosystem and resource use, and evolution.

In every discipline or physical realm, information is needed on the effects of different human land and water use practices on natural systems and natural resources. The addition of contaminants and other potentially disruptive activities must be characterized. Once the character, sources, transport, and fates of materials have been identified, specific relationships between the addition of contaminants and their environmental effects (lethal and sublethal, individual and cumulative) can be determined and quantified. The effects of other activities can also be characterized and quantified.

Through such exercises, a determination of the qualities defining a "healthy" or "desirable" system or

population can be made, and indicators for the health of that type of system or population can be developed. Appropriate water quality standards, human health standards, indicators, or triggers could, for example, be developed or refined.

Synthesis reports and refined conceptual models may be products of this stage of scientific inquiry.

Refined conceptual Model or Quantitative Model Creation: Finally, when sufficient data have been collected, and sufficient understanding of the processes at work within the system of interest has been gained, integration can begin and a "model" (a working picture or a simulation) of the system can be generated. The model may be a refinement of the initial conceptual model or may be a quantitative model.

Models can help to clarify and quantify relationships. Models can be used to display the character of the critical sources, sinks, fluxes, and linkages of materials and processes within the system of concern. Along with viable system indicators, models can be used to establish scenarios, generate predictive responses, estimate possible cumulative effects, and conduct risk assessments. Models can enable resource managers to better answer the question "What if ... ?" Models will thereby allow resource managers to better protect the valuable resources of the near-coastal ocean.

These models should be designed in anticipation of regional application -- they should allow for comparisons with models of other similar systems and they should highlight unique and common system features. These models should be comprehensible to all potential users (scientists and resource managers alike), flexible, and able to be augmented as further data, information, or technology become available.

Specific Desired Characteristics of Research

Research supported by the South Atlantic and Caribbean Regional Marine Research Program must, of course, comply with the national program goal, the national and Regional criteria for "regional research", and the Regional goal.

The following list is not intended to be exhaustive, but to give an indication of the types of research endeavors that will be judged more favorably by the South Atlantic and Caribbean Regional Marine Research Program.

- Direct research towards answering a specific question, but ensure that the question has potential for broader applicability -- e.g., determine the carrying capacity of an embayment and present a model for application of the process to other embayments.
- Where possible, take a "watershed" or "landscape" perspective in the research in an effort to understand large-scale spatial and temporal patterns in the system of interest and in an effort to characterize important human influences.
- To the maximum extent possible, utilize geo-referenced data so that flexibility and long-term utility of the data will be enhanced.
- Coordinate research with as broad a field of players as possible. Coordination must occur from the outset to avoid duplication of effort and to ensure effective and efficient data collection and analysis. Coordination includes cooperation and efficient use of resources and so will likely entail:
 - inter-agency (governmental) communication,
 - inter-institutional (academic) communication,
 - international coordination (in the Caribbean Sub-Region)
 - cooperative endeavors between academic and government institutions,
 - utilization of existing information,
 - inter-disciplinary coordination
 - science - management coordination,
 - maximal use of local expertise,
 - dovetailing with existing efforts (which will require identification of existing efforts), and
 - matching funds

Specific Desired Characteristics of Research Products

- All products should, above all else, be applicable to management needs.
- Products should answer a very specific question but should also give an indication of the possible broader applicability of the results. Products should quantify specific cause and effect relationships in given situations, but should give a more general interpretation of the results. Products should answer questions such as: "If the input of compound x is reduced by y%, what can be expected to happen to the productivity of z?"
- Products should help to identify thresholds of environmental stressors, human responses, etc.
- Products should indicate possible solutions to the problems being studied. Products should, therefore, indicate possible alternative courses of action and the ecological and economic ramifications of those possibilities.
- Possible products include:
 - ecosystem classification schemes with indications of ecosystem function and vulnerability
 - matrices of similarities among ecosystems (within the Region or Sub-Regions)
 - guidelines for data collection (answering: "What must I measure?")
 - guidelines for data interpretation
 - environmental atlases mapping and describing natural resources

IX. REGIONAL RESEARCH IMPLEMENTATION STRATEGY

INTRODUCTION

Following is a description of the approach to be taken in identifying specific research needs, selecting research projects, and implementing research. The initial focus (the first 3-5 years) will be on the two ecosystems of highest priority (Coral Reef Ecosystems and Estuaries and Embayments), but it is intended that the process outlined below will be followed for every one of the ecosystems of concern (e.g., barrier island ecosystems and fisheries habitats) and every one of the major concerns (e.g., other issues related to the loss of habitat and biodiversity) as time and funding allow.

Need for Continued Oversight

The successful implementation of the South Atlantic Regional Marine Research Plan will require continued centralized program oversight and management will be necessary. The implementation of a program of this scope will require oversight by a "Director" to ensure the smooth progression of final planning; the RFP process; grant awards; scientific research coordination, interaction, and oversight; product completion; information dissemination; program review; and renewed program planning.

The program Director will be able to serve as the primary contact person for the program as a whole, maintaining close contact with members of the Board, the Administrators of NOAA and EPA, involved research scientists, interested resource managers, and the general public. The program Director will also be able to lend a sense of continuity to the program as a whole, especially throughout the RFP processes and research oversight processes.

Need for Coordination

To achieve any of the research goals implied below, coordination is needed among scientists and managers from the earliest stages of planning, to the actual implementation of research projects, to the dissemination of research results.

Many related and potentially complimentary programs exist. The Regional Marine Research Program must make a concerted effort to involve the input and actions of pertinent agencies and organizations in the all stages of program implementation. This will help to ensure against duplication of efforts and will help to maximize efficient use of personnel and funds. See the Anticipated Partnerships section below for a more detailed description of coordination efforts.

RFP DEVELOPMENT, PROPOSAL SOLICITATION, AND PROPOSAL REVIEW

Interdisciplinary Ecosystem-Specific Workshops

The two lists of "Priority Research Needs" (Chapter VIII) will serve as the foundation for two Ecosystem-Specific Workshops. Workshop membership will represent both the scientific and resource management communities with representatives of the most closely related programs.

The discussions of each workshop will ensure that the list of "Priority Research Needs" adequately reflects unique priority research needs for the sub-region and melds the information needs of the near-coastal management community with the capabilities and interests of the scientific community. It is in this forum, that coordination between science and management among traditionally distinct disciplines will begin.

The goals of each workshop are:

- to review and prioritize (through consensus) the "Priority Research Needs" outlined for the ecosystem of concern, and
- to promote coordination and interdisciplinary interaction among scientists and resource managers (and the preliminary formulation of teams of research scientists) from the very beginning.

It is in these early planning stages that specific mechanisms for interagency coordination will be determined. Appropriate personnel and projects will be identified and appropriated mean of communication and coordination will be determined.

In order for the interdisciplinary ecosystem-specific workshops to be successful, they will have to be well-advertised, well-planned, and well-run. Lists of invitees will be developed and widely-reviewed prior to the anticipated date of the workshops. The workshops will be announced at least two months in advance of the workshops to ensure maximum participation. The workshops themselves will be attended by Board members, the program Director, a professional facilitator, and a broad spectrum of managers and research scientists -- including all pertinent disciplines of management, physical science, and social science.

Workshop participants will be reimbursed for all travel and daily expenses incurred in relation with the 1 or 2 day workshop. Funding for these workshops will come from the remainder of the planning funds appropriated for the South Atlantic and Caribbean Regional Marine Research Program.

The RFP Process

Based on the outcomes of the Interdisciplinary Ecosystem-Specific Workshops and the input of the Board, the program Director will create the first draft of the Request for Proposals (RFP) and send it to the Board members for their review and comment. In an effort to maximize participation in the proposal submission process and to encourage the best possible science, the RFP should be tightly focused without being exclusionary. The RFP must reflect the national and Regional goals and criteria as well as the recommendations made by the participants in the Interdisciplinary Ecosystem-Specific Workshops.

The RFP will be issued by the Board of the South Atlantic and Caribbean Regional Marine Research Program and distributed widely, using standard avenues of distribution and the networks established through the interdisciplinary ecosystem-specific workshops.

Later RFPs will be created by the program Director based on input from resource managers and scientists. All RFPs will be reviewed by the Board and issued by the Board.

Proposal Review and Selection

Criteria for the selection of interdisciplinary research proposals shall include:

- the national Regional Marine Research Program goal,
- the national and regional criteria for "regional research" (including mechanisms for coordination of research efforts and information dissemination),
- the South Atlantic and Caribbean Regional Marine Research Program goal,
- standards of scientific excellence, and
- as many of the "Desired Qualities of Research and Research Products" identified at the end of Chapter VIII (see page 73).

All proposals will be reviewed by a set of peer reviewers jointly selected by the Board and NOAA Oceanic Research. A panel of experts selected by the Board and NOAA Oceanic Research will review the proposals, assess the peer reviews, and make recommendations to the Board. Based on the recommendations of the panel of experts, the Board will select those proposals it considers to have the

greatest merit and forward its final recommendations to the Executive Council (and so to the administrators of NOAA and EPA) for their consideration and the ultimate decision regarding grant awards.

Grant Awards

The Board will award grants via the appropriate state Sea Grant office according to NOAA's standard operating procedure.

RESEARCH INITIATION

While every research endeavor will differ somewhat, each should follow the basic progression outlined in the previous chapter (see Chapter VIII for more details) to ensure an interdisciplinary character and useful products:

- development of a conceptual model,
- data collection and initial analysis(es),
- system characterization, and
- creation of system models.

Research and coordination efforts will be initiated as outlined in the accepted research proposals. Researchers will be responsible for submitting to the program Director progress reports, draft products, and final products.

The program Director will be responsible for overseeing all research funded through the South Atlantic and Caribbean Regional Marine Research Program and should, therefore, be responsible for:

- serving as the primary contact for all would-be researchers, all active research participants, all representatives of NOAA and EPA, and all involved resource managers,
- overseeing the research funded to ensure that the goals and means of the funded research proposals are being achieved,
- overseeing the research funded to ensure that progress reports, draft reports, and final reports are submitted in a timely fashion,
- overseeing the collection and storage of data to ensure that it is conducted according to the proposal and so is efficient and effective, and, possibly
- overseeing the dissemination of data and results to the research science community, resource management community, and the interested public to ensure that all products are produced in a timely and truly useful manner.

Competent research oversight and management by the program Director will help to ensure a certain level of continuity and focus as regards the goals of the program, levels of funding, specific research endeavors, data collection and storage, and information dissemination.

PROGRAM REVIEW AND PLANNING

The program Director will synthesize, on an annual basis, the results of individual research endeavors and, under the guidance of the Board, will help to develop new foci for future research efforts.

The program Director, under the direction of the Board, will be responsible for conducting reviews and revisions of the South Atlantic and Caribbean Regional Marine Research Plan once every four years. Program review will include consideration of research supported through the Program (endeavors and results) and expenditures.

ANTICIPATED PARTNERSHIPS

The Nature of Coastal Research in the South Atlantic and Caribbean Region and the Need for the Regional Marine Research Program

In the South Atlantic Region there are a great many institutions and agencies conducting coastal marine research. Some are large-scale cooperative endeavors; some are operated by the federal government; some are operated by state government; some are associated with state and private universities. Many of these programs have goals similar or complementary to those of the South Atlantic Regional Marine Research Program.

Most international and global programs address issues of global extent through the conduct of basic research. Most federal and national programs address issues of a general environmental management concern or a basic, non-site-specific scientific concern. Most state and private coastal research institutions apply the majority of their human and financial resources towards the characterization of individual processes and habitats and to the solution of local concerns.

These research efforts together constitute the basic ingredients in the mixture that makes up our understanding of the coastal and the oceans -- the mixture that forms the foundation of marine resource management. But these programs are often developed in isolation. They often begin with very similar efforts of resource characterizations and needs assessments, but then, due to limited funding, pursue only portions of the intended goal. The result is a series of good intentions and a number of serious gaps in our understanding of the near-coastal oceans.

The existing mixture of programs must, therefore, be augmented by studies and programs that ignore traditional political boundaries, bridge disciplinary gaps, and create better understanding of critical interactions and links.

Few research institutions and programs have sufficient funding or expertise to delve into the study of processes and concerns in a regional and truly interdisciplinary manner -- interdisciplinary and inter-agency coordination and cooperation are still quite limited in coastal studies relative to other scientific fields. Few attempts have been made to synthesize existing understanding and coordinate the expertise of disparate fields of research. For these reasons many questions about coastal and marine processes remain.

The Regional Marine Research Program was initiated in an effort to develop understandings of processes and trends from a "big picture" perspective, address the need for truly regional research endeavors, and bridge the traditional gaps among the customary fields of research science and customary divisions of responsibility established by the primary federal, state, and private funding sources and research agencies.

Likely Partners

The 11 regional-scale programs discussed below are seen, at this time, as having missions and foci particularly relevant to those of the South Atlantic and Caribbean Regional Marine Research Program and will be targeted for involvement in the planning and implementation phases. In so doing, the efforts of the Regional Marine Research Program and the coordinating agencies will be facilitated and augmented. Through increased coordination research efforts will be more focused and less redundant; habitat and resource management efforts will be more directed and effective; and issues of human resource use and human health and safety will be addressed more efficiently.

The 11 programs described below have been selected as examples of those most likely to facilitate and augment the efforts of the South Atlantic and Caribbean Regional Marine Research Program, but other programs and projects will be targeted for coordination as deemed appropriate once research projects have been selected.

Coordination efforts will include detailed discussion of current and anticipated research efforts to

avoid duplicated efforts, utilization of existing data as the foundation for future research, coordinated use of facilities and personnel.

For each program listed below, there is a short description of its activities and the likely character of coordination with the South Atlantic and Caribbean Regional Marine Research Program process. For information regarding other related programs or for information regarding more specific research efforts of the programs listed below, see Appendix 2.

CZM (Coastal Zone Management) Programs (NOAA/States): State CZM Programs conduct research and carry out management activities of a nature that will be addressed by the Regional Marine Research Program. One likely avenue of cooperation is participation in the Ecosystem-Specific Workshops and proposal review. When appropriate, research efforts will be coordinated with state research endeavors. Coordination will be readily achieved through existing channels of committee representation and proposal review. Contact: Jeff Benoit, NOAA/OCRM SSMC-4, 1305 East-West Highway, Silver Spring, MD, 20910 (301-713-3074).

COP (Coastal Ocean Program) (NOAA): COP operates numerous programs of research and analysis that address several of the areas of concern identified as crucial within this plan. Likely avenues of cooperation include participation in the Ecosystem-Specific Workshops and proposal review. Coordination will be readily achieved through existing channels of communication among the COP Office, the Board Chair, and the Director. Contact: Don Scavia, Director, NOAA/COP, 1825 Connecticut Ave. NW, Washington, DC, 20235 (202-606-4330).

ELMR (Estuarine Living Marine Resources) (NOAA): ELMR has a mission of large-scale data collection to assist in making species and estuary comparisons in an effort to better understand biological coupling of estuarine and marine systems. Likely avenues of cooperation include participation in the Ecosystem-Specific Workshops and proposal review. Coordination will likely occur through standard channels of *ad hoc* committee participation and proposal review. Contact: Mark Monaco, NOAA N/ORCA1, 1305 East-West Highway, Silver Spring, MD, 20910 (301-713-3000).

EMAP/NS&T (Environmental Monitoring and Assessment Program/National Status and Trends Program) (EPA/NOAA): EMAP and NS&T generate information that is uniquely large-scale (regional) and designed for comparative studies and evaluations. Likely avenues of cooperation include assistance with monitoring, data supply, and data analysis. Specific mechanisms for coordination will be established, as needed, on a project-specific basis. Contact: Andy Robertson, NOAA NOS N/ORCA2, SSMC-4, Monitoring and Bioeffects Division, 1305 East-West Highway, Silver Spring, MD, 20910 (301-713-3032).

NBS (National Biological Survey) (DOI) This program, designed to be akin to the U.S. Geological Survey, will develop a baseline database of biological resources throughout the U.S. Likely avenues of cooperation include proposal review, data exchange and coordination of on-going and anticipated monitoring and research efforts. Since NBS now administers the research efforts of US Fish and Wildlife Service and National Park Service, coordination efforts with those agencies will be established, as needed, through the appropriate NBS offices. Contact: Jim Weaver, Center Director, 7920 NW 71st St., Gainesville, FL, 32606 (904-378-8181).

NEP (National Estuary Program) (EPA/states) (Albemarle-Pamlico and Indian River Lagoon): The NEPs aim to protect the local, state, and national interests in maintaining the ecological integrity of important estuaries through focused research efforts, long-term planning, and management, often at the regional level. Likely avenues of cooperation include participation in the Ecosystem-Specific Workshops, proposal review, data exchange, and regional research efforts. Coordination will likely occur through informal means of communication and cooperative efforts, and official means of coordinated research endeavors. Contact: Wesely "Bo" Crum, Water Management Division, 345 Courtland St., Atlanta, GA 30365 (404-347-1740).

NERRS (National Estuarine Research Reserve System) (NOAA/states) (7 locations within the South Atlantic region): NERRS was established to foster a system of estuary reserves that represent a wide range of coastal and estuarine habitats indigenous to the United States and its territories. NERRS works in cooperation with federal and state authorities to establish, manage, and maintain reserves and to provide for their long-term stewardship and use as research and

education sites. There is a great deal of descriptive and quantitative systems data collected from within the NERRS. NERRS sites will provide ideal databases and locations for research endeavors. Likely avenues of cooperation include participation in the Ecosystem-Specific Workshops, proposal review, and support of research. Coordination will likely occur through informal means of communication and cooperative efforts, and official means of coordinated research endeavors. Contact: Capt. Francesca M. Cava, Chief of Sanctuaries and Reserves, NOAA/NOS/OCRM SSMC-4, Room 12409, 1305 East-West Highway, Silver Spring, MD 20910 (301-713-3074).

NMS (National Marine Sanctuaries Program) (NOAA) (5 locations within the South Atlantic region): Research conducted through the NMS program tends to address marine systems as whole units, much like the ecosystem approach advocated by the Regional Marine Research Program. Coordination of research efforts, therefore, could prove highly beneficial for both programs. Likely avenues of cooperation include participation in the Ecosystem-Specific Workshops, proposal review, and the conduct of research and monitoring. Coordination will likely occur through informal means of communication and cooperative efforts, and official means of coordinated research endeavors. Contact: Capt. Francesca M. Cava, Chief of Sanctuaries and Reserves, NOAA/NOS/OCRM SSMC-4, Room 12409, 1305 East-West Highway, Silver Spring, MD 20910 (301-713-3074).

RMRP (Regional Marine Research Program) (NOAA/EPA): The adjacent Mid-Atlantic and Gulf of Mexico Regional Marine Research Programs will be addressing many issues similar to those targeted by the South Atlantic and Caribbean Regional Marine Research Program in hydrologically, biologically, and anthropogenically connected systems. Most directly, the Mid-Atlantic Program will be addressing issues that relate to the waters and ecosystems ranging from Cape Fear to Cape Hatteras and the Gulf of Mexico Program will be addressing issues that relate to the water quality and ecosystem health of the Florida Keys. Coordination of research efforts in the will occur throughout the planning and implementation stages to ensure the most effective and efficient use of resources. Likely avenues of cooperation include participation in the Ecosystem-Specific Workshops, continued coordination with proposal review and revision, and conduct of research endeavors. Coordination will be readily affected through existing channels of communication at the federal level and individually among Program Chairs and Directors. Contact: Don Scavia, Director, NOAA/COP, 1825 Connecticut Ave. NW, Washington, DC, 20235 (202-606-4330) or the adjacent RMRP offices.

Sea Grant College Programs (NOAA/States): The Sea Grant College Programs in the 5 states and one territory/commonwealth within the South Atlantic and Caribbean Region operate programs of coastal and marine research, outreach, and education. It is likely that all three components the Sea Grant College Programs will be called upon to support and facilitate efforts pursued by the Regional Marine Research Program. Appropriate representatives will be asked to participate in the Ecosystem-Specific Workshops, review project proposals, and support research endeavors in all appropriate manners from data exchange to information dissemination. The channels of communication established as a result of Sea Grant Directors serving as Chairs of the Regional Marine Research Programs will greatly facilitate the timely exchange of information and cooperative efforts. Contact: David Duane, National Sea Grant Office, SSMC1 Room 5470, 1335 East-West Highway, Silver Spring, MD, 21910 (301-725-5725).

CONCLUSION

By focusing on efficient use of resources to accomplish a new goal of linking social and physical science and management from the very beginning and from a regional perspective, the South Atlantic And Caribbean Regional Marine Research Program will create unique benefits for the near-coastal ocean resource management and scientific communities.

X. TIMELINE

The following timeline reflects the understanding of the Director at the time of the completion of this draft. Successful and timely implementation of the tasks described depend in part on the continued cooperation of the scientific and management participants, in part on the NOAA administration's commitment to continue support, and in part on legislative commitment to continue funding.

Year 1 (FY 1992-1993)

Dec	First Draft written
Feb	Regional Interdisciplinary Workshop refines first draft
Mar	Board mail-review of Second Draft
May-Jun	Local Workshops held to review Third Draft
Aug	Board meeting to review Fourth Draft
Aug	Fourth Draft submitted to NOAA and EPA

Year 2 (FY 1993-1994)

Jan	Fourth Draft revised
Feb	Board review of Fifth Draft
Mar	Plan approved (anticipated)
Apr	Interdisciplinary Ecosystem-Specific Workshops held
Mar	RFP #1 created and issued
May-Jun	Pre-proposals due, reviewed, call for final proposals
Jul-Aug	Proposals peer reviewed and selected by Board
Sept	Research proposals submitted to NOAA for funding

Year 3 (FY 1994-1995)

Oct-Dec	Research Plan and RFP are revised
Feb	Research #1 initiated
Mar	RFP #2 issued
May-Jun	Pre-proposals due, reviewed, call for final proposals
Jul-Aug	Proposals peer reviewed and selected by Board
Sept	Research proposals submitted to NOAA for funding

Year 4 (FY 1995-1996)

Oct-Dec	Research Plan and RFP are revised
Feb	Research #2 initiated
Mar	RFP #3 issued
May-Jun	Pre-proposals due, reviewed, call for final proposals
Jul-Aug	Proposals peer reviewed and selected by Board
Sept	Research proposals submitted to NOAA for funding

Year 5 (FY 1996-1997)

Oct-Dec	Research Plan and RFP are revised
Feb	Bi-annual report submitted to NOAA and EPA, Progress Report released for public
Feb	Research #3 initiated
Mar	RFP #4 issued
May-Jun	Pre-proposals due, reviewed, call for final proposals
Jul-Aug	Proposals peer reviewed and selected by Board
Sept	Research proposals submitted to NOAA for funding

APPENDIX 1: PARTICIPANTS IN RESEARCH PLAN DEVELOPMENT

INTRODUCTION

A ten-part process was undertaken in the development of this Research Plan.

- (1) Board members were asked to fill out a questionnaire regarding the state of the environment, on-going research endeavors, and research needs. Responses to the questionnaires were compiled.
- (2) Scientists and managers (over 175) from throughout the Region were approached individually or in small group meetings to discuss at length their views of the state of the environment, on-going research endeavors, and research needs. Careful notes were taken during all meetings. From this information, the first draft of the Research Plan was developed.
- (3) Board members and outside experts (20) met to refine and focus the Research Plan. Careful notes were taken, written comments were received, and minutes of the meeting were developed. From this the second draft of the Research Plan was developed.
- (4) Board members and outside experts were given a chance to review the second draft. Written comments were received and a third draft of the Research Plan was developed.
- (5) Scientist and managers (over 130) were mailed copies of the third draft of the Research Plan and asked to attend one of eight local workshops at which their input was solicited. Careful notes were taken. Revisions were made accordingly and a fourth draft of the Research Plan was developed.
- (6) Board members met and unanimously approved the Research Plan. A final draft was sent to NOAA headquarters for review and comment.
- (7) From the collected body of comments and information gathered, a comprehensive list of research needs was developed by the Director.
- (8) Experts (over 30) from a wide variety of disciplines were sent a questionnaire and asked to rank in order of priority the research needs listed (or any additions). Results were compiled by the Director.
- (10) Based on the comments of NOAA and EPA headquarters staff revisions were made to the fourth draft of the Research Plan, and reviewed and approved by Board members. A final Research Plan was submitted to NOAA headquarters for approval.

Below is a list of those who participated in the process described above. The symbols used are described in the key box below.

Step	Symbol	Group to Which Symbol Refers
2	P	People contacted (personally or by phone) during Preliminary meetings
3	E	Board and outside Experts in attendance at Interdisciplinary Workshop in Puerto Rico meeting (e = invited but not in attendance)
5	W	People sent a copy of the third draft and in attendance at one of the eight Local Workshops (w = invited but not in attendance)
8	R	Experts assisting with Research prioritization (r = solicited but did not respond)
	A	People A dvised of the program who gave some form of input
	*	Experts to be called upon in the future as needed

ST THOMAS/ST JOHN

Pw	Ed Towle	Island Resources Foundation
P	Rick Walton	Island Resources Foundation
PW	Carol Mayes	The Nature Conservancy
PW	Lynn McDonald	University of Puerto Rico Sea Grant
Pw	Caroline Rogers	National Park Service
Pw	Jennifer Bjork	National Park Service
w	Rikki Grober	National Park Service
w	Comm. Roy Adams	Department of Planning and Natural Resources
w	Keith Richards	Department of Planning and Natural Resources
W	Janice Hodge	Department of Planning and Natural Resources
PW	Barbara Kogis	DPNR/Division of Coastal Zone Management
w	Joan Harrigan-Farrelly	DPNR/Division of Coastal Zone Management
w	Leonard Reed	DPNR/Division of Environmental Protection
PEW	Rafe Boulon	DPNR/Division of Fish and Wildlife
w	Ann Seiler	DPNR/Division of Fish and Wildlife
W	Arthur Damman	consultant
w	Laverne Ragster	UVI-Eastern Caribbean Center
W	Norm Quinn	UVI-Eastern Caribbean Center
W	Theresa Turner	University of the Virgin Islands
PRw	Callum Roberts	University of the Virgin Islands
w	James Battey	University of the Virgin Islands
AW	Ray Hayes	University of the Virgin Islands
w	Andre Webber	Fisheries Advisory Committee
w	George Goodwin	Senator
w	Bingley Richardson	Senator

ST CROIX

PW	Olassie Davis	UVI-Agricultural Extension
Pw	Betsy Gladfelter	West Indies Laboratory
PW	Marcia Taylor	University of Puerto Rico Sea Grant
PW	Zandy Hillis	National Park Service
P	Marc Pacifico	Department of Planning and Natural Resources
P	Robin Addley	Department of Planning and Natural Resources
W	Nora Santana	DPNR/Division of Environmental Protection
w	Benjamin Nazario	DPNR/Division of Environmental Protection
PeW	Toby Tobias	DPNR/Division of Fish and Wildlife
P	Peter Sale	University of New Hampshire
P	Hank Tonnemacher	Consultant in marine biology
W	Robin Freeman	St. Croix Environmental Association
w	Dennis Hubbard	
w	Ken Haines	
w	Marylou Colston	
w	Gerard Luz James	Senator
W	Holland Redfield	Senator/staff member representing

PUERTO RICO

w	James Oland	US Fish and Wildlifer Service
P	Ken Foote	US Fish and Wildlifer Service
PEW	Manny Hernandez	University of Puerto Rico Sea Grant
PEW	Jorge Capella	University of Puerto Rico Sea Grant
P	Javier Velez	University of Puerto Rico Sea Grant
P	Jerry Gonzalez Roman	University of Puerto Rico Sea Grant

PEW	Ruperto Chaparro	University of Puerto Rico Sea Grant
P	Juan Lopez	University of Puerto Rico-Mayaguez
P	M. Chaparro	University of Puerto Rico-Mayaguez
P	Amos Winter	University of Puerto Rico-Mayaguez
P	John Kubaryk	University of Puerto Rico-Mayaguez
P	Tom Tosteson	University of Puerto Rico-Pargera
PE	Jorge Corredor	University of Puerto Rico-Pargera
*	Rich Appledoorn	University of Puerto Rico-Pargera
*	Jack Morelock	University of Puerto Rico-Pargera
P	Eric Morales	Environmental Quality Board
w	Carl Soderberg	US Environmental Protection Agency
P	Tere Rodriguez	US Environmental Protection Agency
P	Gary Toranzos	University of Puerto Rico-Rio Piedras
P	Jose Norat	University of Puerto Rico-Rio Piedras
E	Manuel Pizzini	University of Puerto Rico-Rio Piedras
w	Miguel Rolon	NMFS/Caribbean Fishery Management Council
eW	Vance Vicente	NMFS/SE Fisheries Science Center
P	Mirko Restovic	Engineer
W	Jose Gonzalez Libon	Puerto Rico Coastal Zone Management
W	Boris Oxman	Puerto Rico Coastal Zone Management
W	Pedro A. Gelabert	Puerto Rico Department of Natural Resources
W	Jose L Campos	Puerto Rico Department of Natural Resources
W	Anselmo de Portu	Puerto Rico Department of Natural Resources
W	Ricardo Cotte	Puerto Rico Department of Natural Resources
W	Jose Martinez	US Army Corps of Engineers
w	Stephen Benton	US Army Corps of Engineers

FLORIDA

P	Andy Major	National Marine Fisheries Service (St Peteresburg)
P	Quinton White	Jacksonville University
A	Carole DeMort	University of North Florida
*	Fred Calder	
E	Grant Gilmore	Harbor Branch Oceanographic Institution
*	Ned Smith	Harbor Branch Oceanographic Institution
P	John Windsor	Florida Institute of Technology
P	John Trefrey	Florida Institute of Technology
P	Walt Nelson	Florida Institute of Technology
P	Diane Barile	Marine Resources Council
P	Stan Dunn	Florida Atlantic University
P	Stewart Glegg	Florida Atlantic University
P	Pete Scolatos	Florida Atlantic University
P	D.V. Reddy	Florida Atlantic University
P	Barry Steer	Florida Atlantic University
*	Mike Salmon	Florida Atlantic University
P	Peter Lutz	Florida Atlantic University
Pw	Chris Mooers	Rosenstiel School of Marine & Atmospheric Science
P	Mark Harwell	Rosenstiel School of Marine & Atmospheric Science
P	Liz Clarke	Rosenstiel School of Marine & Atmospheric Science
P	Bruce Rosendahl	Rosenstiel School of Marine & Atmospheric Science
P	Dan Baden	Rosenstiel School of Marine & Atmospheric Science
P	Joe Prospero	Rosenstiel School of Marine & Atmospheric Science
PW	Claes Rooth	Rosenstiel School of Marine & Atmospheric Science
W	Roy Watlington	Rosenstiel School of Marine & Atmospheric Science
PW	Don Pybas	Florida Sea Grant
PW	Joe Halusky	Florida Sea Grant
E	Jim Cato	Florida Sea Grant

*	Steve Beggs	
*	John Prons	
*	John Klein	
P	Scott Quackenbush	Florida International University
P	Ron Jones	Florida International University
P	Bill Cooper	Florida International University
P	Anitra Thornhaug	Florida International University
A	Gary Kleppel	Nova University
*	Dick Dodge	Nova University
*	Andrew Cole	Nova University
PeW	John Ogden	Florida Institute of Oceanography
Pew	Robert Menzer	US Environmental Protection Agency
w	Richard Ring	National Park Service-Everglades
w	Michael Robblee	National Park Service-Everglades
w	Richard Curry	National Park Service-Biscayne
w	Garth Redfield	South Florida Water Management District
W	Joel vanArman	South Florida Water Management District
w	Tom Singleton	South Florida Water Management District
w	Rick Alleman	Surface Water Improvement-Biscayne
W	Bill Watkins	St. Johns River Water Management District
W	Bob Days	National Estuary Program
w	Derek Busby	National Estuary Program
w	Mary Williams	Florida Department of Environmental Regulation
w	Peggy Mathews	Florida Department of Environmental Regulation
w	Ken Haddad	Florida Department of Natural Resources
W	George Maul	NOAA/Atmospheric and Oceanic Marine Lab
P	Peter Ortnier	NOAA/Atmospheric and Oceanic Marine Lab
w	Jim Bohesack	NOAA/NMFS/National Marine Sanctuaries
w	Billy Causey	FL Keys National Marine Sanctuary
w	Alan Bunn	Key Largo National Marine Sanctuary
w	George Schmahl	NOAA/National Marine Sanctuaries
W	Brad Brown	NOAA/National Marine Fisheries Service
W	Nancy Thompson	NOAA/National Marine Fisheries Service
wW	Mike Prager	NOAA/National Marine Fisheries Service
P	Al Jones	NOAA/National Marine Fisheries Service
P	Joe Powers	NOAA/National Marine Fisheries Service
w	Steve Miller	National Undersea Research Center-UNC-Wilmington
w	Bo Smith	US Army Corps of Engineers
w	Eugene Shinn	US Geological Survey

GEORGIA

PW	Herb Windom	Skidaway Institute of Oceanography
P	Jack Blanton	Skidaway Institute of Oceanography
P	Rick Yanki	Skidaway Institute of Oceanography
P	Clark Alexander	Skidaway Institute of Oceanography
P	Dave Menzel	Skidaway Institute of Oceanography
*	Ed Charen	University of Georgia
*	John Noakes	University of Georgia
*	Phil Roberts	Georgia Institute of Technology
W	Jim Alberts	University of Georgia Marine Institute-Sapelo
W	Ron Kneib	University of Georgia Marine Institute-Sapelo
W	Mac Rawson	Georgia Sea Grant
W	Reed Bohne	NOAA/National Marine Sanctuaries
*	John Brown	US Fish and Wildlife Service
w	Philip Laumeyer	US Fish and Wildlife Service
w	David Waller	Georgia Department of Natural Resources

w	Lonice Barrett	Georgia Department of Natural Resources
PWE	Stuart Stevens	Georgia Department of Natural Resources
w	Harold Reheis	Georgia Department of Natural Resources
w	Robert Burnett	Armstrong State College
W	Rittin Kahn	Armstrong State College
w	Willian Gardner	Savannah State College
w	Dorothy Lord	Brunswick College
w	John Davis	Savannah Coastal Refuge
w	Nicholas Henry	Georgia Southern University
w	John Bozeman	Freshwater and Wetlands Heritage Inventory
w	Roland Swain	Cumberland Island National Seashore
w	Vernon Martin	Coastal Gerogia Development Center

SOUTH CAROLINA

w	Roger Banks	US Fish and Wildlife Service
PW	Fred Holland	SC Marine Resources Research Institute
*	Bob Van Dolah	SC Marine Resources Research Institute
Pew	Paul Sandifer	SC Marine Resources Research Institute
Pw	Bob Kifer	National Marine Fisheries Service
P	Malcom Meaburn	National Marine Fisheries Service
P	Paul Bauersfield	National Marine Fisheries Service
PW	Geoff Scott	National Marine Fisheries Service
*	Rob Dunlap	National Marine Fisheries Service
P	Lou Burnett	College of Charleston-Grice Marine Lab
w	Bob Johnson	College of Charleston-Grice Marine Lab
P	Phil Ross	The Citadel
PW	Margaret Davidson	South Carolina Sea Grant College Consortium
PW	Rick DeVoe	South Carolina Sea Grant College Consortium
Pw	Bob Mahood	South Atlantic Fisheries Management Council
P	Roger Pugliais	South Atlantic Fisheries Management Council
W	Dennis Allen	National Estuarine Research Reserve/Belle Baruch
W	Mike McKenzie	NERRS/SC Wildlife & Marine Resources Department
*	Liz Blood	W. Belle Baruch
w	John Vernberg	W. Belle Baruch
*	Paul Gayes	Coastal Carolina College
PWE	Philip Murphy	US Environmental Protection Agency
W	Bo Crum	US Environmental Protection Agency
w	Pat Tobin	US Environmental Protection Agency
*	Fred McManus	US Environmental Protection Agency
*	Bob Howard	US Environmental Protection Agency
W	Mel Goodwin	Harborwatch
w	Hayward Robinson	South Carolina Coastal Council
w	Wayne Beam	South Carolina Coastal Council
w	Al Vang	South Carolina Water Resources Commission
w	Ann Hale Miglarese	South Carolina Water Resources Commission
w	Russell Sherer	SC Department of Health and Environmental Concerns

NORTH CAROLINA

w	L.K. Gantt	US Fish and Wildlife Service
P	Wilson Laney	US Fish and Wildlife Service
Aw	Bill Cole	US Fish and Wildlife Service
PEW	Don Hoss	National Marine Fisheries Service
P	Randy Ferguson	National Marine Fisheries Service
A	Bud Cross	National Marine Fisheries Service
P	Dave Engel	National Marine Fisheries Service

*	Pat Tester	National Marine Fisheries Service
*	Gordon Thayer	National Marine Fisheries Service
*	Jeff Govoni	National Marine Fisheries Service
P	John Mariner	National Marine Fisheries Service
P	Mark Fonseca	National Marine Fisheries Service
P	Jim Easley	North Carolina State University
*	Ray Palmquist	North Carolina State University
P	Mike Stoskopf	North Carolina State University
P	Neal Blair	North Carolina State University
P	Dave DeMaster	North Carolina State University
PEW	Len Pietrafesa	North Carolina State University
P	Steve Snyder	North Carolina State University
A	JoAnn Burkholder	North Carolina State University
P	Bruce MacDonald	North Carolina State University
*	Larry Crowder	North Carolina State University
*	Jim Rice	North Carolina State University
A	Tom Hopkins	North Carolina State University
A	Jerry Janowitz	North Carolina State University
A	Dan Kamykowski	North Carolina State University
*	Ernie Knowles	North Carolina State University
A	John Miller	North Carolina State University
A	John Morrison	North Carolina State University
*	Sethu Ramon	North Carolina State University
*	Ping-Tung Shaw	North Carolina State University
*	Bill Showers	North Carolina State University
*	Wendell Gilliam	North Carolina State University
*	Wayne Skaggs	North Carolina State University
P	Tom Wolcott	North Carolina State University
P	Donna Wolcott	North Carolina State University
*	Ed Noga	North Carolina State University
P	Larry Benninger	University of North Carolina-Chapel Hill
P	John Bane	University of North Carolina-Chapel Hill
P	Chris Martens	University of North Carolina-Chapel Hill
P	Marc Alperin	University of North Carolina-Chapel Hill
P	Tom Shay	University of North Carolina-Chapel Hill
P	Dan Albert	University of North Carolina-Chapel Hill
P	Conrad Neuman	University of North Carolina-Chapel Hill
P	Charlie Paul	University of North Carolina-Chapel Hill
P	Bill Kier	University of North Carolina-Chapel Hill
P	Dirk Frankenburg	University of North Carolina-Chapel Hill
P	Hans Paerl	UNC-Institute of Marine Science
P	Pete Peterson	UNC-Institute of Marine Science
P	John Wells	UNC-Institute of Marine Science
e	Mike Orbach	East Carolina University
PE	Stan Riggs	East Carolina University
P	Will Ambrose	East Carolina University
P	Scott Snyder	East Carolina University
P	Don Stanley	East Carolina University
P	Marc Brinson	East Carolina University
E	Jeff Johnson	East Carolina University
P	Bob Christien	East Carolina University
P	Joe Luczkovich	East Carolina University
P	Terry West	East Carolina University
P	Roger Rulifson	East Carolina University
e	Mike Orbach	Duke University Marine Laboratory
P	James Merritt	University of North Carolina-Wilmington
P	Larry Cahoon	University of North Carolina-Wilmington
*	Alan Hulbert	University of North Carolina-Wilmington

P	Ron Sizemore	University of North Carolina-Wilmington
P	Paul Rosier	University of North Carolina-Wilmington
*	Martin Posey	University of North Carolina-Wilmington
P	Dave Linquist	University of North Carolina-Wilmington
Pw	Steve Ross	UNC-W/NC Division of Coastal Management
w	Rich Shaw	NC Division of Coastal Management
W	Alan Clark	NC Division of Environmental Management
w	Randy Waite	National Estuary Program
w	John Taggart	National Estuarine Research Reserve System
E	Chris D'Elia	Mid-Atlantic Regional Marine Research Program

PRIORITY RESEARCH NEEDS REVIEWERS

Coral Reefs:

R	Don Atwood	NOAA/Atmospheric and Oceanic Marine Lab
R	Callum Roberts	University of the Virgin Islands
r	Jim Cato	Florida Sea Grant
r	Billy Causey	National Marine Sanctuaries
R	Jorge Corredor	University of Puerto Rico
R	Chris D'Elia	Maryland Sea Grant
r	Pamela Hallock-Muller	University of South Florida
R	Mark Hay	University of North Carolina-Chapel Hill
R	George Maul	NOAA/Atmospheric and Oceanic Marine Lab
r	Mark Robertson	The Nature Conservancy
r	Caroline Rogers	National Park Service
R	Clay Cook	Harbor Branch Oceanographic Institution
R	Walter Jaap	Florida Department of Environmental Protection
R	Dan Suman	Rosenstiel School of Marine and Atmospheric Science
r	Alina Szmant	Rosenstiel School of Marine and Atmospheric Science
R	Bill Wiebe	University of Georgia
R	James Bill Porter	University of Georgia
r	B.J. Kjerfve	University of South Carolina

Estuarine Systems:

r	Reed Bohne	National Marine Sanctuaries
R	Bud Cross	NOAA/National Marine Fisheries Service
R	Jim Easley	North Carolina State University
R	Fred Holland	SC Marine Resources Research Institute
R	Elizabeth Wenner	SC Marine Resources Research Institute
R	Stan Riggs	East Carolina University
r	Jeff Johnson	East Carolina University
R	Herb Windom	Skidaway Institute of Oceanography
R	Grant Gilmore	Harbor Branch Oceanographic Institution
r	Diane Barile	Marine Resources Council
R	Peter Lutz	Florida Atlantic University
R	Steve Ross	National Estuarine Research Reserve System
r	Marian Mlay	US Environmental Protection Agency
r	Jim Pulliam	US Fish and Wildlife Service
r	Robert Hodson	University of Georgia
r	Lisa Muehlstein	University of Richmond

APPENDIX 2: EXISTING RESEARCH PROGRAMS

INTRODUCTION

Following is a listing of the most pertinent and most significant governmental and academic coastal marine research agencies, programs, and institutions active in the South Atlantic region, and an indication of the breadth of scientific inquiry that they collectively represent. After the title of each program (or sub-program) is a brief description of the program's overall characteristics and activities in the South Atlantic and Caribbean Region, and a contact name, address, and phone number.

This list is intended to give resource managers, researchers, and other interested individuals a very general outline of the numerous agencies and programs involved in coastal issues. Some of the programs listed are actively involved in research efforts in the Caribbean and South Atlantic Bight Sub-Regions. The programs listed are involved in a variety of research efforts at a variety of geographic scales.

It should be noted that some of the programs listed are primarily management programs that conduct few research activities, but serve as clearinghouses of research results and research endeavors. It should also be noted that within the South Atlantic and Caribbean Region there are numerous private and non-profit organizations that range in scope from local or issue-specific initiatives (e.g., St. Croix Environmental Association) to broad national initiatives (e.g., the Nature Conservancy). Such organizations are rarely involved in research efforts and are too numerous to be listed below.

INTERNATIONAL PROGRAMS

The following global and international programs were, by and large, established to study very large-scale events and processes ranging from global climate change to carbon and nitrogen cycling over large areas.

IGBP (International Geosphere-Biosphere Programme): describes quantitatively the interactive physical, chemical, and biological processes that regulated the Earth system and its capacity to support life. **J-GOFS (joint Global Ocean Flux Study):** studies carbon cycling over large areas. J-GOFS is operating a time-series open-ocean station near Bermuda for collecting baseline data. Contact: Hugh D. Livingston, US J-GOFS Office, Woods Hole Oceanographic Institute, Woods Hole, MA, 02543 (508-457-2000x2454).

UN (United Nations)

UNEP (United Nations Environmental Program)

CEP (Caribbean Environment Programme) also "Wider Caribbean Regional Seas Program": provides a mechanism whereby the culturally, economically, and politically diverse states and territories of the region could collectively address the protection of the marine and coastal resources (and the terms of the Cartagena Convention) of the Wider Caribbean. Contact: Beverly Miller, Deputy Coordinator, CEP RCU 14-20 Port Royal Street, Kingston, Jamaica (809-922-9267).

CEPNET (CEP Regional Programme on Information Systems for the Management of Marine and Coastal Resources in the Wider Caribbean): assists with the management of scientific data, but is not undertaking activities around the U.S. Virgin Islands or Puerto Rico at this point in time. Contact: Beverly Miller, Deputy Coordinator, CEP RCU 14-20 Port Royal Street, Kingston, Jamaica (809-922-9267).

CEPPOL (CEP Regional Programme for the Assessment and Control of Marine Pollution): in collaboration with IOC studies, monitors, controls, and abates land-based sources of marine pollution. Currently under study in the U.S. Virgin Islands or Puerto Rico are land-based sources of marine pollution, the sanitary quality of bathing and shellfish-growing waters, oil and marine debris pollution, eutrophication, water quality criteria, and measures to control marine pollution. Contact: Beverly Miller, Deputy Coordinator, CEP RCU 14-20 Port Royal Street, Kingston, Jamaica (809-922-9267).

UNESCO (United Nations Educational Scientific and Cultural Organization)

COMAR/COSALC (Coastal Marine Programme/Coastal Systems of Latin America and the Caribbean): provides basic funding for the CARICOMP (see below) cooperative network of research marine laboratories seeking to facilitate cooperation in the study of cross-zonal coastal problems and sharing information and competence in relevant areas. Contact: Marc Steyaert, UNESCO Division of Marine Affairs, 7 Place de Fontenoy, 75007 Paris, France (33-1-45-68-3968).

CARICOMP (Caribbean Coastal Marine Productivity Programme): a cooperative program of coastal marine ecosystem monitoring and research based at 21 marine laboratories in 15 Caribbean countries and Florida. CARICOMP is implementing a basic monitoring protocol for coral reefs, seagrasses, and mangroves to determine long-term trends in biodiversity and global change. Contact: John Ogden, Director, FIO, FSU, 830 First Street, South, St. Petersburg, FL 33701 (813-893-9100).

MAB (Man and the Biosphere Program): by nominating to the International Network of Biosphere Reserves, the MAB program lends its support to the study of protected areas. The MAB program utilizes the services and holdings of the National Park Service, the National Biological Survey, and national refuges and sanctuaries to determine the effects of human activities on natural environments. Three biosphere reserves exist within the South Atlantic and Caribbean region: Guanica forest reserve in Puerto Rico, the research arm of the US Virgin Island National Park in St. John, and the Santee Delta reserve in South Carolina. No primary funding for research is supplied through the MAB program. All research efforts associated with MAB are, therefore, discussed in the sponsoring agencies' sections below. Contact: Ariel Lugo, Chairman, MAB Program, International Institute of Tropical Forestry, Call Box 25000, Rio Piedras, PR, 00928-2500.

IOC (Intergovernmental Oceanographic Commission)

IBCCA (International Bathymetric Chart of the Caribbean Sea and the Gulf of Mexico): is compiling a new bathymetric chart series and bathymetric contour database for the Caribbean Sea and the Gulf of Mexico by means of a cooperative effort among Mexico, the United States, Costa Rica, France, Cuba, Venezuela, and Colombia. Charts will be compiled at a scale of 1:250,000 and 1:500,000. The United States has responsibility for 5 of the 17 map areas: the Gulf of Mexico, the Atlantic off the shores of Florida and Georgia, the northern Bahamas, eastward to the Hatteras Abyssal Plain, and the region around Puerto Rico. NOAA's National Geophysical Data Center is compiling the bathymetric information for these 5 areas. One map area is complete, one map area is in press, and three map areas are 75% complete. Contact: Troy Holcombe, Senior Scientist, Marine Geology and Geophysics Division, National Geophysics Data Center, NOAA, Mail Code E/GC3, 325 Broadway, Boulder, CO, 80303-3328 (303-497-6390).

Implications of Climate Change in the Wider Caribbean Region (subcomm.): is a joint UNEP/IOC task team that sponsors relevant research to examine the potential effects of a 20 cm sea level rise and a 1.5°C increase by 2025 on coastal ecosystems and socio-economic structures and activities of the marine and coastal environments of the "Intra-Americas Seas" (the Caribbean, the Gulf of Mexico, and northern South America). Contact: George Maul, Dept. of Oceanography, Florida Institute of Technology, 150 West University Blvd, Melbourne, FL 32901 (407-768-8000 x8096).

IOCARIBE (Subcommission for the Caribbean and Adjacent Regions): formerly Cooperative Investigations of the Caribbean and Adjacent Regions (CICAR), coordinates the 25 member states in all aspects of international and inter-governmental marine research programs that are too large to be undertaken by individual countries. The subcommission also serves to enhance the scientific and technical base of participating developing countries through associations with nations such as the United States, the United Kingdom, France, and Germany. There are 5 major program areas which address issues of global climate change and other environmental changes in the Caribbean Sea, the Gulf of Mexico, the Bahamas, and the northeast coast of South America: (1) physical

ocean processes, sea level, and climate; (2) ocean sciences in relation to living resources; (3) ocean sciences in relation to non-living resources; (4) ocean pollution, control, and abatement; and (5) ocean mapping. IOCaribe is sponsoring many relevant research projects such as the establishment of a regional monitoring network, fish recruitment studies, beach dynamics, and pesticide studies. Contact: George Maul, Dept. of Oceanography, Florida Institute of Technology, 150 West University Blvd, Melbourne, FL 32901 (407-768-8000 x8096).

WOCE (World Ocean Circulation Experiment): Sponsors relevant research to understand the general circulation of the global ocean well enough to be able to model its present state and predict ocean response and feedback to long-term (decadal-scale) changes in the atmosphere, oceans, and climate. WOCE aims to provide the scientific background for designing an observing system for long-term measurement of the large-scale circulation of the ocean. In general, WOCE-sponsored research efforts address issues of boundary conditions and exchanges with the atmosphere, inter-basin exchanges, vertical exchanges within the ocean, heat transport and storage mechanisms, general circulation, and modeling. WOCE's research activities in the South Atlantic and Caribbean Region include hydrographic work, current meter moorings, surface drifter and sub-surface float deployments, XBT lines, and satellite coverage. Contact: Piers Chapman, US WOCE Office, Department of Oceanography, Texas A&M University, College Station, TX 77843-9988 (409-845-1443).

FEDERAL/NATIONAL PROGRAMS

There is a tremendous diversity of players represented in the following list of federal and national programs -- from initiatives primarily concerned with planning and coordination (NOPPA), to agencies primarily involved with resource management but also involved with some research and/or monitoring (USFWS), to agencies primarily involved with the support of basic research (NSF). There is also a tremendous diversity of fields of interest represented in the following list from life histories of individual species (NOAA/NMFS) to large-scale geological processes (USGS). Emphasis has been given to agencies involved in research into fields of particular relevance to the South Atlantic and Caribbean Regional Marine Research Program.

Some of the initiatives are undertaken by individual federal agencies (DOE's Ocean Margin Program); some are undertaken by several agencies in cooperation (Coastal America); and some are implemented by individual or cooperating states (EPA's National Estuary Program). Listed below are those programs that are currently undertaking and involved for the long-term in near coastal research in the southeast and Caribbean. Omitted from the list are the many other federal programs exist that hold extensive coastal and marine databases, assist in information management and dissemination, or develop and implement coastal policy.

DOC/NOAA (Department of Commerce/National Oceanic and Atmospheric Administration): conducts research and management activities related to the observation, description, and prediction of the natural variability of the global earth system and the identification of any changes in the earth system (living and non-living resources) caused by human activity. Contact: D. James Baker, 14th and Constitution Ave. NW, Washington, DC, 20230 (202-377-3436). NOAA Directory Assistance (301-443-8910).

COP (Coastal Ocean Program): strengthens NOAA's stewardship of coastal waters through a science-oriented program. Contact: Donald Scavia, Director, Coastal Ocean Office, Room 15140, SSMC-3, 1315 East-West Highway, Silver Spring, MD, 20910 (301-713-3338).

Coastal Fisheries Ecosystems Theme: supports ecological and oceanographic research to help improve conservation and management of living resources. The program is studying means of reducing uncertainty in resource management decisions, focusing on better understanding recruitment variability and compensatory mechanisms and species interactions in fisheries. In the South Atlantic Bight the Coastal Fisheries Theme funds the South Atlantic Bight Recruitment Experiment (SABRE). SABRE conducts basic research on the recruitment of estuarine-dependent fish from coastal spawning areas into nursery areas to understand the relationship between variation in environmental factors and the variable recruitment of "estuarine dependent" fishes (Atlantic menhaden in particular) in the South Atlantic Bight. Research topics include physical processes that transport fish, age and growth of surviving larvae, and effects of predators. Research is cooperative between federal agencies and

academic institutions. Contact: Dr. Donald Hoss, NMFS Laboratory Pivers Island, Beaufort, NC, 28516 (919-728-8746).

EHP (Estuarine Habitat Program): conducts research to locate and determine the extent of critical habitats and the rate of loss, determine habitat function and process (with focus on impacts on living marine resources), study possibilities for restoration, conduct analyses of habitat change over time in various watersheds, and create synthesis documents. In the southeast, EHP is supporting C-CAP activities (see below) and many studies of marsh and seagrass form and dynamics. Study topics include the exploration of genetic diversity, possibilities for restoration, and the importance of scale and patch patterns. Contact: Leon Cammen, National Sea Grant College Program, R/ORI, 1335 East-West Highway, Silver Spring, MD, 20910 (301-713-2435).

NECOP (Nutrient Enhanced Coastal Ocean Productivity): sponsors research in the Gulf of Mexico to predict the effects of nutrient over-enrichment in coastal waters. Contact: Bill Graham, SSNC-1 Room 5204, 1315 East-West Hwy, Silver spring, MD, 20910 (301-713-0799).

RID (Resource Information Delivery): studies user groups and their needs for access to data and information. RID is developing a national synthesis document that contains regionally-specific modules providing guidance for resource managers to plan, execute, and evaluate sea grass restoration, creation, and mitigation projects. Contact: Mark Fonseca, NOAA/NMFS, Beaufort Lab, Beaufort, NC, 28516 (919-728-8729).

Toxic Ecology Program: conducts research to establish comprehensive baseline data on chemical pollution and its effects, to follow temporal trends, to answer priority management questions regarding living marine resources and their habitats, and to allow measurement of the environmental quality of coastal and estuarine waters. The program is closely associated with NOAA's National Status and Trends Program (see below) and utilizes many of the same sampling sites. The program is comprised of two segments: (1) field surveys to document the status and trends of concentrations of chemical contaminants in sediment and (2) development and survey use of marine fish as biomarkers of contaminant effects (e.g., reproductive impairment or oxidative DNA damage). In the southeast sediment toxicity tests (using three tests of toxicity) and fish biomarker surveys are underway at the National Status and Trends sampling sites in Biscayne Bay, Brunswick Harbor, Savannah River, Winyah Bay, and Charleston Harbor. Contact: Usha Varanasi, NOAA/NMFS, Northwest Fisheries Science Center, Environmental Conservation Division, 2725 Montlake Blvd. East, Seattle, WA 98112-2097 (206-860-3330) or Andy Robertson, Director, Coastal Monitoring and Bioeffects Assessment Division, NOAA/N/ORCA-2, 1305 East-West Highway, Silver Spring, MD, 20910 (301-713-3032).

NESDIS (National Environmental Satellite and Data Information System): manages the Nation's civil earth-observing satellite systems and global data centers for meteorology, land sciences, oceanography, sun-earth physics, and solar-terrestrial sciences through four "centers": NODC (National Oceanographic Data Center), NGDC (National Geophysical Data Center), NSIDC (National Snow and Ice Data Center), NCDC (National Climate Data Center). None of the Centers engage in primary research in the near-coastal zone, but all hold extensive databases, some of which may be of relevance to research associated with the South Atlantic and Caribbean Regional Marine Research Program. NODC, for example, holds the C-CAP data, Coastwatch AVHRR data, and the coastal buoy data and NCDC holds all precipitation data. Contact: Gregory Withee, NESDIS, Federal Building 4, Room 2069, Suitland and Silverhill Road, Suitland, MD, 20233 (301-763-7190).

NGDC (National Geophysical Data Center): rescues, archives, manages, and provides ready access to publicly available geological and geophysical data for land and marine areas, including the U.S. territorial waters of the Atlantic and Gulf of Mexico. NGDC is currently overseeing the digitization of historic coastal bathymetric data from paper plotting sheets. NGDC is also archiving and managing data from multi-beam bathymetric data sets and the digital NOAA/Coast and Geodetic Survey hydrographic database for all U.S. territorial waters. Contact: Troy Holcombe, Senior Scientist, Marine Geology and Geophysics Division, National Geophysics Data Center, NOAA, Mail Code E/GC3, 325 Broadway, Boulder, CO, 80303-3328 (303-497-6390).

NMFS (National Marine Fisheries Service): provides guidance for effective stewardship of the nation's living marine resources through research, planning, conservation, restoration, and education efforts. NMFS is conducting a wide variety of research relevant to topical living marine resource issues and the maintenance of long-term databases.

CoastWatch: provides near real-time remotely-sensed and in situ data for coastal ocean research and decision-making. CoastWatch receives provides on-line to federal, state, and local resource managers high-resolution, near-real-time sea surface temperature and visible satellite imagery from NOAA's polar orbiting satellites. Imagery covers the area from North Carolina through Florida. In addition, the program has access to imagery from other regions as well as *in situ* data streams (such as NOAA C-MAN and fixed buoys) stored in the CoastWatch archive in Washington, DC. Images are supplied to cooperating state, federal, and academic institutions in near-real-time via Internet. Applications include monitoring of environmental quality, assisting with fisheries management, and elucidating issues of hazards mitigation. Products are available through the NMFS Beaufort Lab and the National Hurricane Center in Miami. Contact: Kent Hughes, Program Manager, NOAA/NESDIS, Federal Building 4, Room 1069, Suitland, MD, 20746 (301-763-1564) or Alex Chester, NOAA/NMFS Beaufort Lab, 101 Pivers Island Rd., Beaufort, NC 28516 (919-728-8774). *C-CAP (Coastal-Change Analysis Program)*: is developing a comprehensive, nationally standardized, information system for land cover and habitat change in the coastal region of the U.S. and is producing change analysis charts of coastal habitats. Contact: Ford (Bud) Cross, NOAA/NMFS Beaufort Laboratory, 101 Pivers Island Rd., Beaufort, NC, 28516 (919-728-8724).

S.E. Regional Office (St Petersburg, FL): establishes marine policy appropriate to the resource protection mandate of NMFS. Oversees permitting, law enforcement activities, state/federal grant administration, and operation of the Science Center. Contact: Andy Kemmerer, NMFS Regional Director, Duval Bldg., 9450 Koger St., St. Petersburg, FL 33707 (813-893-3144).

S.E. Fisheries Science Center (Miami, FL) oversees the research of 7 laboratories in the southeast (3 within the Region). The S.E. Fisheries Science Center establishes research priorities, compiles information, provides administrative and academic support, and conducts research addressing issues of fisheries biology. The SEFSC conducts basic and applied research to support management bodies responsible for the conservation and management of living marine resources, particularly fishery stocks. Research emphases vary among laboratories, but include assessing the status of fishery resources, advancing fishery predictions, promoting a health fishery industry, accelerating growth of aquaculture, reducing the impact of human activity on protected species, assessing the status for coastal ecosystem management, developing a national monitoring program of coastal ecosystems, and increasing scientific understanding of the importance of ecosystem functioning. Contact: Albert Jones, Director of the Research Management Division, S.E. Fisheries Center, 75 Virginia Beach Dr., Miami, FL, 33149 (305-261-4259).

NMFS Labs in the S.E. Region (Beaufort, NC; Charleston, SC; Miami, FL): conduct research and implement policy decisions made by the Regional Offices. The Beaufort Laboratory conducts both fisheries and habitat research. Fisheries research is conducted on menhaden and reef fisheries. Biological information and population assessments are provided to fisheries managers. Assessments are also conducted for weakfish and red drum. Habitat research addresses the importance of estuarine and coastal habitats to the survival of larval and juvenile fish. Emphasis is on the role of natural factors in coastal ocean and marsh and seagrass in estuaries. Studies are also conducted on the effects of toxic metals on marine food chains, distribution of sea turtles in NC sounds, and marine mammal strandings. Contact: Bud Cross, NOAA/NMFS Beaufort Lab, 101 Pivers Island Rd., Beaufort, NC 28516 (919-728-8724). The Charleston Laboratory primarily conducts research on chemical issues and issues of disease, but also conducts some studies on fisheries ecology. Contact: Bob Kifer, NOAA/NMFS Charleston Lab, PO Box 12607, Charleston, SC, 29422-0607 (803-762-1200). The Miami Laboratory primarily conducts research on population levels of fishery stocks for management application, but also conducts some studies on fisheries ecology. Contact: Brad Brown, Director, S.E. Fisheries Center, 75 Virginia Beach Dr., Miami, FL, 33149 (305-261-4259).

NOPPA (National Oceanic Pollution Planning Act): NOPPA required the development of a comprehensive 5-year plan to address ocean pollution. The plan identifies 6 broad goals regarding understanding and addressing the sources, transports, and effects of pollutants and a few specific research or monitoring needs to help achieve each goal. The contents of the plan were considered and incorporated in development of this Research Plan. Several of the topics addressed in the NOPPA Plan were incorporated in this Research Plan. The National Ocean Pollution Prevention Office no longer exists, but the contents of the plan will be available for reference and guidance.

NOS (National Ocean Service): produces nautical and aeronautical charts and related publications for safe and efficient passage in coastal waterways and the national airspace system. Contact: S. Wilson, Assistant Administrator NOS, SSMC-4, 13th Floor, 1305 East-West Highway, Silver Spring, MD, 20910 (301-713-3074).

ORCA (Office of Ocean Resources Conservation and Assessment): supports research to help determine the long-term ecological, economic, and social consequences of human activities on coastal and marine environments and human environments. Contact: Charles (Bud) Ehler, N/ORCA, SSMC-4, Station 10409, 1305 East-West Highway, Silver Spring, MD, 20910 (301-713-2989).

Coastal Monitoring and Bioeffects Assessment Division: collects and compiles information from primary investigators, monitoring programs, and state databases to generate data reports. Contact: Andy Robertson, Director, Coastal Monitoring and Bioeffects Assessment Division, NOAA/N/ORCA-2, 1305 East-West Highway, Silver Spring, MD, 20910 (301-713-3032x210).

NS&T Program (National Status and Trends Program): contracts and conducts water quality and biotic health monitoring to determine the current status of (and to detect changes in) the environmental quality of our nation's estuarine and coastal waters. Primary support comes from the Coastal Ocean Program Office. NS&T is composed of 7 major components including the Mussel Watch Project, the National Benthic Surveillance Project, and the Bioeffects Surveys. The Mussel Watch Project collects mussels, oysters, and some sediment from roughly 240 sites nationwide and analyzes samples for roughly 70 different contaminants. Sites sampled within the Region include Pamlico Sound, Charleston harbor, Sapelo Sound, St. Johns River, and Biscayne Bay. The National Benthic Surveillance Project analyzes chemicals in bottom-dwelling fish livers and associated sediments to determine exposure to contaminants and associated bioeffects. Sites sampled within the Region include Pamlico Sound, Charleston harbor, Sapelo Sound, St. Johns River, and Biscayne Bay. The Bioeffects Surveys involve more intensive sampling procedures and are conducted in areas where NS&T monitoring projects indicate the potential for significant environmental degradation. There are currently surveys on the bioeffects of contaminants being undertaken in Charleston Harbor, North Edisto Bay, and Winyah Bay, and Biscayne Bay (see description of COP's Toxic Ecology Program).

Contact: Andy Robertson, Director, Coastal Monitoring and Bioeffects Assessment Division, NOAA/N/ORCA-2, 1305 East-West Highway, Silver Spring, MD, 20910 (301-713-3032x210).

Hazardous Materials Response Division: responds to issues regarding spills or leaks of hazardous materials in the environments. The Division is studying the recovery of mangroves at the Vista Bell oil spill site with site visits and evaluations over time and is studying the natural resource risks associated with the shipment and transfer of (dense) oil in sensitive coastal regions (study site is Jacksonville to Sanford, FL). Contact: Robert Pavia, Hazardous Materials Response Division, 7600 Sand Point Way, NE, Seattle, WA, 98115 (206-526-6319).

SEA (Strategic Environmental Assessment) Division: creates comprehensive compilations and analyses of information on characteristics of large coastal areas, usually from the head of tide in estuaries through the 200 mile U.S. Exclusive Economic Zone in an effort to describe and quantitatively analyze spatial, temporal, and ecological relationships. SEA offers technical and analytical support for internal and external assessments on contract. At any given time, many projects are underway such as a regional eutrophication assessment, regional biogeographic characterizations, regional risk assessments and mapping projects, chart development support work, and habitat studies. Contact: Dan Basta, Strategic Environmental Assessment Division, N/ORCA-1, Office of Ocean Resources Conservation and Assessment, 1305 East-West Highway, SSMC-4, 9th Floor, Silver Spring, MD, 20910 (301-713-3000).

ELMR (Estuarine Living Marine Resources) Program: conducts, in coordination with NMFS, research to support the development of a consistent database on the spatial and temporal distribution, relative abundance, and life history characteristics of 40 species of fishes and invertebrates found in 20 southeastern estuaries to complement information on the physical characteristics of the estuaries, to enable comparisons among species and estuaries, to gain understanding of the biological coupling of estuarine and marine habitat, and to begin to define estuarine biogeography. Contact: Mark Monaco, Strategic Environmental Assessment Division, N/ORCA-1, Office of Ocean Resources Conservation and Assessment, 1305 East-West Highway, SSMC-4, 9th Floor, Silver Spring, MD, 20910 (301-713-3000).

OCRM (Office of Ocean and Coastal Resources Management): manages and helps to protect coastal resources and ecosystems through a combination of federal and federal/state cooperative programs. Contact: Jeff Benoit, NOAA/OCRM, SSMC-4, 1305 East-West Highway, Silver Spring, MD, 20910 (301-713-3074).

NERRS (National Estuarine Research Reserve System) (NOAA/states): acquires, maintains, monitors, studies, and operates as natural field laboratories estuarine areas for the collection of data and the generation of understanding of the on-going natural and human process by numerous and diverse research scientists. NERRS provides some grants for the study of estuarine ecology, human impacts on estuarine resources and processes, and educational outreach. Contact: Capt. Francesca M. Cava, Chief of Sanctuaries and Reserves, OCRM/NOS/NOAA, SSMC-4, Room 12409, 1305 East-West Highway, Silver Spring, MD, 20910 (301-713-3145).

PR (Jobos Bay Reserve)

FL (Rookery Bay): research topics include effects of increased nutrients on mangroves, effects of pesticides on indicator species, effects of mosquito control practices on the bay.

GA (Sapelo Island Reserve): research topics include effects of nonpoint source pollution (soil erosion) and wildlife/habitat management practices on ecosystem function.

SC (Ace Basin Reserve, North Inlet-Wynyah Bay Reserve): research topics include effects of treated lumber on benthos.

NC (NC National Estuarine Research Reserve, 5 components): research topics include effects of treated lumber on benthos, characterization of sediment oxygen metabolism in high and low-light areas, structure and function of *Zostera* and *Halodule* as fish habitat.

NMS (National Marine Sanctuaries) (NOAA): acquires, maintains, monitors, studies, and operates areas of marine environment of special national significance for their human use or resource value. NMS provides some grants for the study of marine ecology, human

impacts on marine and historical resources and processes, and educational outreach.
Contact: Capt. Francesca M. Cava, Chief of Sanctuaries and Reserves, OCRM/NOS/NOAA, SSMC-4, Room 12409, 1305 East-West Highway, Silver Spring, MD, 20910 (301-713-3145).

- *FL (Florida Keys, Looe Key, Key Largo)*: research efforts include site characterizations and coral reef studies.
- *SEAKEYS (Sustained Ecological Research Related to Management of the Florida Keys Seascape)*: is one component of the overall monitoring program of the NMS program. SEAKEYS is a cooperative program of 4 institutions (University of Miami, University of Georgia, Florida Department of Environmental Protection, and Harbor Branch) directed at long-term monitoring of physical forcing, water quality, and benthic community organizations in the Florida Keys National Marine Sanctuary. Contact: John Ogden, Florida Institute of Oceanography, 830 First St. South, St. Petersburg, FL, 33701 (813-893-9100).
- *GA (Gray's Reef)*: research efforts include site characterizations, fishery assessments, fish surveys, and side-scan sonar surveys.
- *NC (The USS Monitor)*: research efforts include current studies and artifact studies.

OAR (Oceanic and Atmospheric Research)/Oceanic Research: conducts environmental research regarding global and national problems of the oceans. Contact: Ned Ostenso, OAR, 1335 East-West Hwy., Silver Spring, MD, 20910 (301-713-2458).

AOML (Atlantic Oceanographic and Meteorological Laboratory): is one of 12 Environmental Research Laboratories (ERLs) that are housed within NOAA's OAR. AOML conducts basic and applied research in oceanography; coastal, deep ocean, and atmospheric chemistry, acoustic applications for fisheries recruitment variability and coastal effluent plume dispersion, and tropical meteorology. Oceanographic investigations center on fluxes of energy, momentum, and materials through the air-sea interface; the transport and composition of water and sediments; the effects of the ocean environment on fisheries populations; and mechanics of effluent plume dilution and dispersion in coastal waters. Atmospheric chemistry studies focus on the origin, existence, and potential effect of various substances in the atmosphere on global climate. Meteorological studies focus on the description, understanding, and prediction of hurricanes. Some research is conducted in coordination with the Rosenstiel School of Marine and Atmospheric Science at the Cooperative Institute for Marine and Atmospheric Studies. Studies within the South Atlantic and Caribbean region include analyses of sea level change around the Florida Keys, studies of fisheries recruitment, analyses of coastal and deep water currents, studies of the effects of Hurricane Andrew, and studies of ocean effluent plumes. Contact: Hugo Bezdek, 4301 Rickenbacker Causeway, Miami, FL, 33149-1026 (305-361-4300).

NCRI (National Coastal Resources Research and Development Institute): applies the results of research to implementation of regional marine resource use and so assists in the economic development of the commercial marine and coastal sectors. Areas of application include fisheries, aquaculture, coastal business and community development, marine technology and product development, and seafood technology. In the South Atlantic and Caribbean region NCRI is supporting many projects including the development of a coastal educational center, the development of cryogenic processes for the preservation of crab meat, the development of hybrid striped bass brood stocks, and the development of reverse osmosis technology for water purification. Contact: Earle Buckley, 528 SW Mill, Suite 222, PO Box 751 Portland, OR, 97207 (503-725-5725).

NURP (National Undersea Research Program): supports research in the region through two National Undersea Research Centers: the University of North Carolina-Wilmington and the Caribbean Marine Research Center on Lee Stocking Island, Bahamas. Research is conducted using manned research submersibles, SCUBA and mixed-gas diving, remotely operated vehicles, and the Aquarius underwater habitat located in 49 feet of water offshore Key Largo, Florida. Research is conducted on the following subjects: natural stresses (e.g., temperature, UV-radiation, chemistry, bacteria, currents) and anthropogenic stresses (e.g., pollution, freshwater discharge, nutrient loading) on coral reef ecosystems; recruitment of lobster and conch larvae; population dynamics of commercial fisheries; the role of sea level changes on the deposition and erosion of carbonate banks; predation of reef fishes; marine diversity in

coral environments; nutrient dynamics and sediment transport related to ocean processes; the fate of algal organic matter on the continental slope; and the effects of groundwater discharges on marine habitats. Contact: David Duane, SSMC-1 Room 5470, 1335 East-West Hwy., Silver Spring, MD, 20910 (301-713-2448).

Sea Grant College Program: funds (cooperatively with the sponsoring states) centers for marine resources research, education, and training and Marine Advisory Service outreach programs. In the South Atlantic and Caribbean region are five Sea Grant programs, Puerto Rico (including the Virgin Islands), Florida, Georgia, South Carolina, and North Carolina. These Sea Grant programs are conducting research in the South Atlantic and Caribbean on the following major subjects: the structure and function of key coastal ecosystems and the impacts of eutrophication on these ecosystems; fisheries oceanography as related to recruitment of estuarine dependent species; the role of marshes, seagrass beds, and mangroves in the life cycles of fishes and crustaceans; the ecology and management of coral reef community fisheries; problems in coastal erosion, sediment transport, and beach renourishment; understanding the life cycles of commercially important fish and crustaceans; development of finfish and shellfish for aquaculture; development of new fishing gear technology; development of new or improved seafood processing technology; and economic and social studies on fisheries management and problems of coastal management and development. In addition, the Sea Grant programs are providing information and technology transfer in the above areas through their advisory programs. Contact: David Duane, SSMC-1 Room 5470, 1335 East-West Hwy., Silver Spring, MD, 20910 (301-713-2448).

DOD (Department of Defense)

USACE (U.S. Army Corps of Engineers)/Coastal Program: is involved in a coastal field data collection program which collects directional wave data from buoys off mid-Florida. USACE is also involved in the development of tools such as numerical models for shoreline evolution and storm-induced erosion, breakwater stability, sediment transport, and beach renourishment design. Contact: Carol Holmes, USACE Coastal Engineering Research Center, Coastal Programs, CEDES-CP-C, 390 Halls Ferry Rd, Vicksburg, MS, 39180 (601-634-2025).

U.S. Navy/ONR (Office of Naval Research): has 6 departments that address different aspects of research that will benefit U.S. Naval operations. Each department is divided into divisions and thence into programs. ONR also oversees the NRL (Naval Research Labs), the sites of the field activities of ONR. ONR accepts unsolicited research proposals and broadcasts its specific interests over a variety of media including electronic mail, the postal service, newspapers, journals, and at conferences. Contact: Tom Kinder, ONR Code 1121CS, 800 N. Quincy St., Arlington, VA, 22217-5000 (703-696-1206).

Coastal Sciences Program: Through grants and contracts ONR's Coastal Sciences Program supports process-oriented research that will be broadly applicable and readily "portable". There is a strong emphasis on the fluid mechanics of the water column above continental shelves, including near-shore hydrodynamics and sediment dynamics. Other areas of research include the Eastern Boundary Current, meso-scale interactions in weakly non-linear regimes, and shelf dynamics. Contact: Tom Kinder, ONR Code 1121CS, 800 N. Quincy St., Arlington, VA, 22217-5000 (703-696-1206).

Naval Research Laboratories: are headquartered in Anacostia, Maryland and has satellite field laboratories across the nation each of which specializes in certain issues such as acoustics, ship design, fluid dynamics, or environmental oceanography. In coordination with the Naval Oceanographic Office the Naval Research Laboratory is putting together an extensive coastal database for training and readiness exercises for military operations in the South Atlantic region. The primary focus of this effort is between Wilmington, NC and Cape Hatteras, NC, but there are efforts underway between south Florida and Cap Cod. Contact: Maria T. Kalcic, Stennis Space Center, Bldg 1100, NRL Code 7441, Stennis, MS, 39529 (601-688-4436).

DOE (U.S. Department of Energy): maintains a program of research that addresses issues such as water mass movements, dispersal and fate of energy-related materials and biological resources, energy production and use, and the effects on global earth systems of energy production and use. Contact: 202-586-5000.

Ocean Margins Program: sponsors research to better understand the role of ocean margins in the global carbon cycle. Current research efforts focus on understanding how carbon and suspended and resuspended sediment cycle along the oceanic margins and how they are transported between estuarine environments, the shelf, and the open ocean. Current research focuses on the Mid-Atlantic Bight, but will address issues of transport between the Mid-Atlantic region and the South Atlantic Bight. Contact: Ari Patrino, Acting Associate Director for Health and Environmental Research, Ecological Research Div., Office of Energy Research, DOE, 1000 Independence Ave., SW, Washington, DC, 20585 (301-903-3281).

DOI (Department of the Interior): through its numerous natural resource mission agencies conducts research in a wide variety of fields and provides scientific information to a variety of user groups.

MMS (Mineral Management Service): manages and coordinates utilization of federal mineral resources in the EEZ and to conduct environmental studies to define the impact of resource reclamation on the marine environment. MMS is conducting a study in the Cape Hatteras region collecting physical oceanographic data to better understand processes associated with flow between slope area and shelf break, flow across the shelf break, and long shore flow on the shelf region; developing and validating a South Atlantic Circulation Model; and evaluating oil spill risks in the South Atlantic Region. MMS conducted a physical oceanographic study in the Straits of Florida. Contact: Ronald Lai, Chief of the Environmental Policy and Program Division, 391 Elden St., Herndon, VA, 22070 (703-787-1714).

NBS (National Biological Survey): oversees the research endeavors of the National Park Service and the US Fish and Wildlife Service (see below) in an effort to develop a coordinated database of biological information. Contact: Jim Weaver, Director, National Fisheries Research Center, 7920 NW 71st St., Gainesville, FL, 32606 (904-378-8181).

NPS (National Park Service): promotes and regulates the use of National Parks, Monuments, and Reservations for the conservation of scenery, wildlife, and natural and historic objects while leaving the areas unimpaired for future generations. The Park Service, under the direction of the National Biological Survey, also undertakes primary research efforts such as coral reef monitoring, studies of the impacts of human use, studies of fisheries harvest, sea turtle monitoring, and water quality and quantity monitoring. Contact: Suzette Kimball, Regional Chief Scientist, NPS, 75 Spring St., Suite 1092, Atlanta, GA, 30303 (404-331-4916) or Jim Weaver, Director, National Fisheries Research Center, 7920 NW 71st St., Gainesville, FL, 32606 (904-378-8181).

- *U.S. Virgin Islands*: Inventory and monitoring efforts include: coral reef studies, anchor damage assessment and recovery, reef fish study, black band disease study, sea urchin study, sponges and octocorals, sea turtles, seagrass beds, shallow reef community disturbance, and water quality.
 - *Virgin Islands Nat'l Park*, 6310 Estate Nazareth, Charlotte Amalie, USVI, 00802 (809-775-6238)
 - *Buck Island Reef N.M.*, PO Box 160, Christiansted, St. Croix, USVI, 00820 (809-773-1460)
- *Puerto Rico*:
 - *El Morro*
- *Florida*: Research efforts include tests of herbicide controls, studies of fire management, studies of ecology and population dynamics, studies of turtle and mammal ecology, studies of water quality, and studies of hurricane effects.
 - *Everglades National Park*, 40001 State Rd 9336, Homestead, FL, 33034-67331 (305-242-7710)
 - *Fort Matanzas National Parks*, 1 Castillo Dr., St. Augustine, FL, 32084 (904-829-6506)
 - *Big Cypress National Preserve*, Star Route, Box 110, Ochopee, FL, 33943 (813-695-2000)
 - *Cape Canaveral National Seashore*, 308 Julia St., Titusville, FL, 32780 (407-267-1110)
 - *Biscayne National Park*, PO Box 1369, Homestead, FL, 33030-1369 (305-247-2044)
- *Georgia*: Research efforts include studies of marshes and studies of invertebrate populations.
 - *Fort Pulaski National Monument*, PO Box 30757, Savannah, GA, 31410-0757 (912-786-5787)
 - *Fort Fredrica Nat'l. Monument*, Rt 9 Box 286-C, St. Simons Island, GA, 31522 (912-638-3630)
 - *Cumberland Island National Seashore*, PO Box 806, St. Marys, GA, 31558 (912-882-4338)
- *South Carolina*:
 - *Fort Sumter National Monument*, 1214 Middle St., Sullivan's Island, SC 294?? (803-883-3123)
- *North Carolina*: Research efforts include baseline flora surveys, Lyme Disease surveys,

and marine bird and turtle ecological studies.

- *Cape Hatteras National Seashore*, Rt 1 Box 675, Manteo, NC, 27954 (919-473-2111)
- *Lookout National Seashore*, 131 Charles St., Harkers Island, NC 28531 (919-728-2250)

USFWS (U.S. Fish and Wildlife Service): conserves, protects, and enhances fish, wildlife, and their habitats for the continuing benefit of the American people. The Service, under the direction of the National Biological Survey, also conducts research and provides information and technical assistance in support of the South Florida Ecosystem Restoration Initiative, coral reef management efforts, and the recovery of the endangered West Indian manatee. The Service is responsible for the implementation of the *Endangered Species Act* and the *Coastal Wetlands Planning, Protection, and Restoration Act*. The Service operates through: *USFWS Research Centers, Fisheries and Wildlife Assistance Offices, and Fisheries and Wildlife Enhancement Offices, USFWS Regional Offices*. Contact: Ed LaRoe, Director of the Cooperative Research Units Center, 1839 C St NW, Washington, DC, 20240 (703-358-1709) or Jim Weaver, Director, National Fisheries Research Center, 7920 NW 71st St., Gainesville, FL, 32606 (904-378-8181).

USGS (U.S. Geological Survey): conducts research in coordination with state and regional efforts in past climate change, regional hydrology, the carbon cycle, and coastal erosion.

Office of Energy and Marine Geology: supports work through two branches: Energy and Marine and Coastal Geology. Gary Hill, Chief, 12201 Sunrise Valley Drive, Reston, VA, 22092 (703-648-6470) or Janet Morton, Associate Chief of Marine Geology, 12201 Sunrise Valley Drive, Reston, VA, 22092 (703-648-6470).

Marine and Coastal Geology Program: conducts research and mapping efforts under four themes: environmental quality and preservation, natural hazards and public safety, natural resources, and information and technology. It also conducts regional studies of geologic systems. Studies within the region include: pollution and waste disposal studies and hydro-geologic processes studies in south Florida; wetland habitat studies in the Florida Keys; inlet, coastal, and offshore erosion studies in Florida, South Carolina, and Puerto Rico; mineral (sand and gravel) studies in Puerto Rico; beach renourishment studies in Florida; and regional plate dynamics and coral reef studies. Janet Morton, Associate Chief of Marine Geology, 12201 Sunrise Valley Drive, Reston, VA, 22092 (703-648-6470).

Two branch laboratories are located on the eastern seaboard and support the research efforts described above. The *Atlantic Marine Geology Branch* is supporting efforts to map sediment transport in coastal North Carolina and to better understand near-shore and coastal erosion in South Carolina. They are also lending support to a number of geologic resource inventory projects within the South Atlantic region. Contact: Brad Butman, Atlantic Marine Geology, Woods Hole Oceanographic Institute, Woods Hole, MA (508-457-2211). The *Center for Coastal Geology* also supports research efforts. Contact: Abby Sallenger, USGS, 600 4th St., S., St. Petersburg, FL, 33701 (813-893-3684 x3002).

EPA (Environmental Protection Agency): assesses, evaluates, and manages ecological systems, human interactions, and health-related issues.

Office for International Activities/Wider Caribbean Initiative: supports other programs and provides outreach, training, and technical assistance. The Wider Caribbean Initiative is establishing the Caribbean Environmental Information Center in Puerto Rico to provide environmental information to countries throughout the Wider Caribbean and Latin America, is conducting a sediment pesticide analysis in Nicaragua, and developed a seminar on environmental health risk assessment and risk management for all Central American countries and the Dominican Republic. Contact: Martha Shimkin, Caribbean Manager, EPA Office of International Activities, 401 M St. SW, Washington, DC, 20460 (202-260-8502) or Al Krogi, EPA Region IV, 345 Courtland St., Atlanta, GA, 30365 (404-347-7109).

Office of Research and Development: oversees three offices which, in turn, oversee EPA's research labs: the Office of Modeling and Monitoring Systems and Quality Assurance, the Office of Health and Environmental Assessment, and the Office of Environmental Processes and Effects Research. The research labs conduct the research necessary support EPA's regulatory policies such as water quality standards and supporting discharge standards. They conduct research in

issues of environmental criteria and assessment of ecosystem health and marine and freshwater modeling. Contact: William Farland, Director, Mail Code 8601, Room 3700M, OHEA, 401 M St, SW, Washington, DC, 20460 (202-260-7317) and Courtney Riordan, Director, Mail Code 8401, OEPER, 401 M St, SW, Washington, DC, 20460 (202-260-5950).

EMAP (Environmental Monitoring and Assessment Program): is a nationwide, innovative, environmental research, monitoring, and assessment program, designed to: (1) estimate current status, trends, and changes in selected ecological indicators, (2) estimate the distribution and extent of the nation's ecological resources, (3) discover associations between selected indicators and anthropogenic stress, and (4) provide statistical summaries of the nation's ecological resources. It focuses on 7 major ecological resource categories (including estuaries and wetlands -- EMAP Estuaries and Wetlands operates in close coordination with NOAA's National Status and Trends Program). EMAP employs a peer-reviewed strategy that uses a statistically randomized sampling grid to monitor environmental conditions and assess environmental health. EMAP is in the "pilot" or "demonstration" phase. It is collecting data on physical, chemical, and biological aspects of the relevant resource categories and compiling regional databases. In the South Atlantic region the Carolinian Province (the Indian River Lagoon, FL to Cape Henry, VA) 84 estuarine/wetland sites are being sampled for a variety of chemical/physical (e.g., dissolved oxygen, salinity, pH, PCBs, and PAHs), toxicological (e.g., sediment toxicity), and biological variables (e.g., species composition and abundance) as indicators of pollutant exposure, natural habitat exposure, and biological responses. Contact: John Paul, USEPA ERL, 27 Tarzwell Dr., Narragansett, RI, 02882 (401-782-3037) or Jeff Hyland, Manager of the Carolinian Province Office, NOAA/NOS, 217 Fort Johnson Rd., Charleston, SC, 29422-2559 (803-762-5415).

Savannah River Eco-risk Initiative: in conjunction with the Office of Wetlands, Oceans, and Watersheds, the Office of Research and Development has begun a program of watershed-scale ecological risk assessment. One component of that program is a cooperative effort, headed by the Region IV Office in Atlanta, GA, to establish management goals and tools for system-wide analysis in the Savannah River Basin. The methods of ecological risk assessment will be able to be widely applied. Contact: M. Craig Barber, USEPA/ERL, 960 College Station Road, Athens, GA, 30605-2720.

Office of Water

OWOW (Office of Wetlands, Oceans, and Watersheds): brings together EPA's programs that manage and protect the aquatic ecosystems of inland and coastal watersheds. OWOW's activities are mostly management-oriented, but involve the collection and compilation of pertinent information. A few of the most relevant programs are described below. Contact: Bob Wayland, Director, OWOW, WH-556F, 401 M Street, S.W., Washington, DC, 20460 (202-260-7166).

Assessment and Watershed Protection Division: conducts no research on its own, but oversees several projects involving primary research in the near-coastal zone. Contact: Carl Myers, USEPA, 4503-F, 401 M St. S.W., Washington, DC, 20460 (202-260-7040).

Savannah River Basin Watershed Project: coordinates a multi-agency/organization management and protection effort in the Savannah River Basin. The Project takes a basin-wide approach to water quality and aquatic resources management by prioritizing impact areas and addressing causes and effects of changing water quality and quantity on the edge of the ocean. Planning for the technical components of the project are underway. Contact: Meredith Anderson, Water Management Division, USEPA, 345 Courtland St., Atlanta, GA, 30305 (404-347-2126).

National Estuary Program (EPA/states): supports ecosystem-level research to help determine the health of designated estuaries of national significance and create comprehensive conservation and management plans for such estuaries. Through the NEP research (specific to the estuarine system of concern) is being conducted on issues such as water quality and coastal and terrestrial environmental health, habitat health, fisheries, and socio-economics. Contact: Wesley "Bo" Crum, Water Management Division, 345 Courtland St NE, Atlanta GA, 30365 (404-347-1740) or Mario DelVicario, EPA Region II, 26 Federal Plaza, NY, NY, 10278 (212-264-5170).

Primary research areas for each of the NEPs within the South Atlantic and Caribbean region are listed below:

- *PR (San Juan Bay)*: nutrient loading to shallow coastal waters, solid waste in the coastal zone, coastal habitat loss, toxicants in coastal habitats, the health of coral reef ecosystems.
- *FL (Tampa Bay, Sarasota Bay, Indian River Lagoon)*: water quality, nutrient loading to shallow coastal waters, coastal habitat loss, toxicants in coastal habitats, disease and death of fish, shellfish, and marine mammals, and conflicting uses of the coastal zone.
- *NC (Albemarle-Pamlico Sounds)*: water quality, nutrient loading to shallow coastal waters, land use practices, coastal habitat loss, toxicants in coastal habitats, disease and death of fish and shellfish, and conflicting uses of the coastal zone.

Oceans and Coastal Protection Division: Contact: Marian Mlay, Director OCPD, 401 M St. S.W., Box WH556F, Washington, DC, 20460 (202-260-1952).

ASA (National Aeronautics and Space Administration): supports basic research designed to prove techniques, technologies, and environmental applications of remote-sensing, algorithm development, and modeling. Contact: Frank Muller-Karger, Code YSE, NASA/HQ, Washington, DC, 20546.

SeaWiFs (Sea-viewing Wide Field-of-view Sensor) Program: uses satellite technology to improve our understanding of the mean variance and control of ocean primary production and multiple spatial and temporal scales in order to improve our understanding of the role of oceanic primary production in global bio-geo-chemical cycles, especially the carbon cycle. While SeaWiFs is not currently supporting research in the Region, it is developing a remote-sensing algorithm which will ensure that SeaWiFS-derived products are useful to the regional research community. Contact: Robert Kirk, Project Manager, NASA Goddard Space Flight Center, Code 970.2, Greenbelt, MD 20771 (301-286-7895).

NIH (National Institutes of Health): consists of 12 Institutes in Bethesda, MD and one Institute in Research Triangle Park, NC (described below).

NIEHS (National Institute of Environmental Health Sciences): conducts marine and aquatic biomedical research through grants with institutions within the region including Duke University and Rosenstiel School of Marine and Atmospheric Sciences (RSMAS). At the Duke University Marine and Freshwater Biomedical Sciences Center multidisciplinary research is addressing mechanisms and effects of toxic chemicals in the environment and the use of marine and freshwater organisms as experimental models and/or biomarkers to better understand issues of human and environmental health. Studies are focused on oxygen and metal toxicity, non-mammalian models for toxicological studies, and human health consequences of ecosystem perturbations. At the RSMAS Marine and Freshwater Biomedical Sciences Center scientists are developing several models of how selected bioactive compounds in the marine environment affect human health as disease agents, carcinogens, neurotoxins, or immune system perturbations. Contact: Jerry Phelps, NIEHS, Office of Program Planning and Evaluation, Mail Drop B2-08, PO Box 12233, RTP, NC, 27709 (919-541-4259).

NSF (National Science Foundation)/Division of Ocean Sciences: supports basic research and scientific coordination in an effort to understand the interacting forces and processes involved in the dynamic functions of Earth's natural environment (atmosphere, earth, and oceans) and critical human components (social, behavioral, and economic components). Five areas of research are supported: biological oceanography, chemical oceanography, marine geology and geophysics, ocean technology and interdisciplinary coordination, and physical oceanography. Topics of research funded within the region include: biological oceanography (benthic reef fish habitat and settlement, population modeling, recovery of mangroves after Hurricane Andrew, trophic interactions and aging rates, life history of fishes), chemical oceanography (J-GOFS (see under international efforts), and biochemical cycling in organic-rich coastal environs), marine geology and geophysics (oral-based climate reconstruction, carbonate ramp deposition, and use of plankton to infer surface water hydrology), ocean technology and interdisciplinary coordination (CoOP, see under regional efforts), and physical oceanography (Gulf Stream variability, modeling 3-dimensional circulation in shallow water bodies, and WOCE (see under international efforts)). Contact: Michael Reeve, Chief of the Division of

LTRE (Long-Term Ecological Research) Program: establishes long-term monitoring sites in relatively pristine areas to develop baseline information about ecosystem structure and function. There is one LTER site in South Carolina (Winyah Bay) and one site in Puerto Rico (near San Juan). Through the program grants are awarded for ecological monitoring, research, and modeling efforts. LTER research at North Inlet, SC is a large, multi-investigator project involving monitoring water quality parameters, macrofauna, zooplankton, chlorophyll, climate, and other variables in the estuary over the past 12 years. Contact: Jim Morris, Department of Biological Sciences, University of South Carolina, Columbia, SC, 29208 (803-777-3948).

LTREB (Long-Term Research in Environmental Biology): supports small-scale projects of long-term measurements of biological processes and communities. LTREB is conducting basic research on the regulation of primary production (of *Spartina*) in saltmarshes at North Inlet, SC. Production has been monitored monthly since 1984. Contact: Jim Morris, Department of Biological Sciences, University of South Carolina, Columbia, SC, 29208 (803-777-3948).

REGIONAL INITIATIVES

A number of regional initiatives have been undertaken as cooperative partnerships among federal, regional, and state organizations to begin to understand and manage broad area of oceanic environments and resources. Studies of processes that bridge state or federal boundaries (such as Gulf Stream transport) or resources that migrate throughout broad regions (such as migratory fish) lend themselves to regional research and management initiatives.

CIFO (Cooperative Institute of Fisheries Oceanography) (Duke, UNC, NMFS): stimulates and coordinates cooperative research and education efforts to address priority fisheries management problems in the South Atlantic Bight. CIFO addresses issues of productivity and fisheries harvests from hardbottom communities biodiversity of hardbottom communities and sargassum communities, fisheries recruitment as affected by Gulf Stream dynamics, and the connections between water quality and biodiversity. Contact: Dr. B.J. Copeland, Box 8605 NCSU, Raleigh, NC, 27695 (919-515-2454).

CoOP (Coastal Ocean Processes (NSF): is attempting to draw the academic community to a consensus regarding the priorities for coastal zone research for the next decade in order to develop quantitative understanding of the processes that dominate the transports, transformations, and fates of materials on the continental margins. Contact: Cheryl-Ann Butman, Woods Hole Oceanographic Institute, Woods Hole, MA, 02543 (508-457-2000x2442).

GARP (Gulf and Atlantic Recruitment Experiment) (NOAA/states): supports monitoring and research to develop an understanding of inter-regional blue crab population dynamics at biologically relevant scales. GARP is conducting a coordinated sampling effort for blue crab megalopae from Delaware Bay, Chesapeake Bay, the sounds of NC, Charleston Harbor, Georgia, Mississippi, Alabama, Louisiana, and Texas. Daily collections of megalopae are made using artificial substrates and numbers of larvae are compared to meteorological, lunar, and tidal events. Contact: Robert Orth, Virginia Institute of Marine Science, Gloucester Point, VA, 23062 (804-642-7332).

MARFIN (Marine Fisheries Initiative) (NOAA/NMFS): funds research and development of full and wise use of fisheries in the South Atlantic and the Gulf of Mexico. MARFIN provides single and multi-year funds for scientific research of fisheries issues in the Gulf of Mexico, Caribbean, and South Atlantic waters. Research priorities are determined by solicitation from outside experts and have included shrimp trawler bycatch, reef fish, migratory pelagic fisheries, coastal herrings, and economic constraints of fisheries management. MARFIN provides a vital cooperative link between state, university, private industry, and federal interests toward solving pressing fisheries concerns. Contact: Ellie Roche and David Pritchard, Cooperative Programs Division, Southeast Regional Office, NMFS, 9450 Koger Blvd., St. Petersburg, FL, 33702 (813-893-3720).

MARMAP (Marine Monitoring, Assessment, and Prediction) (MRRI/SC, NOAA/NMFS): conducts long-term fish surveys (using trawl, trap, and photographic gear) for shallow water reef fish throughout the South Atlantic Bight. MARMAP conducts age/growth, life history, movement, and

fecundity studies on key species under management. MARMAP supports specific management problems such as survival rate of released reef fish. The information collected supports the needs of the South Atlantic Fishery Management Council. Contact: Scott Nichols, Director, NMFS Mississippi Laboratories, 3209 Frederic St., Pascagoula, MS, 39567 (601-762-4591) or Jack McGovern, SC Wildlife and Marine Resources Division, PO Box 12559, 217 Fort Johnson Rd., Charleston, SC, 29422 (803-795-6530).

RecFIN (Recreational Fisheries Information Network): is designed to develop and implement a cooperative state-federal program to collect, manage, and distribute statistical data and information on marine recreational fisheries of the South Atlantic, Gulf of Mexico, and Caribbean areas. This program is being initiated as a 3-year pilot program. A RecFIN Strategic Plan has been developed and the program using approved annual operating plans has been implemented. Contact: Ron Likens, Gulf States Marine Fisheries Commission, PO Box 726, Ocean Springs, MS, 39564 (601-875-5912).

SEAMAP (Southeastern Monitoring and Assessment Program) (NOAA/NMFS): is a cooperative state/federal program that collects, manages, and disseminates fishery-independent information needed by management agencies and users of living marine resources within the Atlantic and Caribbean region. SEAMAP activities in the South Atlantic Bight are coordinated by the Atlantic States Marine Fishery Commission (ASMFC) and include workgroup meetings (e.g., Crustacean, Shallow Water Trawl, Data Management, and Bottom Mapping) and research projects (e.g., a trawl survey of near-shore waters, development of a hardbottom database, description of northeast Floridian benthic fauna, and tagging of striped bass off North Carolina. Contact: Dianne Stephen (Atlantic SEAMAP), ASMFC, 17776 Massachusetts Ave, N.W., Suite 600, Washington, DC, 20036 (202-452-8700) or Aida Rosario (Caribbean SEAMAP), PO Box 3665 Marina Station, Mayaguez, PR, 00684 (809-833-2025).

SEFCAR (Southeastern Florida and Caribbean Recruitment): is conducting investigations from Miami to the Dry Tortugas of recruitment mechanisms of reef fish (especially the influence of currents on transport). Sampling is conducted during periodic research vessel cruises and from small boats. Gear used includes MOCNESS 1 and 10, channel nets, light traps, and push nets. Contact: Dr. William Richards, NOAA/NMFS S.E. Fisheries Science Center, 75 Virginia Beach Dr., Miami, FL, 33149 (305-361-4249).

STATE AGENCIES AND PROGRAMS

A wide variety of state management agencies operate within the South Atlantic region. Many undertake monitoring efforts and data analyses in cooperation with regional or federal initiatives or as the direct result of federal delegation of responsibility. Most state management agencies rely on federal guidelines and/or contract out their research needs to federal or private research institutions. Pertinent responsibilities within the near-coastal zone have been listed below to give an indication of the data and information bases that the individual agencies and programs hold.

U.S. Virgin Islands:

Department of Planning and Natural Resources: water quality, fisheries, land use, coastal zone management

University of Puerto Rico Sea Grant: water quality, fisheries and associated technologies, coastal zone management

Puerto Rico:

Department of Environmental Quality and the Environmental Quality Board: water quality and land use

Department of Natural Resources: land use, water quality, coastal zone management

University of Puerto Rico Sea Grant: water quality, fisheries and associated technologies, coastal zone management

Florida:

Florida Department of Environmental Protection: water quality, fisheries, land use, coastal zone management

Florida Port Authority: vessel traffic and harbor maintenance

Florida Sea Grant: water quality, fisheries and associated technologies, coastal zone management

Surface Water Improvement Management (SWIM) plans (Biscayne Bay, Indian River Lagoon, St. Johns River): water quality

Water Management Districts (St. Johns, South Florida): water quality, water use, development

Georgia:

Georgia Department of Natural Resources: water quality, fisheries, land use, coastal zone management

Georgia Port Authority: vessel traffic and harbor maintenance

Georgia Sea Grant: water quality, fisheries and associated technologies, coastal zone management

South Carolina:

South Carolina Coastal Division in the SC Department of Health and Environmental Control: water quality, coastal zone management

South Carolina Department of Natural Resources: marine resources, fisheries, coastal habitats

South Carolina Port Authority: vessel traffic and harbor maintenance

South Carolina Sea Grant Consortium: water quality, fisheries and associated technologies, coastal zone management

North Carolina:

North Carolina Department of Environment, Health, and Natural Resources: water quality, fisheries, land use, coastal zone management

North Carolina Port Authority: vessel traffic and harbor maintenance

University of North Carolina Sea Grant College Program: water quality, fisheries and associated technologies, coastal zone management

RESEARCH INSTITUTIONS

Each state, commonwealth, and territory within the South Atlantic and Caribbean Region has federal, state, and privately supported institutions involved with near-coastal ocean research. Some specialize in individual disciplines, some offer very broad experience in a number of different disciplines. Through grant-supported research, all have helped to formulate the framework of understanding within which further scientific endeavors and deeper understanding are developed and from which we may continue to improve our ability to effectively manage the resources of the near-coastal oceans.

U.S. Virgin Islands:

Division of Fish and Wildlife, Dept of Planning and Natural Resources

Island Resources Foundation

University of the Virgin Islands

Puerto Rico:

Ponce School of Medicine

Puerto Rico Tropical Marine Biotechnology Center

University of Puerto Rico -- Rio Piedras

University of Puerto Rico -- Mayaguez

Florida:

Eckerd College

Florida Atlantic University

Florida Institute of Oceanography

Florida Institute of Technology

Florida International University

Florida Keys Marine Laboratory

Florida Marine Research Institute

Florida State University

Harbor Branch Oceanographic Institution

Jacksonville University

Mote Marine Lab

National Undersea Research Center

Nova University

South Florida Research Center (Everglades)
Surface Water Improvement and Management Program
University of Central Florida
University of Florida (Marine Lab and Whitney Lab)
University of Miami Rosenstiel School of Marine and Atmospheric Sciences
University of North Florida
University of South Florida
University of West Florida
USEPA Gulf Breeze Laboratory

Georgia:

Armstrong State College
Brunswick College
Georgia Institute of Technology
Georgia Southern University
National Fish Hatchery -- Bo Ginn (USFWS)
Savannah State College
Skidaway Institute of Oceanography
University of Georgia Marine Institute
USEPA in Athens and Atlanta

South Carolina:

The Citadel
Clemson University
Coastal Carolina College
University of Charleston, Grice Marine Lab, Charleston
HarborWatch (Charleston NPO)
Medical University of South Carolina
National Fish Hatcheries -- Bears Bluff and Orangeburg (USFWS)
South Carolina Marine Resources Research Institute (SCDNR)
South Carolina State University
University of South Carolina

North Carolina:

Duke University Marine Lab
East Carolina University
Elizabeth City State University
North Carolina Agricultural and Technological University
North Carolina State University
University of North Carolina at Chapel Hill
University of North Carolina at Charlotte
University of North Carolina at Wilmington

APPENDIX 3: REFERENCES

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